USING COMPUTER-GENERATED ADVICE FOR MANUFACTURING PARTNER SELECTION IN INDUSTRY 4.0

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Sonia CISNEROS CABRERA

ALLIANCE MANCHESTER BUSINESS SCHOOL
Management Sciences and Marketing Division (MSM)

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Abstract

This thesis presents an investigation that identifies the factors that decision-makers consider when selecting business partners to form collaborative networks, conceptualises, designs and implements a computerised advisor supporting such decision-makers, and identifies the factors that influence users to utilise the computer-generated advice from that kind of computerised advisors. The research is undertaken in the context of inter-organisational collaboration and digitalisation in manufacturing industries, motivated by the fourth industrial revolution's push to transforming the team formation process for inter-organisational collaboration through information systems. The investigation utilises the methodology known as Action Design Research (ADR). ADR implies cooperation between researchers and practitioners to address a specific problem embedded in an organisation, and in the case of this research, the focus is on the business partner selection problem. The outcome of ADR is a composite artefact developed with the knowledge acquired through the researcher-practitioner collaboration; in this work, the artefact comprises a computerised advisor and a theory of computer advice utilisation applicable when the advice is provided by a computer in support of business partner selection in manufacturing industries. This research benefits from the involvement of practitioners from a number of organisations including a European aircraft manufacturer, a German aviation cluster with several members from small and medium-sized enterprises (SME), and a Welsh SME platform provider to automotive, aerospace and electronic manufacturing clusters. These organisations worked collaboratively in a European Project, to which this investigation had access to, called Decentralised Agile Coordination Across Supply Chains (DIGICOR)[1]. This work extends the limits of knowledge regarding computerised business advisors, knowledge management, and virtual teams in four interwoven contributions. The two major contributions are (1) a working example of a computerised advisor supporting business partner selection, named "Tender Decomposition and Matchmaking System" (TDMS); and (2) a theory of computer advice utilisation identifying, describing and explaining the motivating factors and their relationships when it comes to end-users following computer-generated advice applicable in manufacturing industries. The two ancillary contributions are (3) a theoretical tool to assess the readiness of collaborative platforms and collaborative technologies toward inter-organisational collaboration in the digitalisation context; and (4) an example of the use of Action Design Research method (ADR) for theorising.

[1] https://www.digicor-project.eu, collaboration with grant agreement No 723336

Declaration

No portion of the work referred to in the thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

Copyright

Dedication

To my parents

To my four grandparents

To all of those who represent the love that exists in my life

Acknowledgements

"If I have seen further it is by
standing on the shoulders of Giants"
— Isaac Newton

I would like to thank my supervisors Prof Nikolay Mehandjiev, and Dr Pedro Sampaio, who always did all that they could possibly do to support me in this PhD journey, and who always believed in me and my work. I am deeply grateful for their invaluable mentorship, and I am proud of having had the opportunity of working with them. In addition, I want to express my gratitude to my examiners, Prof Luis Camarinha-Matos, and Dr Nadia Papamichail, for their insightful discussion and comments to improve my work.

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About the Author

Sonia Cisneros-Cabrera has a background as Computer Systems Engineer, graduated in 2014 from the Technological University of Coacalco (Tecnológico de Estudios Superiores de Coacalco) in Mexico. She was part of Deloitte Mexico as an internal business technology analyst and part of the Information Technology (IT) project management office during 2015, just before joining The University of Manchester where she obtained her Master’s degree (MPhil) in the School of Computer Science in 2016. Her MPhil work was developed on High-Performance Computing, Big data, and Data Quality subject areas.

Sonia then moved to the Alliance Manchester Business School in 2017 to pursue a PhD. Her doctoral research investigates what are the factors that lead users to utilise advice from a computer when selecting business partners towards supporting the development of collaborative systems for manufacturing in the context of digitalisation and inter-organisational collaboration.

During her doctoral research, she took part as a research associate and contribution manager in a European Commission project called DIGICOR. She also competitively secured a funding grant under the Early Career Researcher Placement Scheme, from the UK Engineering & Physical Sciences Research Council (EPSRC), which allowed her to collaborate with external researchers in the Graz University of Technology, in Austria, and the Aalto University School of Business, in Finland, to further develop her research.

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Related Research Outputs

1. **Digital Marketplaces for Industry 4.0: A Survey and Gap Analysis**

Cisneros Cabrera, S, Ramzan, A, Sampaio, P & Mehandjiev, N 2017, Digital Marketplaces for Industry 4.0: A Survey and Gap Analysis. in Collaboration in a Data-Rich World. 1 edn, vol. 506, IFIP Advances in Information and Communication Technology, no. 1, vol. 506, Springer, Cham, pp. 18-27, PRO-VE 2017: Working Conference on Virtual Enterprises, Vicenza, Italy, 18/09/17. https://doi.org/10.1007/978-3-319-65151-4_2

2. **A B2B Team Formation Microservice for Collaborative Manufacturing in Industry 4.0**

Cisneros Cabrera, S, Sampaio, P & Mehandjiev, N 2018, A B2B Team Formation Microservice for Collaborative Manufacturing in Industry 4.0. in 2018 IEEE World Congress on Services (SERVICES)., 8495784, Proceedings - 2018 IEEE World Congress on Services, SERVICES 2018, IEEE, pp. 39-40, IEEE World Congress on Services, San Francisco, United States, 2/07/18. https://doi.org/10.1109/SERVICES.2018.00032

3. **User acceptance of AI advice in the context of collaborative supply chains formation**

Cisneros Cabrera, S, Mehandjiev, N, Felfernig, A, Sampaio, P & Kununka, S 2019, 'User acceptance of AI advice in the context of collaborative supply chains formation', Network Plus: Industrial Systems in the Digital Age Conference 2019, Nottingham, United Kingdom, 25/06/19 - 26/06/19. https://connectedeverythingmedia.files.wordpress.com/2019/07/ce2019_paper_16.pdf

4. **A Laddering Approach to Explore the Motivations of Taking Computer Advice for Supply Networks Formation**

Cisneros Cabrera, S, Mehandjiev, N, Felfernig, A, Sampaio, P & Kununka, S 2020, 'A Laddering Approach to Explore the Motivations of Taking Computer Advice for Supply Networks Formation', The Pacific Asia Conference on Information Systems (PACIS), Dubai, United Arab Emirates, 20/06/20. https://aisel.aisnet.org/pacis2020/218/

5. **Digital Services for Industry 4.0: Assessing Collaborative Technology Readiness**

Ramzan, A, Cisneros Cabrera, S, Sampaio, P, Mehandjiev, N & Kazantsev, N 2019, 'Digital Services for Industry 4.0: Assessing Collaborative Technology Readiness', Paper presented at 16th European, Mediterranean & Middle Eastern Conference on Information Systems, Dubai, United Arab Emirates, 9/12/19 - 10/12/19. https://doi.org/10.1007/978-3-030-44322-1_45. Received "Best Paper Award".

6. **Dynamic Modelling of Production Supply Chains of SMEs with Large OEMs in DIGICOR**

Ramzan, A, Cisneros Cabrera, S, Sampaio, P & Mehandjiev, N 2017, 'Dynamic Modelling of Production Supply Chains of SMEs with Large OEMs in DIGICOR', Network Plus: Industrial Systems in the Digital Age Conference 2017, Glasgow, United Kingdom, 20/06/17 - 21/06/17.
<https://connectedeverythingmedia.files.wordpress.com/2017/07/network_plus_2017_paper_14.pdf>

7. **Dynamic Modelling of Production Supply Chains of Small and Medium Enterprises with Large Original Equipment Manufacturers in DIGICOR**

Ramzan, A, Cisneros Cabrera, S, Sampaio, P & Mehandjiev, N 2017, 'Dynamic Modelling of Production Supply Chains of Small and Medium Enterprises with Large Original Equipment Manufacturers in DIGICOR', American Conference on Information Systems 2017: International Workshop on Smart Manufacturing, Boston, United States, 10/08/17 - 12/08/18 pp. 1-2.
<https://aisel.aisnet.org/cgi/viewcontent.cgi?article=1007&context=sigbd2017>

8. **Collaborative Technologies in Automotive and Aerospace Industries towards Industry 4.0**

Ramzan, A, Cisneros Cabrera, S, Kazantsev, N, Sampaio, P & Mehandjiev, N 2017, 'Collaborative Technologies in Automotive and Aerospace Industries towards Industry 4.0', American Conference on Information Systems 2017: International Workshop on Smart Manufacturing, Boston, United States, 10/08/17 - 12/08/18.
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9. **A Governance Metamodel for Industry 4.0 Service Collaborations**

Kazantsev, N, Sampaio, P, Pishchulov, G, Cisneros Cabrera, S, Liu, Z & Mehandjiev, N 2018, A Governance Metamodel for Industry 4.0 Service Collaborations. in 2018 IEEE World Congress on Services (SERVICES). IEEE, pp. 47-48, IEEE World Congress on Services, San Francisco, United States, 2/07/18. https://doi.org/10.1109/SERVICES.2018.00037

10. **Facilitating demand–driven supplier collaborations using a tender decomposition and matchmaking service**

Pishchulov, G, Cisneros Cabrera, S, Sampaio, P, Liu, Z, Kununka, S & Mehandjiev, N 2019, Facilitating demand–driven supplier collaborations using a tender decomposition and matchmaking service. Saint Petersburg State University, Saint Petersburg, pp. 346-347, 2nd International Conference on Business Management in the Digital Economy, Saint Petersburg, Russian Federation, 21/03/19.
< https://events.spbu.ru/eventsContent/events/2019/digital/Pishchulov.pdf>

Chapter 1

Introduction

In recent years, industrial trends such as Industry 4.0 brought the digitalisation of key business processes to the forefront of research agendas within Information Systems (IS) and Information and Communication Technologies (ICT) (Lasi et al. 2014; Obitko and Jirkovsky 2015). Industry 4.0 envisages traditionally non-digitalised processes to become available in virtual environments supported by appropriate technologies and tools (Alcácer and Cruz-Machado 2019; Hahn 2020; Nambisan et al. 2017). As such, the relevance of identifying the business processes which can be digitalised relies on advancing the knowledge to understand the phenomenon and the utility of such knowledge to support the realisation of the processes' digitalisation.

This thesis focuses on the process of business partner selection for inter-organisational collaboration within manufacturing industries and explores the phenomenon of its digitalisation. Manufacturing industries, such as the aerospace, automotive or heavy machinery engineering, are at the core of the industries impacted by Industry 4.0 (Geissbauer et al. 2014; Gilchrist 2016; Havle and Ucler 2018; Kagermann 2015; Muhuri et al. 2019; Trotta and Garengo 2018) and within them, inter-organisational collaboration appears as one of the business processes which can benefit from digitalisation (Arıcıoğlu and Yiğitol 2020; Camarinha-Matos et al. 2017; Keller et al. 2014; Schniederjans et al. 2020). To enable the inter-organisational collaboration, the business partner selection process is key (Beckett and Jones 2012; Camarinha-Matos et al. 2009; Lau and Wong 2001; Mesquita et al. 2017; Polyantchikov et al. 2017).

Digitalisation envisions the business partner selection to happen with the help of intelligent matchmakers (Chai et al. 2013; Crispim and Pinho de Sousa 2009; Elia et al. 2020; Ho et al. 2010), in this sense, this thesis presents one conceptualisation, design, and implementation of such matchmakers taking the form of computerised advisors recommending suitable business partners to form an inter-organisational collaboration within manufacturing industries. Considering the computerised advisor scenario, the results of the research presented in this thesis contribute to advance the understanding of the phenomenon of a digitalised process of selecting business partners towards its implementation in real-world scenarios; this understanding takes the form of an investigation that *identifies the factors that decision-makers* *consider when selecting business partners to form collaborative networks, conceptualises, designs and implements a computerised advisor supporting such decision-makers, and identifies the factors that influence users to utilise the computer-generated advice from that kind of computerised advisors.*

In greater detail, the results of this investigation contribute to advance the knowledge of IS within the knowledge management and virtual organisations domains, adding to the state of the art of what is known about the acceptance of computer-generated advice, and supporting the realisation of business collaborations within a digital context. In literature, there are noticeable gaps related to the acceptance of the advice (formally called "advice utilisation" (Bonaccio and Dalal 2006; MacGeorge and Van Swol 2018)) made by IS. This type of "acceptance" differs in nature from accepting technology, considering that users may actively use and accept a system but not necessarily accept the suggestions made by it (Chow et al. 2015; Westin et al. 2013).

The investigation follows an Action Design Research (ADR) methodology, and benefits from access to the context of inter-organisational collaboration and digitalisation through the development of ADR within the Decentralised Agile Coordination across Supply Chains (DIGICOR[2]) project, a European Commission project aimed at generating technologies to be utilised towards Industry 4.0 collaborative networks within European organisations (DIGICOR 2016).

The remainder of this chapter is organised as follows: Section 1.1 presents a review of related research by describing the role of collaborative networks in the context inter-organisational collaboration and digitalisation, and how IS can support the selection of business partners towards the inter-organisational collaboration. The purpose of Section 1.1 is to support the specification of the problem relevance and to explore how the inter-organisational collaboration is envisaged to be supported by technologies. Chapters 3, 4, and 5 of this thesis present further literature reviews describing the state-of-the-art of digital collaboration platforms and collaboration technologies (Chapter 3), inter-organisational collaborative networks formation approaches (Chapter 4), and computer advice utilisation knowledge (Chapter 5).

Section 1.2 presents the research specifics, namely the research questions, and its corresponding research objectives; an overview of the research approach; and an account of this research's contributions to knowledge.

[2] https://www.digicor-project.eu/

The investigation has three research questions; the first one explores the context of the research and looks for understanding the non-digitalised side of the business partner selection process. The second question explores how the non-digitalised side of the process can be digitalised, and the third question inspects the digitalised implementation of the process toward obtaining theoretical knowledge.

Following the presentation of the research questions and objectives, the Section 1.2.2 presents an overview of the research approach utilised in this investigation, namely Action Design Research (ADR); Chapter 2 presents the details of the research approach. The final part of Section 1.2 specifies the contributions of the research formed by two major ones: (1) a computerised business advisor, and (2) a theory of computer advice utilisation; and two ancillary contributions: (3) a tool to assess the readiness of collaborative platforms, and collaborative technologies to the context of inter-collaboration and digitalisation, and (4) this research being itself an example of utilising ADR for theorising in IS research.

Section 1.3 describes the structure of this thesis, formed by six chapters. This thesis is presented in an alternative format, i.e. Chapter 3, Chapter 4, and Chapter 5 are in a format suitable for self-contained publication yet constituting a coherent and continuous thesis. The rationale for the thesis to be presented in an alternative format rather than a traditional format derived from the research strategy where the research questions allow for analysing the business partner selection process from different perspectives (i.e. non-digitalised analysis, digitalised implementation, and the theoretical knowledge of the digitalised process; as described above) and, therefore, presents research outputs which can be disseminated throughout the development of the research. This on-going dissemination allows for timely feedback from the academic community. The feedback from the community enables refinement of the research and provides useful expert advice that can potentially lead to higher quality research outcomes (Bornmann 2011). Furthermore, ADR, as the methodology used in this investigation requires continuous and iterative assessment of the progress and results (Sein et al. 2011) and the process of elaborating papers suitable for publication also support the fulfilment of this ADR requirement.

Four papers are presented in this thesis, and they are materialised by the author of this thesis in collaboration with the PhD supervisory team, other researchers from The University of Manchester, and researchers from external institutions. Section 1.4 declares the specifics of the contributions of the authors in the papers.

1.1 Related Research

1.1.1 Researching the Digitalisation of Inter-organisational Collaborations

The collaboration in manufacturing industries is carried out through collaborative networks in the form of "alliances", "clusters" or "virtual enterprises (VE)" (Gunasekaran et al. 2008; Gunasekaran and Ngai 2004; Power 2005; Trappey and Hsiao 2008), where several independent organisations join workforces and resources together to fulfil large and complex business opportunities (L. M. Camarinha-Matos and Afsarmanesh 1999; Martinez et al. 2001; Mehandjiev et al. 2010).

In a collaborative network, each node brings a strength or core competence to enable collaboration to occur as a single unit for the achievement of a specific business goal, and it can reach its dissolution once the business opportunity is gone (L. M. Camarinha-Matos and Afsarmanesh 1999; Martinez et al. 2001; Mehandjiev et al. 2010). Among the digitalisation characteristics pushed by Industry 4.0, there is the support of formation, management and implementation of collaborative networks to extend business opportunities (Camarinha-Matos et al. 2017; Cisneros-Cabrera et al. 2017).

Automation towards providing support in collaborative networks is one of the topics that the Horizon 2020 programme (European Commission 2015) supports towards enabling the vision of Industry 4.0 (DIGICOR 2016). The vision behind including automation and support of collaborative work particularly pursues the inclusion of Small and Medium Enterprises (SMEs) into new business opportunities. SMEs can benefit by augmenting their competitiveness and efficiency to fulfil large manufacturers' demands in a supply chain with dynamic and complex characteristics (Hong and Jeong 2006; Macpherson and Wilson 2003; Mehandjiev et al. 2010). For this, technological, organisational, and business innovations are to be developed, and collaborative networks provide a way to potentiate SME participation in the supply chain.

1.1.2 Selecting Business Partners with the Help of Information Systems

The process of identifying suitable business partners with the help of IS could be solved using different approaches presented by the called "problem-solving" packages: from computerised advisors deciding on behalf of the user, to the basic retrieval of a list of registered organisations within a database. This subsection presents an overview of the available problem-solving type of IS that could support business partner selection, and how each could implement the proposal of a computerised advisor.

The different mechanisms in which an IS can support computer-generated advice for selecting business partners in manufacturing industries presents a view on how the type of IS is not relevant to define the scope of the investigation of computer-advice utilisation, and rather explains how a computerised advisor can take different implementation forms.

In the most automated level there are the called Expert Systems (ES), a branch of Artificial Intelligence (AI) systems (Giarratano and Riley 1989; Jackson and P. 1986; Nelson Ford 1985) which emulate the reasoning done by expert humans in a given domain when specific knowledge is required to find a solution (Beemer and Gregg 2008; Berry 1997; Coursey and Shangraw 1989; Garson 1990; Jackson and P. 1986; Nelson Ford 1985; Turban et al. 2005). The ES's use is focused on well-structured problems with a defined and narrow domain and automation of concrete problem-solving situations (Beemer and Gregg 2008; Turban et al. 2005), for example, troubleshooting (Giarratano and Riley 1989) in mathematics, engineering, and computer science domains (Carroll and McKendree 1987). ES are rule-based, with two components: a knowledge base and an inference engine (Beemer and Gregg 2008; Feigenbaum 1981; Jackson and P. 1986).

To handle unstructured and more unclear defined problems, Decision Support Systems (DSS) rely on knowledge-based components (KB) (Beemer and Gregg 2008; Burstein and Holsapple 2008; Forslund 1995; Mintzberg et al. 1976). DSS provide users with pertinent and relevant information to support the identification of a problem and the decision making towards a solution (Power n.d.; Power and Sharda 2009; Zhou et al. 2004). The responsibility of making decisions and selecting solutions is on the user, not the system (Forslund 1995; Sniezek 1999). DSS are typically identified as having three components which include the user interface, a knowledge base and a knowledge processing system (Bonczek et al. 1981; Sprague Jr and Carlson 1982).

Advisory systems are a kind of ES (Beemer and Gregg 2008; Forslund 1995) which have as a focus to advice on the potential solutions to the problem in hand where the problem is unstructured and has a degree of uncertainty (Beemer and Gregg 2008), similar to the type of problems that DSS typically handle. Advisory systems are suitable for problems where there is no single correct answer (Beemer and Gregg 2008). Most common areas for advisory systems are found in those where the diagnosis is required in a variety of situations within the same domain such as health, pharmaceutical, and mechanical. Business Intelligence (BI) and infrastructure procurement have also benefited from the use of advisory systems (Beemer and Gregg 2008; Sniezek 1999). It is to note that within these domains human judgement remains relevant mainly due to ethical reasons (Forslund 1995). Advisory systems present a knowledge base over which a reasoning engine works, and a User Interface (UI) to interact iteratively with the user in the process of solving the problem, as well as a monitoring agent which helps in the profiling of sub-problems or situations that also may need a solution (Beemer and Gregg 2008; Forslund 1995; Mintzberg et al. 1976).

Another area of IS which presents useful artefacts to support the selection of business partners for inter-collaboration is the field of Recommender Systems (RS) and Matchmaking Systems (MMS). Recommender systems are based on predictions of the likeliness of a user to be interested or to prefer an item (Isinkaye et al. 2015; Melville and Sindhwani 2010; Ricci, Rokach, et al. 2011); in this sense, RS are categorised as "information filtering systems" (Konstan and Riedl 2012) where from extensive database elements, only the most relevant are presented to each user, generally in a personalised way (Isinkaye et al. 2015). For this, recommender systems can be seen as a decision making strategy system (Rashid et al. 2002) normally focused on a single kind of recommended item (Ricci, Rokach, et al. 2011) and mostly focused on underpinning personalisation. RS are based on algorithms that filter the information based on previous preferences from the user, preferences by a group of users similar to the user, or a hybrid approach of both (Jannach et al. 2010).

MMS, also part of the information filtering solutions (Adomavicius and Tuzhilin 2005; Baudisch 1999; Brozovsky and Petricek 2007), provide results to a query based on the knowledge representation model designed and the variables and constraints involved (Joshi et al. 2009). Matchmaking is about potential solutions satisfying to the highest degree possible a requirement to be fulfilled (Famaey et al. 2012; Li and Horrocks 2004; Lutz et al. 2003; Zhi-Hao and Shi 2008). Recommender systems can also utilise matchmaking approaches (Adomavicius and Gupta 2009; Adomavicius and Tuzhilin 2005).

A table summarising the characteristics of the reviewed problem-solving systems can be found in Table 1.1, and a summary of those presented considering the context of this research can be found in Table 1.2.

Table 1.1: *Overview of the characteristics of the available types of IS that could be utilised to support the business partner selection. Where: Artificial Intelligence (AI), Knowledge-based (KB), Expert Systems (ES), and Information Filtering Systems (IFS).*

System type	Derive from	Input	Output	Goal	Technique	Components	Good for	Decision taken by
Expert systems	AI	Knowledge acquisition from human experts	Solve a problem and deliver a solution	Emulate human decision processes	Rule-based reasoning	Knowledge base, inference engine	Well-defined problems	System
Decision support systems	KB	Raw data and interaction with user	Suggestions to improve decisions	Help and complement the human's problem-solving process	Knowledge and Model-based reasoning	Knowledge base, model base, user interface	Semi-structured and unstructured problems	User
Advisory systems	ES	Raw data, interaction with user and with the help of the monitoring agent	Suggestions of possible solutions		Case-based reasoning	Knowledge base, inference engine, user interface, monitoring agent	Unstructured and loosely defined problems	User
Recommender systems	IFS	can be mined from available data, from monitoring, explicitly given	A set of items that are very likely to be of interest/utility to the user		Information filtering techniques	Information filtering algorithms, learning algorithm	Provide suggestions for items to be of use to a user	User
Matchmaking systems	IFS	Set of characteristics from a database, and a query given by the user	A set of results satisfying the requirements specified in the input query		Knowledge representation models	Set of constrains, matchmaking algorithm	Pair up two items (or groups of items) based on given requirements and constraints	User

Table 1.2: *Summary of the approaches available in IS to support the selection of suitable partners to form a collaborative network and how each system would present their suggestions.*

IS available	How it would apply to the problem
Expert systems	Automated selection of partners
Decision support systems	Covers the process of identifying the requirements until selecting the partner(s). Selection is made by the user
Advisory systems	Proposes suitable partners identifying the requirements with the help of the monitoring agent
Recommender systems	Proposes suitable partners based on the user personal preferences and past history, for example
Matchmaking systems	Proposes suitable partners based on a given set of requirements and constraints

1.1.3 Accepting Technology Research Differs from Computer Advice Utilisation Research

Business practice and technology research initiatives do not always find a common path for adoption (Al-Surmi et al. 2020; de la Boutetière et al. 2018; Leonard-Barton and Kraus 1985). One of the challenges is to develop flexible and simple enough research solutions which can be included in existing industrial systems (Al-Surmi et al. 2020; de la Boutetière et al. 2018). Another challenge is the alignment of technology with business aims, in such ways that both pursue shared objectives and find support on each other (Al-Surmi et al. 2020; de la Boutetière et al. 2018; Leonard-Barton and Kraus 1985); this is one example of the importance of having guidelines on the acceptance of new developments coming from technology research, especially those thought to be utilised in a real-world setting.

The Technology Acceptance Model (TAM) first presented by Fred D. Davis in 1985 (Davis 1985) has received much attention and is considered the most influential theory in IS (Benbasat and Barki 2007; Lee et al. 2003). TAM presents Perceived Usefulness (PU) and Perceived Ease of Use (PEOU) as the factors involved in people accepting technology integrations to their daily activities (Davis 1985). Originally, TAM was developed with the orientation to serve as a baseline for the design and implementation of "end-user systems" (a class of IS (Davis 1985)), where people could anticipate the acceptance of the system and therefore, implement the required changes to increment the success opportunities (Davis 1985). The questions motivating the development of TAM were regarding the relations between the features of the IS artefact and how these shape user behaviour, adapted from the psychology Theory of Reasoned Action (TRA) (Fishbein and Ajzen 1977).

Since TAM's first publication, several studies have been developed to add evidence to the model (See Benbasat & Barki 2007; Mortenson & Vidgen 2016; Marangunić & Granić 2015; Yucel 2013; Stei & Rossmann 2016; Lai 2017), and to address the objective and subjective sides of the constructs proposed by TAM. Such issues were indeed pointed out as future direction from the initial work (Davis 1985). However, much focus has been done to the factors and to "extensions" of TAM, setting aside the original purpose of the model towards design, evaluation and implementation of IS (Benbasat and Barki 2007; Marangunić and Granić 2015).

The proposed research in this thesis, although dealing with topics related to end-users accepting outputs from an intelligent IS, is not an extension of TAM. TAM tackles acceptance of technology in terms of users starting to use it in general. In contrast, the research described here focuses on whether outputs from intelligent IS can impact decisions of users, not what factors impact user's decision to use the intelligent IS in general. The focus is on the factors that motivate end-users to use advice by intelligent IS (here called a computer advisor).

Despite these differences, it is worth noting that this investigation shares with the Technology Acceptance Model (TAM) a reliance on EVT (Fishbein and Ajzen 1977) to shape the way in which they model behaviour. Indeed, TAM explains a behaviour through drawing on EVT (Davis 1989), yet TAM is focused in a different type of behaviour than the behaviour of deciding to use IS advice studied in this thesis: the behaviour of accepting and using technologies (Legris et al. 2003). In this sense, this thesis argues that computer-generated advice is not an element of IS use as defined by (Legris et al. 2003). To consider this in detail, an end-user could indeed use the computerised advisor because of its "usefulness" and "ease of use", but this does not necessarily mean that a) the end-users would utilise the advice, or that b) end-users utilising the advice would fully adopt the computerised advisor. The detailed investigation of such cases beyond their sheer possibility is out of the scope for this research, which instead focuses on identifying what drives users to utilise the computer-generated advice. As such, this thesis conceives computer advice as a different unit of analysis than general information systems and even different from the information systems giving that advice.

This research theorises about the elements involved in users utilising or discarding advice given by a computerised advisor. An "advice" is usually formulated in terms of a "recommendation" (Bonaccio and Dalal 2006) conceptualised as a piece of information which intends to support problem-solving (Bonaccio and Dalal 2006; Dalal and Bonaccio 2010;

MacGeorge et al. 2008). Advice utilisation, then, refers to the extent to which the recipient of an advice follows it (Bonaccio and Dalal 2006).

This thesis refers to “Computer Advice Utilisation” to the phenomenon of advice utilisation when the advice is given by a computerised advisor; the concept of Computer Advice Utilisation is defined in this thesis as “*the decision of the advice-recipient, a human, to integrate advice given by a computerised advisor into her/his decision-making”*.

The investigation considers the relevance and nature of inter-organisational collaboration and digitalisation, as mentioned before. The interest of this research is to understand what is involved in the advice utilisation of advice given by computerised advisors in support of business partner selection in manufacturing industries; this, considering the goal of those systems is indeed to provide advice that the user will utilise for their decision-making. The interest is the advice with the particular nature of being given by a computer instead of a person.

Industry 4.0 promotes new technologies and new business models and pushes forward the digital transformation of business processes (Ben-Daya et al. 2019). As such, new challenges also arise, and one of them is the technological support to business collaborations, identified as one of the core enablers of the current industrial trends (Camarinha-Matos et al. 2017). Understanding motivators involved in business partner selection towards business collaboration would bring a basis for suitable development and knowledge to support such processes adequately. To date, extant research identifies only a few factors as to what makes end-users utilise computer-generated advice. Such factors are found within the scenarios of movie and music selection (Jin et al. 2017; Köhler et al. 2011), route choice (Bonsall 1992; Takahashi et al. 2007), medical recommendations for clinicians (Chow et al. 2015), finance decisions (Ye and Johnson 1995), border control deception (Giboney et al. 2015), and air traffic management decisions (Westin et al. 2013); however, these research outcomes do not specify the relationship among the factors. Furthermore, there is no information regarding what influences computer advice utilisation for advice in support of business partner selection. This thesis presents an overview of such knowledge gap, the context around it, the methods used within this research to bridge the gap, and the results of the investigation work.

1.2 Research Specifics

1.2.1 Research Questions and Objectives

This investigation aims to provide artefacts in the form of technological solutions and accompanying knowledge that supports the realisation of business partner selection in the context of inter-organisational collaboration and digitalisation. The completion of the aim mentioned above addresses the following research questions (RQ):

RQ 1. In the context of inter-organisational collaboration and digitalisation, what are the factors that decision-makers consider when selecting business partners to form a collaborative network?

RQ 2. What is a suitable realisation of a computerised business advisor supporting business partner selection for collaborative networks' formation?

RQ 3. What factors influence end-users to follow the advice made by a computer business advisor when selecting business partners to form a collaborative network?

The strategy to address the research questions involves aligning them with the objectives below to guide the work within the investigation:

- **Objective 1 Problem formulation**. This objective is aligned with **RQ 1** and includes understanding the background to define the concepts and methods concerning the formation of collaborative networks in the context of inter-organisational collaboration and digitalisation and identifying the research gap.
- **Objective 2 Computerised business advisor's development**. This objective is aligned with **RQ 2** and includes the design and implementation of a computerised business advisor which supports business partners' identification in manufacturing industries, as well as the evaluation and selection towards forming collaborative networks. The computerised business advisor is the IS generating the advice object of the study (i.e. the computer-generated advice) and is used to support the theorising process by serving as an example when discussing with stakeholders.
- **Objective 3 Formalisation of knowledge.** This objective is aligned with **RQ 3** and includes the validation and theorisation about the factors influencing computer advice utilisation for computer-generated advice for business-value decision-making.

1.2.2 Overall Research Approach

This research utilises Action Design Research (ADR) (Sein et al. 2011) as a methodology to tackle the objectives and address the research questions. ADR is recognised as suitable when there is access to practitioners (as it is in the case of this research) and known to encourage the rigour of research and to optimise for practitioners interaction with such research (Sein et al. 2011). The expected outcome of the ADR methodology is an artefact (Sein et al. 2011) developed through the interaction with the context knowledge where the research was carried out; this is done through the ADR stages (Formulation of the problem, Building-intervention-evaluation, Reflection and learning, and Formalisation of learning). Furthermore, to produce the theoretical contribution of the artefact, i.e. the factors influencing computer advice utilisation for computer-generated advice, this research engages with the processes of the general method of theory building (i.e. conceptual development, operationalisation, confirmation or disconfirmation, and application) (Lynham 2002) within the ADR stages to continuously refine and develop the theoretical knowledge. Chapter 2 presents the details of this research approach.

1.2.3 Contributions to Knowledge

This research contributes to the body of knowledge of IS by pushing forward the boundaries of what is known about computer advice utilisation. Contribution 1 and Contribution 2 are considered major contributions, and the remaining two, are considered ancillary, as follows:

Contribution 1. A state-of-the-art computerised advisor, available to support the selection of business partners in manufacturing industries towards forming inter-organisational collaboration.

Contribution 2. Addition to the IS theory of Computer Advice Utilisation (CAU) applicable when the advice is provided by a computer in support of business partner selection in manufacturing industries, thus, adding a theory in the domain of computerised advisors for business decision making and inter-organisational collaboration in manufacturing industries supported by IS.

Contribution 3. A pair of tools to assess collaborative platforms and collaborative technologies towards supporting inter-organisational collaboration in the digitalisation context.

Contribution 4. A methodological example of the use of ADR to theorise.

1.3 Overview of the Thesis

This thesis consists of six chapters, where Chapters 3, 4 and 5 present the central part of the thesis in a publication format. The structure of the thesis is the following:

- **Chapter 1** has laid out this research's foundational dimensions and exposed the relevance and context of the investigation, as well as an overview of the overall research approach proposed to fulfil the research objectives.
- **Chapter 2** details the research method utilised in the development of the research.
- **Chapter 3** presents a review of the context's foundations to develop this research, which includes digital marketplaces and digital services related to inter-organisational collaboration.
- **Chapter 4** presents the work carried out to develop the computerised business advisor utilised in this research named "Tender Decomposition and Matchmaking System" (TDMS).
- **Chapter 5** exposes the theorisation work, including details on the methodological approach to come up with the contribution to the knowledge of what motivates end-users in the context of inter-organisational collaboration and digitalisation.
- **Chapter 6** concludes the thesis with a discussion on the overall results and implications for theory and practice, as well as limitations of the work and future research paths.

Figure 1.1 depicts a roadmap of this document including a view connected to the research objectives (see Section 1.2.1). Table 1.3 lists the publications included in this thesis, and the details of the three Chapters containing the publications are presented in the succeeding subsections.

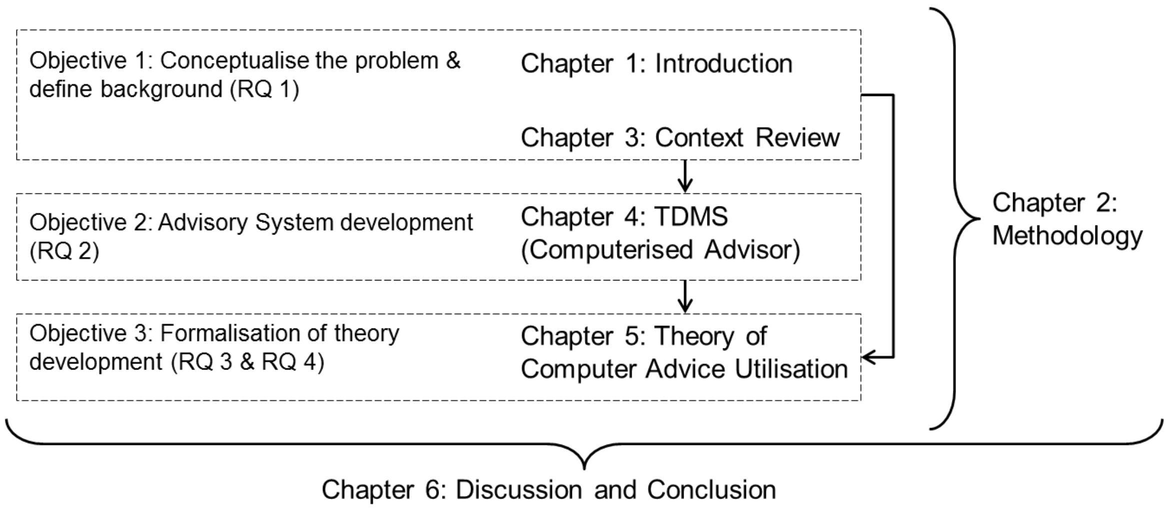

Figure 1.1: Thesis structure

Table 1.3: *Publications included in this thesis*

Chapter	ID	Publication title	Authors
Chapter 3	P01	Digital Marketplaces for Industry 4.0: A Survey and Gap Analysis	Sonia Cisneros-Cabrera, Asia Ramzan, Pedro Sampaio, and Nikolay Mehandjiev
Chapter 3	P02	Digital Services for Industry 4.0: Assessing Collaborative Technology Readiness	Asia Ramzan, Sonia Cisneros-Cabrera, Pedro Sampaio, Nikolay Mehandjiev, and Nikolai Kazantsev
Chapter 4	P03	An Approach and Decision Support Tool for Forming Industry 4.0 Supply Chain Collaborations	Sonia Cisneros-Cabrera, Grigory Pishchulov, Pedro Sampaio, Nikolay Mehandjiev, Zixu Liu, and Sophia Kununka
Chapter 5	P04	Computers as Advisors for Inter-organisational Partner Selection: What makes People take Business Advice from a Computer System?	Sonia Cisneros-Cabrera, Nikolay Mehandjiev, Matti Rossi, and Pedro Sampaio

1.3.1 Context Review: Digital Marketplaces for Industry 4.0: A Survey and Gap Analysis & Digital Services for Industry 4.0: Assessing Collaborative Technology Readiness

Chapter 3 exposes the context of the thesis revolving around the concept of Industry 4.0, collaborative networks and their supporting technologies in the supply chain, i.e. inter-organisational collaboration and digitalisation. The chapter is divided into two sections which address the Objective 1 of conceptualising the problem and defining the background.

The first section (Section 3.1) contains a survey and gap analysis presenting the general overview of the functionalities available in collaborative technology-enabled platforms in use, and an analysis of how such platforms are envisioned in the context of Industry 4.0.

The second section (Section 3.2) presents an exploration of technologies that support digital collaboration and shows the work carried out to understand how these align to Industry 4.0 characteristics. In this sense, Section 3.1 presents a big picture of the technological functionalities and implementation of platforms designed to support collaboration, and Section 3.2 takes a look at a granular level of individual technologies enabling such collaboration.

Although the work presented in Section 3.1 was published in 2017, for the purposes of this thesis presentation in 2020, the selected platforms were re-evaluated in July 2020. This re-evaluation found that the updates on the functionality platforms include the diversification of the offer to cover services and industrial products, where, in 2017, those were not yet available; also, the platforms opened to include small and medium enterprises (SMEs), where, in 2017, some of the platforms were focused on large suppliers and manufacturers only. Finally, the re-evaluation also identified the inclusion of security features, although not in all of the platforms. This analysis suggests that the use of digital platforms has been extended in the last 3 years since the original paper was published, and collaboration became wider in the needed coverture of products and services, but also grew to include smaller businesses, likely as a response of how the digitalisation has advanced to reach an increased number of industries and businesses (Jeansson and Bredmar 2019; Joensuu-Salo et al. 2018; Kergroach 2020). The updated assessment is reflected in Table 3.1-1 located in Section 3.1, where the changes that the re-evaluation produced are marked with a grey background in the corresponding cells.

Results of the work presented in Chapter 3 represent the input to the work carried out for Objective 2 and 3 of this research, and represent a concise view of the requirements of technologies that support collaboration, such as computerised advisors in the manufacturing industries.

1.3.2 TDMS: An Approach and Decision Support Tool for Forming Industry 4.0 Supply Chain Collaborations

Chapter 4 presents the work carried out to address the Objective 2 of the research. Objective 2 addresses the research question about what kind of computerised business advisor can be used to provide advice on business partner selection for collaborative networks' formation. The development of this objective is supported by the Design Science Research (DSR) method (Hevner et al. 2004); appropriate to guide the development of any tool that solves an important IS problem. The tool developed is called "artefact" (Hevner et al. 2004). The computerised business advisor proposed within the scope of this second objective enables contributions to knowledge by combining the understanding of the state-of-the-art with innovation (Hevner and Chatterjee 2010).

The design and implementation of the system utilised industry standards, such as Unified Modelling Language (UML) (Rumbaugh et al. 2004) modelling and validation with technology experts, part of the DIGICOR team, i.e. the practitioners' team in ADR; a microservices (Nadareishvili et al. 2016) architecture was followed, and programming standards were also utilised in the implementation, such as known Java web-based frameworks (Angular 4[3]). The design was built according to a phase of requirements elicitation and iterations with end-users. As part of the DSR method guidelines, expert feedback was collected to analyse the benefits of the artefact from their perspective. Offline experiments were implemented using a manual selection of teams to fulfil a given call-for-tenders (CfT) based on the designed data model for the computerised advisor. The experiment was used to give an account of the matchmaking algorithm utilised in the system.

[3] https://angular.io/

1.3.3 Theory of Computer Advice Utilisation: Computers as Advisors for Inter-organisational Partner Selection: What makes People take Business Advice from a Computer System?

Chapter 5 presents the work carried out as part of the Objective 3 of validating and theorising about the factors influencing computer advice utilisation for computer-generated advice for business-value decision-making, embedded in a theory named the "Computer Advice Utilisation (CAU)" theory, applicable when the advice is provided by a computer in support of business partner selection in manufacturing industries. This chapter specifies how ADR (Sein et al. 2011) was utilised in this investigation to come up with theoretical propositions that specify what drives computer advice utilisation within the context of inter-organisational collaboration and digitalisation. This chapter also presents how this research work uses the Judge-Advisor System (JAS) (Bonaccio and Dalal 2006; Sniezek and Buckley 1995) to conceptualise the phenomenon of study, and the Expectancy-Value-Theory (Edwards 1954; Fishbein 1963; Fishbein and Ajzen 1977) to model the relationships of the identified factors. Finally, this chapter presents the details of the procedure used to simulate and validate the theoretical propositions through a BN (Holmes and Jain 2008; Korb and Nicholson 2010).

1.4 Contribution of Authors in the Publications Included in this Thesis

The publications presented in this thesis are the result of a collaboration of several researchers, for accountability purposes, this subsection presents the description of the contributions made by the authors, separated by (1) the author of this thesis, i.e. Sonia Cisneros-Cabrera, (2) the supervisory team, i.e. Prof Nikolay Mehandjiev, and Dr Pedro Sampaio, (3) the internal researchers, part of the University of Manchester, i.e. Dr Asia Ramzan, Dr Grigory Pishchulov, Dr Zixu Liu, Dr Sophia Kununka, and Mr Nikolai Kazantsev, and (4) the external researchers, part of other institutions, i.e. Prof Matti Rossi, and Prof Alexander Felfernig.

Table 1.4 presents a quick reference for the individual contribution of the author of this thesis in each publication included in Chapter 3, Chapter 4, and Chapter 5; such table is based on a systematic view of the activities associated in research publications (Winston 1985).

Table 1.4: *Account of individual participation of the author of this thesis in the list of publications included (see key reference in Table 1.3)*

Activity	P01	P02	P03	P04
Conceptualising and refining research ideas	Yes	Yes	Yes	Yes
Literature search	Yes	Partially	Yes	Yes
Creating research design	Yes	Yes	Yes	Yes
Instrument selection	Yes	Yes	Yes	Yes
Instrument construction/questionnaire design	Yes	Yes	Yes	Yes
Selection of analysis approach	Yes	Yes	Yes	Yes
Collection and preparation of data	Yes	Yes	Yes	Yes
Data analysis	Yes	No	Yes	Yes
Data interpretation	Yes	Yes	Yes	Yes
Drafting manuscripts	Yes	Yes	Yes	Yes
First draft	Yes	No	Yes	Yes
Second draft	Yes	Yes	Yes	Yes
Redraft of a page (on later drafts)	Yes	Yes	Yes	Yes
Editing manuscript	Yes	Yes	Yes	Yes

1.4.1 Author of this Thesis' Contribution

In the publications with ID P01, P03 and P04 (see key reference in Table 1.3), the author of this thesis lead the research efforts; this involves developing all of the activities associated in research publications (Winston 1985) (see Table 1.3) on the level of primary role, i.e. being the person responsible to conceptualise, execute, manage and take decisions concerning the research activities.

In the publication with ID P02, the author of this thesis co-led the research effort in parallel with the first author of the paper, this involves that the author of this thesis did not develop the first draft. The reason for this is that the first author has experience in taxonomy development, and therefore took the lead on this aspect of the literature search and in the data analysis on this regard. The author of this thesis participated in the rest of the associated research activities for P02, including a co-authorship level of refining and addressing feedback to shape the final draft, also, the author of this thesis proposed the initial conceptualisation of the research, which follows a line based on P01, and since the first draft took a major participation in the ideas developed.

1.4.2 Supervisory Team's Contribution

The supervisory team has provided guidance and senior consultancy on the research directions of the research outputs. They were involved in providing guidance and scholarly criticism that aided the discussions and emergence of research results. The supervisory team worked closely with the author of this thesis advising and providing the resources needed to achieve the research objectives that are included in the publications presented in this thesis. Such resources take the form of funding allocation, time of discussion, pointing to relevant scientific literature to support the research, facilitation of appropriate training courses, and accompaniment to meet and acquire support from external entities, such as external researchers, and practitioners.

1.4.3 Internal Researchers' Contribution

The research in all of the publications received the collaboration of other internal researchers, part of a research group in the University of Manchester, under the lead of the supervisory team. The internal researchers contributed with their expertise at different levels (reflected in the listed order of authors on each publication). The participation of internal researchers produced discussions that came from different points of views, given that the internal researchers pursue different research interests each; this enriched the research and pushed the boundaries of what could have been developed without such discussions. The main role of the internal researches was to support the author of this thesis in the associated research activities; however, the publications presented in this thesis are not the internal researcher's main research work, and the lead and higher responsibility remained with the author of this thesis.

1.4.4 External Researchers' Contribution

This research benefited from access to external researchers who participated in advising the author of this thesis as experts on the research methodology used in this research (i.e. ADR), and applied artificial intelligence particularly concerning recommendation systems and similar systems. This access enabled the research to receive feedback and refine the publications. The external researchers participated mainly in the research design discussions, the instrument construction/questionnaire design refinement, and manuscript final reviews.

1.4.5 Detailed Manuscript Contribution

Digital Marketplaces for Industry 4.0: A Survey and Gap Analysis

In this paper, the author of this thesis conceptualised and refined the research idea and the objective of the paper, as well as its structure, design research, and wrote the first manuscript draft. She also did the work on investigating suitable methods to approach the task of developing a gap analysis, the literature review, identified the potential platforms to analyse, and performed the gap analysis over the selected platforms, she was also the corresponding author, and presented the research results in the PRO-VE 2017: 18th IFIP Working Conference on Virtual Enterprises.

Dr Asia Ramzan provided suggestions to second and succeeding drafts, provided support in the proof-reading task, and shared ideas of potential available platforms. Dr Pedro Sampaio and Prof Nikolay Mehandjiev provided feedback, guidance, and recommendations to the process of the research development, including support in critically analysing the adequacy of the methods for the purpose of the research work, and discussions to help refining the details such as the research methods and improvement of the manuscript presentation.

Digital Services for Industry 4.0: Assessing Collaborative Technology Readiness

In this paper, the author of this thesis provided the base concept of the research idea, and jointly with Dr Asia Ramzan refined the objective of the paper, as well as its structure and design research. Sonia Cisneros-Cabrera also collaborated on investigating suitable methods to approach the task of developing taxonomy development, contributed to define the publishing strategy, discussed the taxonomy final version to support its refinement and directly worked on the presentation design, updated the description of the taxonomy, abstract, introduction and conclusion, served as proof-editor, corresponding author, and lead and primarily addressed the reviewer's comments for the camera-ready version; she also presented the research results in the 16th European, Mediterranean, and Middle Eastern Conference, EMCIS 2019.

Dr Asia Ramzan elaborated the first draft of the manuscript, carried out the data analysis to develop the taxonomy, and the validation approach of the taxonomy. Dr Pedro Sampaio and Prof Nikolay provided feedback, guidance, and edits to the completed manuscripts to improve its final shape as well as decision support in the scope and research outcomes. Mr Nikolay Kazantsev provided critical analysis to intermediary versions of the manuscript and added his suggestions to improve the work.

An Approach and Decision Support Tool for Forming Industry 4.0 Supply Chain Collaborations

The author of this thesis developed the first draft of the manuscript, as well as the conceptualisation, design and technical details of the implementation of the decision support tool, the data collection, and data analysis; she also led the collaborative effort to address the reviewer's comments, and worked on addressing those not directly related to the ontology. Dr Grigory Pishchulov developed and implemented the algorithm of the decision support tool based on the concept design and his expertise in supply chain management, and wrote the first draft of the sections detailing such implementation, including the ontology implementation; he also worked in addressing the reviewer's comments along with the first author. Dr Pedro Sampaio and Prof Nikolay Mehandjiev participated in the refinement of the manuscript and supported the author of this thesis in the development of the decision support, particularly regarding design decisions. Dr Zixu Liu participated in the development and execution of the validation section, and Dr Sophia Kununka participated in the data analysis for the verification section. The author of this thesis collaborated with all of the authors in their participation for all of the required activities that produced the manuscript.

Computers as Advisors for Inter-organisational Partner Selection: What makes People take Business Advice from a Computer System?

The author of this thesis elaborated the first manuscript, conceptualised, refined and executed the research idea, strategy, and the theory presented. She also collected the data and performed the specified analyses. For the laddering interviews, she collaborated with Prof Alexander Felfernig to guide the development of the laddering study, and Dr Sophia Kununka supported the execution of the interviews in parallel to the author of this thesis, such attributions are presented in the authorship of the publication containing the laddering results in (Cisneros-Cabrera et al. 2020). The paper presented in this thesis, however, utilises such results.

For this paper, Prof Nikolay Mehandjiev participated in the refinement of the research strategy and the theorising process, as well as providing feedback and suggestions to improve the manuscript on all of its sections. Prof Matti Rossi provided guidance on the methodological approach, and Dr Pedro Sampaio provided comments and suggestions for the improvement of the manuscript.

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Chapter 2

Research Methodology

2.1 Overview of the Research Process

To tackle the objectives posed in Chapter 1, this research espoused the methodology of Action Design Research (ADR) (Sein et al. 2011). ADR combines the converging methods of Action Research (AR) to support theory development in close cooperation between researchers and practitioners (Collatto et al. 2018; Robertson 2000); and Design Science Research (DSR) (Collatto et al. 2018; Sein et al. 2011), suitable for building artefacts designed to address a practical problem (Baskerville et al. 2018). In ADR, the information technology (IT) artefact is shaped by the context of its creation and by the problem it is designed to address. For this, ADR reuses the collaboration guidelines of AR and adds an ongoing artefact evaluation and knowledge generation to DR, where conventionally the evaluation is done once the artefact is completed (Collatto et al. 2018; Hevner et al. 2004; Sein et al. 2011). As such, the work developed within ADR is iterative in nature and comprises four distinct yet interwoven stages as shown in Figure 2.1: (1) Problem formulation, (2) Building, intervention, and evaluation (BIE), (3) Reflection and learning, and (4) Formalisation of learning (Sein et al. 2011). The iterations of BIE stages allow for the iterative development of an artefact combined with the formalisation of new knowledge (Sein et al. 2011).

ADR is considered suitable to address the research objectives of this investigation since it offers a means to optimise the interwoven processes of developing theoretical knowledge and building a computerised business advisor. It is also geared to support the engagement between researchers and practitioners within the context of a practical problem, which in our case is the problem of business partner selection described in Chapter 1.

These interwoven processes of creating knowledge and ensemble artefact took place within a 36-month Industry-Academy research project involving the University of Manchester, called Decentralised Agile Coordination Across Supply Chains (DIGICOR). DIGICOR was funded by the European Commission under the Horizon 2020 programme to develop a technology platform supporting the creation and operation of collaborative networks in manufacturing domains (DIGICOR 2016). The practitioners represented three organisations: a European aircraft manufacturer, a German aviation cluster with a number of SME members, and a Welsh SME platform provider to primarily automotive, but also aerospace and electronic manufacturing clusters. The interest of these organisations lies in seeking for the alignment of their businesses with the emerging industrial paradigms, particularly the Industry 4.0, and DIGICOR offered an opportunity to address the need of developing digital solutions that would support the innovation and updated services level to fulfil the demands of the industry (Dalmarco and Barros 2018; DIGICOR 2016; Heng 2014; Kannan et al. 2017).

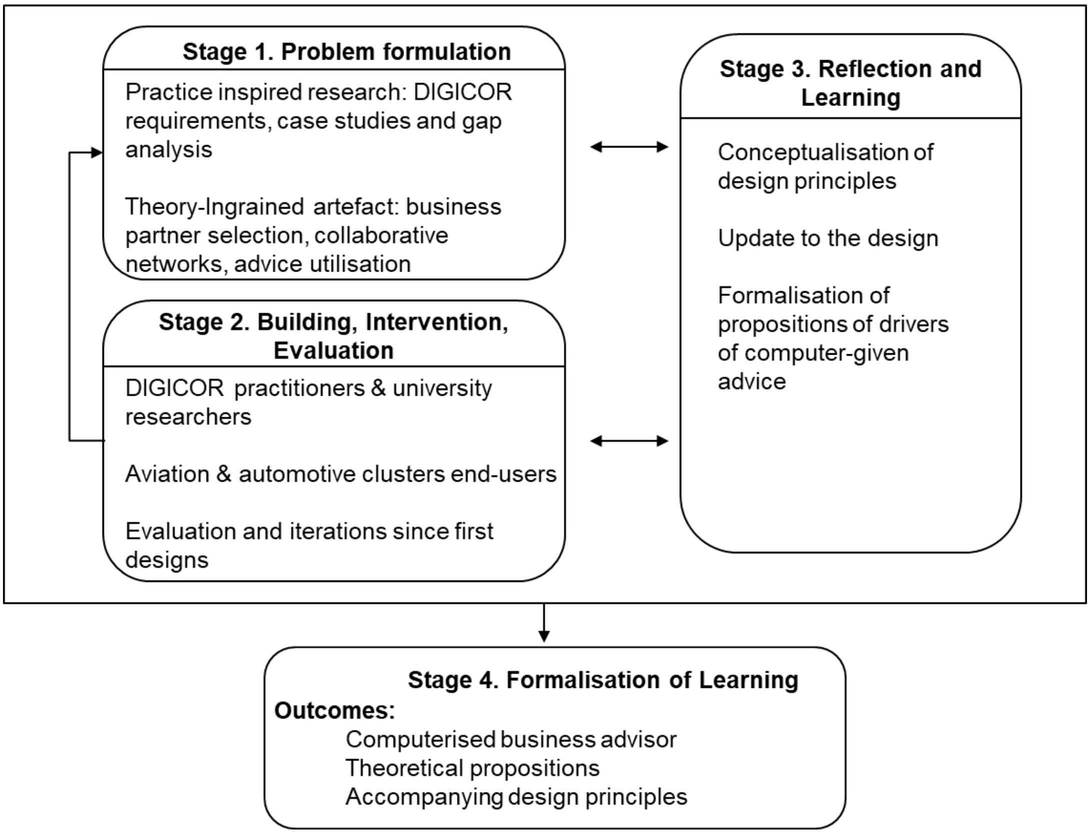

Figure 2.1: ADR stages as applied in this research. Adapted from (Sein et al. 2011)

In Stage 1 of ADR, the involvement of the practitioners enabled the understanding of the requirements and problems to be addressed within DIGICOR in the context of inter-organisational collaboration and digitalisation, as well as the analysis of the DIGICOR use cases, and analysis of extant collaborative platforms and tools in terms of their coverage of user requirements and use cases.

Within Stage 2, a series of workshops involving practitioners from the Welsh SME platform provider and the German cluster took place. The workshops were focused on building, trialling and updating the design of the computerised business advisor through iterative prototyping (Goldman and Narayanaswamy 1992).

Stage 3 supports the knowledge collection through feedback from the first two stages, facilitating the initial conceptualisation of the theoretical propositions and the supporting design principles for business partner selection systems (computerised advisors). It is to note that ADR is iterative, and thus, the execution of the Stages happen in cycles, however, for presentation purposes, the Stages are ordered and presented sequentially as in Figure 2.1 (Sein et al. 2011).

In the final stage of ADR (Stage 4, Formalisation of learning) the main tasks involve the formalisation of theoretical propositions; this formalisation was aided by a pattern matching approach (Sinkovics 2018) used as a theory development mean to converge both theoretical and empirical knowledge. Figure 2.1 presents a summarised view of the concepts and activities addressed within each ADR stage in this research.

2.1.1 Overview of Methods and Outcomes within each ADR Stage

While ADR guides the overall research process of this investigation, several distinct methods are used within each stage, depending on the tasks required to fulfil the associated research objective (see Chapter 1) (Chu and Ke 2017; Kholeif et al. 2008). The paragraphs below present an overview of the methods utilised to achieve each objective.

In Stage 1, the activities under *Objective 1* address the first research question (*RQ* 1). These include reviewing the literature of collaborative networks, examining existing digital services supporting manufacturing and collaboration technologies, and eliciting the published factors that influence computer advice utilisation. These activities support the development of understanding the environment of the phenomena being investigated and identify the research gap. The outcomes of this objective include (1) a survey tool to assess marketplaces regarding its readiness to support Industry 4.0 and (2) a gap analysis of extant marketplaces utilising this tool, (3) a survey tool to assess collaborative technology readiness in their support for Industry 4.0 based on a taxonomy of collaborative technologies, and (4) the background and contexts sections of Chapters 3, 4 and 5 of this thesis.

In Stage 1, Stage 2, and Stage 3, the activities under *Objective 2* address the second research question (RQ 2) by focusing on the artefact design activities of ADR i.e. building a computerised business advisor, developed with the interaction enabled by the ADR methodology and coined as “Tender Decomposition and Matchmaking Service” (TDMS). In the paper describing our work we have chosen to represent these activities framed as a Design Science Research project (Hevner et al. 2004), thus simplifying the narrative within the paper, and retaining alignment with the ADR methodological framework of the overall thesis. Indeed, the alignment of DSR within ADR (Iivari and Venable 2009; Maccani et al. 2015) responds to the scope of each in the following way: ADR overall looks at a much wider context through the organisational intervention, and evaluation is also part of the work (Sein et al. 2011), whereas DSR focuses on the development of the new artefact rather than in the interaction between existing theory and an industrial need (Hevner et al. 2004; Sein et al. 2011), and Objective 2 required such DSR focus.

In Stage 2, Stage 3, and Stage 4, *Objective 3* addresses the third research question (RQ 3) by combining elicitation instruments such as a laddering end-user interview study (Reynolds 1988) and survey questionnaires with a simulation technique based on a Bayesian network (Heckerman 2008; Holmes and Jain 2008) to simulate the predicted outcomes of the theory. The outcomes predicted by the theory are then checked against a vignette-based questionnaire study of end-users (Hughes and Huby 2004). The outcome of achieving this objective is the formalisation of the knowledge obtained in the pursuit of Objectives 1 and 2 in the form of a theory (Kuechler and Vaishnavi 2008) of computer advice utilisation.

Table 2.1 presents a structured summary of the objectives, the methods utilised within each one, and the outcomes obtained, including the publication target for the self-contained research articles developed within each objective.

Table 2.1: *Summary of the research strategy*

	RQ	ADR stage	How tackled	Outcome	Publication target
Objective 1	RQ 1	Stage 1: Problem formulation	Literature Review Gap Analysis Taxonomy development	Literature review analysis Taxonomy for Industry 4.0 readiness	Inclusion in other publications Working Conference on Virtual Enterprises (Pro-VE, published) European, Mediterranean and Middle Eastern Conference on Information Systems (EMCIS, published)
Objective 2	RQ 2	Stage 1: Problem formulation Stage 2: BIE Stage 3: Reflection & learning	Design Science Research	Automated Business Advisor (TDMS)	Computers in Industry Journal (Submitted)
Objective 3	RQ 3	Stage 2: BIE Stage 3: Reflection & learning Stage 4: Formalisation of learning	Survey & Interviews Bayesian network exercise & validation	Theory of Computer Advice Utilisation	The Pacific Asia Conference on Information Systems (PACIS, published) Management Information Systems Quarterly (MISQ, not submitted)

2.2 Insights into the ADR Process

Stage 1: Problem Formulation

The first stage of ADR involves the identification of the problem and the specification of what is known as the "ADR team", formed by a subteam of practitioners, and a subteam of researchers (Sein et al. 2011). In the case of this research, the ADR practitioners team ranges in roles from project managers, chief executive officers (CEOs), and research coordinators within their companies — part of a German aviation cluster, and a Welsh SME platform provider to primarily automotive, but also aerospace and electronic manufacturing clusters. The ADR practitioners' team are the people who contributed to shaping the outcomes of the ADR.

In this research, a review of literature on selecting business partners is a key instrument for clarifying the target problem. The background sections of each chapter of this thesis present the results of the literature review. This first ADR stage also includes a gap analysis of existing collaborative platforms and technologies to survey the opportunities for supporting partner selection in manufacturing domains. The results of the gap analysis of platforms identify the need for working technological solutions to support the formation of collaborative networks according to the Industry 4.0 vision. The analysis of technologies assessed their readiness against the Industry 4.0 requirements. This analysis serves to explore the context of technologies available to support digital collaboration and expand the set of requirements for this research.

Finally, the results of the gap analysis are discussed with two practitioners from the Welsh SME platform provider and further requirements are collected for the initial wireframe prototype of the computerised business advisor to be developed. These results also contribute to the initial development of the theoretical outcome. These activities allow for the conceptualisation of the problem and guide the follow-on ADR stages. Table 2.2 presents a summary of the activities involved in this ADR stage and its outcomes.

Table 2.2: *Summary of activities carried out in the ADR Stage 1 (Problem formulation)*

Description	Objective	Method	Date and Stakeholders	Outcome
Literature review: inter-organisational partner selection and advice acceptance	Understand the extant literature and influence our research through existing theory	Literature review	February – March 2017 and iteratively across the research Stakeholders not required	Partner selection criteria is analysed from two fronts usually not connected: the objective selection and the people-centred. Lack of research integrating the knowledge and deepening in advice acceptance for partner selection aspects supported by technology
Assessment of digital marketplaces towards Industry 4.0 capabilities	Gain a general overview of the state-of-the-art functionalities available and required in Industry 4.0 in the supply chain collaborative platforms	Survey and Gap Analysis	April 2017 Stakeholders not required	Team formation is yet not widely supported in the most popular business-to-business (B2B) digital environments
Digital Services for Industry 4.0: Assessing Collaborative Technology Readiness	Explore popular technologies supporting digital collaboration and gain an understanding of how these align to Industry 4.0 goals	Taxonomy development	April 2017 Stakeholders not required	A taxonomical solution proposing Industry 4.0 characteristics for collaborative technologies
Discussion regarding the findings of the work in Stage 1	Gain insights and initial perspectives from practitioners with regards to the use of technological support for business partner selection	Interview	June 2017 Welsh SME platform provider (2 people)	Results from the initial analyses were aligned to the practitioner's perspective

Stage 2: Building, Intervention, and Evaluation

The activities to develop the solution to solve the specified problem are carried out in the second stage of ADR. This stage requires iterations of what is known as "Building-Intervention-Evaluation" (BIE). BIE iterations reflect the dynamic of designing and creating the artefact and further shaping it by the influence of the practitioners.

The evaluation part requires a reflection and building on top of the knowledge acquired, which also goes back to further evaluations, reshaping of the problem specification, and a continuous learning through the BIE process. In ADR, the outcome of this stage is the advancement of the design principles, the artefact, and the theory with the knowledge of Stage 1 and the BIE cycles.

In this, Stage 2, the following ADR principles apply: (1) the influence of the artefact design and creation to the organizational context of the artefact and vice versa, and (2) the notion of a concurrent evaluation towards a formative learning (Sein et al. 2011). In our research, the ADR researchers and practitioners teams worked together since the first sketches of the artefact.

The overall strategy to fulfil the research objectives includes the development of a computer advisory system which proposes a number of alternative collaborative teams to its users. As mentioned in the introduction chapter of this document, this computerised advisor receives the name of “Tender Decomposition and Matchmaking Service (TDMS)”, after the mechanism utilised in it. TDMS decomposes a business opportunity (i.e. a tender) into components required to fulfil such opportunity, and matches requirements for components to capabilities of potential partners to propose alternative teams (Cisneros-Cabrera et al. 2018). The following tasks took place along the ADR Stage 2 to support the development of the TDMS, the theory of computer advice utilisation, and the corresponding design principles. These were testing different stages of the development and advanced building on top of the acquired understanding:

Workshop presenting a wireframe version. In early October 2017, the research ADR team presented a mock-up of the initial concept of the TDMS. This was done to collect the views from the practitioners and further iterate on the design based on the outcomes of this session. This workshop included the presentation of the mock-ups and the explanation of each part proceeded by a session of questions to know what the practitioners consider that such tool would need to implement to satisfy their needs, and why they think such tool would be, or not, a “good idea” for their businesses. This workshop involved 4 people from the Aerospace cluster in the German Aviation cluster premises. The mock-up presented is shown in Appendix A.1.

Feedback session presenting a demo version. In late October 2017, a second version was presented to practitioners and potential end-users. The version presented was the “TDMS demo” and the sessions aimed to survey the views on the use of such a tool for the support of partner selection in manufacturing industries. This session provided hints about the main concerns of users to implement a computerised business advisor in their decision-making for partner selection. The session involved 5 people from the German Aviation cluster, who did not see the previous mock-ups, and they were asked about their views and what they consider would be the main barriers of such a system to be used as an advisor in their businesses. Appendix A.2 shows the designs presented in this session, which took place in the “America Center Hamburg” premises.

Laddering interviews. In April 2019, a laddering end-user study (Reynolds 1988) was carried out to identify what are the motivators for users to utilise advice for business partner selection in manufacturing industries. The laddering interview technique facilitates the development of a "cognitive map" indicating the attributes, consequences and values concerning a given element, where a "chain" of related attribute-consequence-value is called a "ladder" (Reynolds 1988). There are several instances of studies where this technique was successfully utilised in Information Systems (IS) research (e.g. (Chiu 2005; Hänninen 2015; Heinze et al. 2017; Li et al. 2016; Sun et al. 2009; Wieneke et al. 2016)), particularly in topics related to phenomena of users interacting with IS, such as IS success and user acceptance. The supporting theory of the laddering technique, the Means-End theory (Gutman 1982; Reynolds 1988), underpins the aim of identifying what motivates users to comply with a behaviour through "means" they possess towards reaching an "end", in this sense, the study designed for this research investigates what leads users to reach the *end* of utilising computer-generated advice.

These interviews collected information about the attributes of the advice, the system and the concept of using a computerised business advisor, and the associated reasons as to why each attribute is considered important for the end-users. The cognitive map developed through this technique is called "Hierarchical Value Map (HVM)" which, for this research, provides a theoretical model of factors that should be taken into consideration when developing computerised business advisors of this type.

The HVP obtained from this study depicts the user-valued functionalities of computerised business advisors in support of business partner selection decision-making and an understanding of the linkages between functionalities, and the purpose users look to accomplish through such functionality. The result of the study offers insights that lead to our objective of understanding the drivers of people in following the said advice.

A total of 25 participants were involved at the Hamburg Aircraft Interiors Expo 2019 which took place in Hamburg, Germany from April the 2nd to 4th, 2019. Manufacturing aircraft interiors is a key element of aircraft manufacturing, with more flexible supply chains to respond to new materials and trends. SME manufacturers are also better represented, and they tend to form collaborative teams to complement their skillsets and produce winning tenders. All participants were involved in forming collaborative supply chains since this is the core aim of the event[4,5]. Their profiles ranged from decision-makers at SME suppliers to

[4] https://www.aircraftinteriorsexpo.com/en-gb/exhibitor-directory.html,
[5] https://www.aircraftinteriorsexpo.com/en-gb/about.html

purchasers at large Original Equipment Manufacturers (OEMs) such as Airbus and Boeing. These were all potential users of computerised advisors such as the one we developed.

Table 2.3: *Summary of the study procedure*

Item	Description	Time (minutes)
Interviewer presentation	Present yourself (name and organization) and a general explanation of the study and process steps (the study is composed of three parts: approval sheet, video and laddering interview)	5
Approval sheet & demographics	Demographics, general information and acceptance of participation	5
System functionalities	Video demonstrating functionalities of the tool	5
Laddering structure	Semi-structured questions	15

Table 2.4: *General guiding questions to address the gathering of functionalities (attributes) of the system, the underlying importance of such functionalities to the users (consequences) and the goal linked to such importance (value)*

ID	Useful for unveiling	Guiding questions
1	Attribute	What two functionalities of the system did you like the most?
2	Consequence	What did you like about <attributeN>?
3	Value	Why is <consequenceN> important to you?
4	Attribute	What functionalities do you think are missing or could be improved? If you were the designer of it, what would you include?
5	Consequence	Why is <attributeN> something you would like to have?
6	Value	Why is <consequenceN> important to you?
7	If yes, pass to ID9. If no, pass to ID8.	If the system would have <attributeN>, would it make you likely to follow the recommendation the system gives to you on who to choose as suppliers for the collaborative team?
8	Attribute	What are the three most important decisive functionalities that would make you likely follow the recommendation the system gives to you?
9	Consequence	What is it about <attributeN> that increases the likelihood of you following the recommendation from the system?
10	Value	Why is <consequenceN> important to you?

Table 2.5: *Specific questions regarding explanations*

ID	Useful for unveiling	Guiding question
1	Attribute	Would you prefer the system to have explanations for the proposed set of team compositions (the advice)?
2	Consequence	Why is it important / not important for you to have explanations in -the system?
3	Attribute	Which type of explanations would you prefer, the options are: (1) why a given set of companies was proposed, (2) why a given set of results is empty, or (3) how the system came up with the results in general?
4	Consequence	What makes <option selected> to be your choice over the other two?
5	Value	Why is <consequence> important?

Table 2.6: *Specific questions regarding trust*

ID	Useful for unveiling	Guiding question
1	Attribute	What system functionality can you think of that would make you trust the recommendation the system gives to you?
2	Consequence	Why <attributeN> makes you trust in the recommendation?
3	Value	Why is <consequence> important?

From the 25 participants, 20 interviews were deemed as valid based on completeness criteria for the data analysis (i.e. at least one complete ladder) (Phillips and Reynolds 2009). The study was carried out by two researchers from the ADR researchers team. The sessions included a showcase of a 5-minute video of the main functionalities of the developed computerised business advisor and a 15 minutes laddering interview. The objective of the video was not to place the participants on an emulated use of the system but rather position them with the picture of how a system of such type would look like.

Table 2.3 shows a summary of the study procedure, and Table 2.4 presents the guiding questions utilised in the laddering interview; if after the first 9 minutes of the interview the participant did not mention anything related to "explanations" or "trust" — two of the most mentioned aspects concerning advice acceptance (Ricci, Semeraro, et al. 2011) and not covered already with the rest of the questions — some additional guiding questions were placed to investigate the perceptions of such elements in the context of the research.

Appendix A.3 presents the sheet handled to the participants, and Tables 2.5 and 2.6 present the corresponding guiding questions specific to trust and explanations. All of the interviews took place at the Aircraft Interiors Expo Venue.

The analysis of the laddering interviews results adopted the approach as presented by Reynolds, 1988 (Reynolds 1988), where the steps include the identification of summary content codes from the interview transcriptions, the generation of an implication matrix indicating the direct and indirect relationships using the content codes, and the construction of a hierarchical value map based on the relationships found. The first step, therefore, was to transcribe the audio-recordings of the 25 interviews. The transcriptions were done omitting pauses and sounds of the speech (e.g. "ahm").

In the second step, the content-coding analysis was done using Atlas.ti[6] software on its English version (version 8) following the Gioia systematic approach for qualitative analysis (Gioia et al. 2013) as follows: (1) line by line analysis of the transcription to identify phrases where, in its context, make reference to a potential code – called "1st order concepts", (2) identification of codes from the 1st order concepts into the called "2nd order themes", and (3) grouping codes into a common theme, e.g. "meet deadlines" and "deliver on time" codes into "timeliness", known as "aggregated dimensions". The result of this procedure yielded 34 codes where 8 were identified as Attributes, 16 as Consequences, and 10 as Values. Table 2.7 presents

[6] https://atlasti.com/

some extracts of 1st order concepts and its assigned 2nd order theme; this represents an example of the process followed in the analysis for all of the codes obtained.

Table 2.7: *First-order concepts extract and its process towards aggregated dimensions*

1st Order Concepts	2nd Order Themes	Aggregate Dimension
To make a long-term company not just one highlight.	Business continuity	Financial benefit
To grow, for growth strategy.		
To save money.	Cost-saving	
To have the full cost overview and identify who is paying the price.		
To have more turnover.	Profit	
To make money out of it.		
To make sure you are profitable.		

The Gioia approach enables the rigorous and structured qualitative analysis in tasks such as content-coding, offering credibility and transparency through its systematic procedure (Gioia et al. 2013). The Gioia approach contrasts with other qualitative approaches which offer more loose guidelines to qualitative content analysis, such as the method of "immerse, reduce, and interpret" (Forman and Damschroder 2007), and general guidelines which indeed recommend adopting a systematic approach to content coding (Cope 2017; Schuster and Weber 1986).

Atlas.ti forms part of the known "computer-assisted qualitative data analysis software (CAQDAS)" which assist researchers in qualitative analysis tasks, such as content-coding analysis, by providing tools to manage the raw information to be analysed, generate content codes, create relationships among them, themes and different order levels, among other related tasks (Lewins and Silver 2009). Another example of such CAQDAS is NVivo[7], and MAXqda[8], however, these provide more complex and an increased number of functionalities given that those support not only qualitative but also mixed methods research, compared to Atlas.ti which is simple yet adequate for the purpose of using a software only for content-coding analysis.

For the third step, the ladders from each participant were extracted from analysing the coding work done in Atlas.ti and the construction of the attribute-consequence-value chains. For this, the ladderUX[9] software was utilised to record the identified ladders, and 5 interviews were found to have incomplete ladders, reaching only up to a consequence point and not to a

[7] https://www.qsrinternational.com/nvivo-qualitative-data-analysis-software/home
[8] https://www.maxqda.com/
[9] https://ladderux.org/

value item. Those interviews without at least one ladder were discarded of the analysis from this point; we obtained a total of 46 ladders. Appendix A.4 shows the ladders obtained.

LadderUX allows the researcher to automatically generate the corresponding implication matrix and the hierarchical value map (HVM) with the indicated cut-off value (Vanden Abeele et al. 2012). As recommended by (Reynolds 1988), different cut-off values were utilised (2, 3 and 4) to finally present 2 as the cut-off that depicts the most informative HVM considering the sample size is 20. Two researchers analysed the ladders where Coder 1 analysed 100% of the transcripts and derived an initial set of ladders from each participant; a second researcher, Coder 2 independently derived ladders from 50% of the total number of transcripts chosen randomly, and later the two coders compared both ladders. Any identified difference on the ladders was reconciled among the coders. Appendix A.8 presents the demographics the demographics of the results of the study.

Usability study. A questionnaire was developed aiming at establishing potential end-users' views about the usability of the TDMS. For this study, a TDMS "beta version" was presented; this version was updated based on the previous study results. This study concerns about the users' work and the intention of the computerised business advisor. The findings contributed to further improve the advisory system and to the analysis regarding the usability of such a system to solve the practical problem for which it was designed. This study was conducted between the 18th and 20th June 2019 at the Paris Air show in Paris, France[10], the international point of meeting for aerospace manufacturing businesses. The study participants were asked to provide their views by filling in an anonymous questionnaire after being explained the idea of the system; in this study, a shorter version of the TDMS capabilities video was also presented to them (due to time constraints of the event) to aid in the understanding of what type of systems we are dealing with, and 36 responses were collected. The selection criteria applied considered only participants who had any level of knowledge about the partner selection processes in their businesses towards forming collaborative networks. Appendix A.5 presents the questionnaire that was applied, and Appendix A.8 presents the corresponding demographic data.

Task-based questionnaire. Based on the findings from the laddering technique, a task-based questionnaire was designed, aiming at further confirming the initial findings, for this, 5 responses were obtained where the participants utilised the TDMS system themselves. The task the respondents were required to complete included using the TDMS to form a team that would

[10] https://www.siae.fr/en/

suit their organisation. After the exercise, the participants filled a questionnaire indicating their views on what would make them follow the advice proposed by the system. This study took place on 28th June 2019, in a practitioners gathering, part of the German aviation cluster.

A second session collected 18 responses from the Welsh SME platform provider related practitioners on 17th October 2019; these practitioners come from aerospace, automotive, and electronics clusters and were handled the questionnaire after being explained the characteristics and objectives of the TDMS to position their understanding to the topic of computerised business advisors. In this session, the task-based exercise was not applied because the time allocated with each participant did not allow this. The questionnaire applied for both the sessions in June and October 2019 is presented in Appendix A.6, and Appendix A.8 presents the corresponding demographics data.

Table 2.8 presents a summary of the activities carried out within the Stage 2 of the ADR method and an overview of the results obtained. Further details on the results are presented in Chapters 4 and 5 of this document.

Table 2.8: *Summary of activities performed in the ADR Stage 2 (BIE)*

Description	Objective	Method	Date and Stakeholders	Outcome
Initial concept: Mock-ups	Gather feedback to further shape the details of the approach and its alignment with a tool design.	Workshop	October 2017 European Aerospace corporation and European Union Project members (4 people)	General expectation: Less time and effort for forming a team Less risk of ending without a beneficial deal. “Quick” and “easy” mechanism Control over the final decisions: users
Initial demo designs	Obtain initial comments regarding the idea of the use of a tool recommending business partners to form a team and the design presented	Workshop	October 2017 German Aviation Cluster (5 people)	End-users appear positively expectant (usage and benefits) Concerns about trust and information security
First version of the system (live and running)	Understand insights of what would make end-users accept the advice coming from our system to further shape the design (iteration)	Laddering interview	April 2019 Expo Air show (Germany) 25 people	Identified drivers: Trust Financial benefits Competitiveness Possibility of fulfilling other responsibilities Success Role of explanations in trust-building

Updated version of the system. Usability study	Assess the perceived usability of the system to analyse the potential towards solving the specified problem of selecting partners supported by a computer advisory system	Paper-based questionnaire	June 2019 Paris Air Show (France) (36 people)	Feedback on desired functionalities: More clarity in the company profile information Intuitive and user-friendly interface. Trust in the partners is important Positive usability was found for: Supporting the team formation Reducing time, cost and effort in selecting a suitable business partner
Updated version. Task-based exercise.	Further explore the insights obtained in the laddering interviews and analyse if such results apply as well with other practitioners and domains	Task-based questionnaire and paper-based questionnaire	June 2019 German aviation cluster premises (Germany) (5 people) October 2019 Welsh SME platform provider premises (Wales) (18 people)	The laddering results were also found valid Proposed design principles were found accepted Simplicity is expected in the design of the system Trust remained a highly relevant driver and concern in the use of the system

Stage 3: Reflection and Learning

The third stage of ADR occurs in parallel to the first two stages. A reflection and learning process was carried out guided by a pattern matching approach (Sinkovics 2018) iteratively in concurrence with the learnings from Stages 1 and 2 of the ADR process. Pattern matching allows the comparison of theoretical and empirical patterns around a given phenomenon of study (Sinkovics 2018), for this, the theoretical analysis focused in the findings from the literature review on business partner selection, the computer-generated advice utilisation, and the inter-organisational collaboration domains. These form the theoretical realm patterns and were matched with the empirical realm coming from the workshops, interviews, and data collected through the questionnaires applied with practitioners of the manufacturing domains.

The analysis identified what seems to be the motivation of people utilising computer-generated advice for the particular context of this research and was contrasted with the findings from the theoretical side. To this end, initial theoretical propositions were derived and design principles were conceptualised, developed from the learnings obtained from the pattern matching. The parallel nature of this stage supported the continuous improvement and update of the TDMS design, in alignment with the ADR purposes, at the time that theorisation processes were carried out. Figure 2.2 depicts this pattern matching process occurred in the ADR Stage 3.

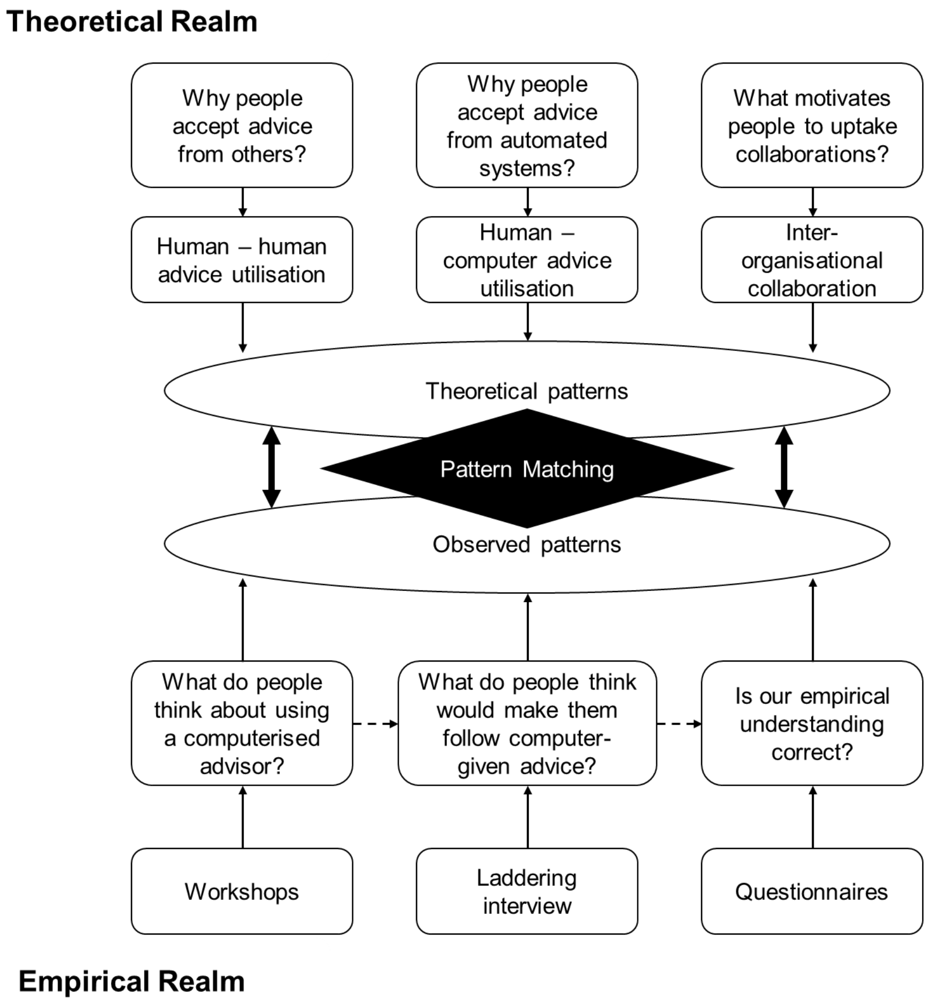

Figure 2.2: Pattern Matching applied in ADR Stage 3. Diagram adapted from (Sinkovics 2018)

Stage 4: Formalisation of Learning

The purpose of the Formalisation stage is to assess the ADR project outcomes regarding its support to generalise the learnings into a wider class of problems from the same field of the problem addressed (Sein et al. 2011). In this stage, the TDMS was explicitly defined as a representative of the class of computerised business advisors. This resulted in the formalisation of a set of design principles and the theoretical propositions to form the theory of computer advice utilisation. This theory was further validated through a Bayesian network exercise (Niedermayer 2008) where the conditional probability tables (CPT) were developed based on knowledge elicitation from experts and a sensitivity analysis was applied to adjust the CPT. The data collected for the sensitivity analysis was obtained through an online vignette questionnaire. A vignette is a brief description of a situation presented with the purpose of obtaining a response of the judgemental type regarding the situation described (Rooks et al. 2000); in this research, vignettes were used to describe a situation where the levels of the influencing factors to computer advice utilisation varied, and the study aimed to validate the predicted judgement results against the ones collected. Chapter 5 presents a detailed description of the study and its results. Appendix A.7 shows the vignette study as presented to the respondents, and Appendix A.8 presents the corresponding demographics data.

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Chapter 3

Context Review

3.1 Digital Marketplaces for Industry 4.0: A Survey and Gap Analysis

Cisneros-Cabrera S., Ramzan A., Sampaio P., Mehandjiev N. (2017) Digital Marketplaces for Industry 4.0: A Survey and Gap Analysis. In: Camarinha-Matos L., Afsarmanesh H., Fornasiero R. (eds) Collaboration in a Data-Rich World. PRO-VE 2017. IFIP Advances in Information and Communication Technology, vol 506. Springer, Cham. *https://doi.org/10.1007/978-3-319-65151-4_2*

Abstract. Industry 4.0 is the called 4th technological revolution, where digital and physical marketplaces and manufacturing technologies converge to enable smart manufacturing and factories of the future. This paper presents an overview of a representative set of marketplace platforms available to support supply chain processes underpinning Industry 4.0. We develop a gap analysis of existing marketplaces assessing their ability to support Industry 4.0 requirements. Finally, we position our survey and gap analysis in the context of the European Union's Horizon 2020 programme, in particular on the Digital Automation call topic addressing the theme of collaborative manufacturing and logistics.

Keywords: Industry 4.0, Supply Chain, Digital Marketplace, Collaborative Technologies, Gap Analysis.

3.1.1 Introduction

Corporations are steadily moving to a mode of competition and collaboration coined "Industry 4.0", which uses Internet technologies, sensors and big data to develop industry solutions (Alcácer and Cruz-Machado 2019; Gilchrist 2016; Lasi et al. 2014). The shift in computing towards the cloud, the wide availability of information services that can be remotely accessed, and the new business models enabled by the software as a service paradigm, are the catalysts for the vision of Industry 4.0 to become operational (Brettel et al. 2014; Geissbauer et al. 2014). For the full accomplishment of this vision, it will be essential that digital marketplace mechanisms are created to support the service ecosystems arising from the multitude of market players and service portfolios (Havle and Ucler 2018).

In this paper, we present a survey of digital marketplace platforms with a potential towards supporting Industry 4.0 initiatives. In particular, this survey aims to provide an assessment of service marketplace design and configuration platforms that will enable the dynamic evaluation and composition of hundreds of thousands of potential candidate services towards developing Industry 4.0 solutions. We develop our gap analysis taking into account the context of the European Union's Digital Automation call topic aimed at developing technologies towards enabling Industry 4.0 collaborative networks within European organisations (European Commission 2015). The survey and analysis conducted in this paper have the following research questions, which outline the future directions for developing an Industry 4.0 solution:

1. What concepts, techniques and services of Industry 4.0 are available in current marketplace environments for collaborative supply chain systems?
2. How can a digital marketplace platform address capability gaps in traditional approaches to collaborative supply chains?
3. How can digital marketplace tools impact the business, organisational and Information Technology (IT) architectural approaches within collaborative supply chains?

This document is organised as follows: Section 3.1.2 discusses background and related work; Section 3.1.3 presents the research method and our gap analysis. Section 3.1.4 includes an analysis of the research questions' answers, Section 3.1.5 discusses the results and concludes the paper summarising key findings.

3.1.2 Background and Related Work

Industry 4.0 moves towards efficient manufacturing systems, augmenting the automation of the processes and actors involved in Industry, and aiming at a highly efficient response to internal and external events, seeking for resilience and adaptive systems (Lasi et al. 2014; Obitko and Jirkovsky 2015). The EU's Digital Automation call topic, supported by the Horizon 2020 programme, presents a vision towards innovations on collaborative networks across manufacturing value chains within Industry 4.0 (European Commission 2015). Particularly, the vision presented requires development to support Small and Medium Enterprises (SME) participation and collaboration with large Original Equipment Manufacturer (OEM) companies in the supply chain comprising management, control, manufacturing, and logistics capabilities (European Commission 2015). The main objectives of the call involve the development of technological means for a resilient, flexible and event-responsive procurement process, capable of coping with a dynamic environment providing automated reconfiguration within the supply chain processes (European Commission 2015). The research involved in the EU's Digital Automation call topic includes addressing the development of solutions able to optimise and facilitate collaboration among different stakeholders involved, including supply clusters, companies, factory machines and objects (European Commission 2015).

Within EU's Digital Automation call topic, a marketplace refers to the tool that will support the entire supply chain life cycle processes, which will be used by both demand-side (requestors) and suppliers when participating in the bidding process, and will enable suppliers to form temporary coalitions, towards fulfilling complex call bids where multiple suppliers might be needed, with a strong focus on enabling SMEs to participate in the marketplace.

3.1.3 The Supply Chain Digital Marketplace

Ten platforms were selected and analysed as the representative platforms of today's marketplace. The selection criteria include the relevance of the platform, where the platform should be utilised by at least 1000 members, however, most of the platforms surveyed have millions of users (Amazon Business 2020; CloudBuy 2019; Company 2020; Digital Marketplace 2016; IndiaMart 2020; Izberg 2017; Mirakl 2017; OFWeek 2019; Smith 2020; Su and Cha 2016); a second selection criterion involves the platform's support for business-to-business (B2B) transactions, where companies on both sides of the digital marketplace (requestors and suppliers) participate, rather than only individual users; a third aspect considered was the identification of the platform as an eProcurement one; finally, the marketplace selected should be of high relevance and impact within its domain area, measured by their geographical span (regional or worldwide, but not local). These criteria were defined to eliminate the risk of selecting platforms that might be tackling different objectives to those relevant to Industry 4.0, in such a way that each of the platforms is indeed a tool that supports the supply chain management cycle in a virtual environment.

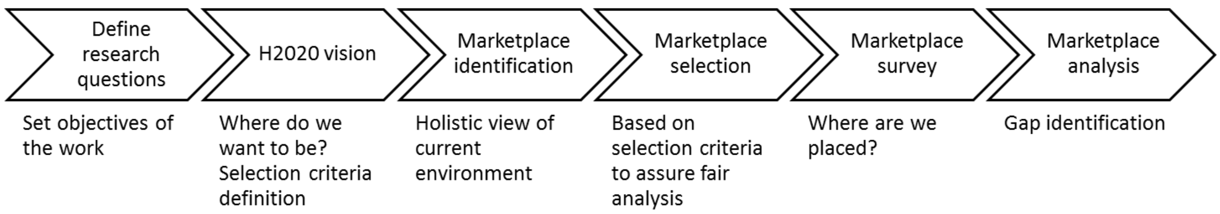

Figure 3.1-1: Gap analysis method applied

Figure 3.1-1 outlines the method we utilised to carry out the work presented and define the criteria summarised above. The first step comprised defining the research questions to set the objectives of the analysis. Secondly, we explored the European Union's Horizon 2020 program's vision (H2020), in particular, the Digital Automation call topic towards Industry 4.0; this exploration provided the context of the study and enabled the recognition of the most relevant elements that are needed to develop a working Industry 4.0 solution. Based on the exploration conducted, we were able to define a selection criterion for the platforms to be surveyed accordingly. The third phase gathered information on available marketplaces, where more than 20 trading platforms available to the European market were identified; however, a fourth phase was dedicated to selecting only those platforms that met the criteria defined in the second phase. This was done to avoid creating an unfair comparison and analysis, where there was the risk of including marketplaces out of the scope of the research objectives. Examples of platforms that were left aside include those with little visibility within its domain area, with less than 1000 members, or very low impact and functionalities, and no intention to connect businesses but instead support a peer-to-peer (P2P) approach, as these platforms would provide an exaggerated and not necessarily representative gap. Finally, we proceeded to analyse the selected platforms in terms of the vision identified, thus, we were able to gather insights on the situation of the current representative digital marketplaces and identify the existing gaps.

Table 3.1-1 presents an analysis of the platforms surveyed. The analysis considers the platform's capabilities with regards to collaboration in supply chains and production networks, and their functionalities to support a working marketplace. This gap analysis intends to identify the limitations of the current supply chain marketplace solutions towards accomplishing the EU's Digital Automation call's vision.

The first column in Table 3.1-1 shows the area in which each platform works; the relevance of pointing out the industrial area in which each platform works resides in the discovery of the existing degree of coverage, especially for the industrial and services areas, therefore the area in which more development is needed can be identified. The majority of the platforms work with retail and wholesalers, with no specific domain set; second place is taken by those platforms that are focused on a particular vertical domain. Only one of the platforms surveyed is dedicated exclusively to a specific domain area, which is the case of the UK Government Digital Marketplace, dedicated to IT services such as cloud computing offerings. Finally, it can be identified that not all of the platforms support a service marketplace, where business or individuals can offer or request services and parts. The analysis reveals a capability coverage gap in digital marketplaces available specifically for the aerospace and automotive domains. The EU's Digital Automation call topic has SMEs as one of the main beneficiaries, this is why it is important to analyse the platforms surveyed in terms of SME participation support. The participation of SMEs seems to be a growing area in the marketplace; however, it is not yet fully supported by the majority of the digital marketplaces, as Table 3.1-1 shows. This symbolises an opportunity to cover the gaps to provide wide support for SMEs within an important domain besides general trading.

Table 3.1-1: *Surveyed marketplaces overview. Marketplace platform labels: (UG) UK Government Digital Marketplace*[11]*, (AL) Alibaba*[12]*, (CB) CloudBuy*[13]*, (IM) IndiaMart*[14]*, (OW) OFweek*[15]*, (HA) Haizol*[16]*, (IZ) Izberg*[17]*, (AB) Amazon Business*[18]*, (MI) Mirakl*[19]*, and (TH) Thomas net*[20]*. Where* ✔ *indicates the assessed category is existent in the indicated marketplace, and* ✔ (shaded) *indicate a change in the re-evaluation made in 2020 (see Section 1.3.1)*

Marketplace / Category		UG	AL	CB	IM	OW	HA	IZ	AB	MI	TH
Area	IT services	✔		✔							
	Retail/wholesaler		✔	✔	✔			✔	✔	✔	✔
	Industrial		✔ (shaded)	✔	✔ (shaded)	✔	✔	✔ (shaded)			✔
	Services		✔ (shaded)	✔			✔ (shaded)		✔	✔ (shaded)	✔
SME participation	Supported	✔	✔	✔	✔		✔ (shaded)	✔ (shaded)	✔ (shaded)	✔ (shaded)	
	Not supported					✔					✔
Type	Sellers listing			✔					✔		✔
	Sellers & buyers listing	✔	✔		✔	✔	✔				
	Online shop to third party suppliers							✔		✔	
Evaluation	Internal		✔		✔			✔			
	External	✔					✔		✔		
	None			✔		✔				✔	✔
Security	Existent		✔ (shaded)	✔							
	None explicitly	✔			✔	✔	✔	✔	✔	✔	✔
Connection to external systems	Supported						✔ (shaded)	✔		✔	
	Not supported	✔	✔	✔	✔	✔			✔		✔

[11] https://www.digitalmarketplace.service.gov.uk/
[12] https://www.alibaba.com/
[13] https://www.cloudbuy.com/
[14] https://www.indiamart.com/
[15] http://en.ofweek.com/
[16] https://www.haizol.com/en
[17] http://www.izberg-marketplace.com/
[18] https://www.amazon.com/b2b/info/amazon-business?layout=landing
[19] https://www.mirakl.com/mirakl-marketplace-platform/
[20] http://www.thomasnet.com/

Among the platforms surveyed, three types were identified; the first type is formed by those platforms where the functionality supports products or services listing only for suppliers; the second type of platform identified enables either buyers or contractors to list their requirements as well as suppliers to list their capabilities and interact with each other in a two-way communication, and the third type found is composed of those platforms that provide technological means to create a digital marketplace managed by one of the users, which then will coordinate and be responsible for an internal marketplace available to third party suppliers, called "the sellers". This is the only form in which a kind of Virtual Enterprise (VE) is supported; however, it is not clearly treated as one. There is also no support in any of the platforms for the management of constructs resulting from the assembly of VEs or cooperation to fulfil the same bid. The type classification is of relevance because this category allows us to identify the most utilised model within digital marketplaces, hence, it could be known where is the major gap to cover, and identify where are the emerging developments going as a perspective.

One important issue to solve when talking about VE formation is to consider how the suppliers will be evaluated to form a viable VE. Within the platforms analysed, not all of them have procedures to evaluate if a supplier is reliable or not; this is presented in Table 3.1-1. Normally, the evaluation is done by the same platform (internal evaluation) or the users awarding rates to identify ranges among the available suppliers (external evaluation).

When dealing with bids, sensitive information will be required, such as details of the bid, which might include strategic information, designs not yet ready to be published, contact information from contractors and suppliers, etc., which makes information security and governance information a major concern in the digital marketplace. Among the platforms reviewed in January 2017, only one prioritises security, where Payment Card Industry Data Security Standard (PCI-DSS Level 1) is claimed to be used, and the "buyers" that use the platform are governed by rules selected to limit information access. The last category evaluated is the platform's functionality to connect to external devices, platforms or things, which can be translated in Internet of Things (IoT) capabilities, which is a core functionality towards Industry 4.0. In this category, only two of the platforms surveyed are able to connect to the major e-Commerce solutions, and none considers a connection to physical devices. IoT seems to be an open area for development within marketplaces solutions.

3.1.4 Marketplace Gap Analysis towards Industry 4.0 aims

Six main processes of the supply chain aligned to the EU's Digital Automation call topic could be identifiable: Procurement, Engineering, Manufacturing, Delivery, Risk Evaluation, and Monitoring (Jiru and Harcuba 2017). The marketplace analysis presented in Section 3.1.1 reveals there are some processes not currently available to use from the marketplaces surveyed, and for those processes supported, there is no coverage within the same marketplace platform.

The Procurement process supports the registering of a company to the platform, either to be a contractor or a supplier, this process also supports the functionality to publish a tender or offer a bid, where both sub-processes mentioned are basic functionalities supported by the majority of the platforms. One process not yet available is VE identification and formation (Jiru and Harcuba 2017). The contract management process, part of the Procurement process, is supported by some of the platforms analysed, however, most of the time it is offered in a rudimentary form, with no support for custom/personalised legal features.

Another identified process is called Engineering; this provides guidance and availability for the first statement of the requirements towards initialising the Manufacturing process. As part of the Engineering process, a capacity planning sub-process is contemplated, where data models describing the production plans are required to assess and allocate the capacity of individual participants within a VE to fulfil a bid. The capacity planning is not supported by marketplaces yet, this reflects another example of a VE management process not supported.

The Manufacturing process is currently left to be managed by each supplier on their own, without support from any platform. A production planning process and a scheduling process is required (Jiru and Harcuba 2017), in such a way the suppliers and contractors could monitor each and every phase of the manufacturing process, accompanied by risk management tasks on each phase. This is a helpful functionality towards optimising collaboration and resources.

The Delivery process is covered by the majority of the marketplaces nowadays, but it was found to be very limited. The main functionality towards delivery is to let the involved entities know the date of delivery, and then some marketplaces implement a satisfaction or evaluation (ratings) survey once the delivery is completed. The logistics planning is not supported for VE management, and to a lesser degree, it is supported for multi-vendor situations.

Finally, some major Industry 4.0 processes within the manufacturing value chain are novel, such as the automated risk evaluation and monitoring, where this last one if existent, is supported only by manual updates in the majority of the marketplaces. An overview of the findings towards those Industry 4.0 processes and the platforms surveyed mentioned above are represented in Table 3.1-2 and summarised in Table 3.1-3. The gaps presented offer an overview of the areas in which opportunities and challenges to address exist. IoT appears as the major gap to address, with special attention required on protocols and models designed to cover this gap.

Table 3.1-2: *Designed Industry 4.0 Value Chain processes covered by available marketplaces*

Industry 4.0 Value Chain Process	Sub-process	Covered by marketplaces available
Procurement	Registering company	Yes
	Publishing tender	Yes
	Offering bids	Yes
	Forming consortium	Partially
	Contract management	Yes
Engineering	Capacity planning	No
Manufacturing	Production planning	No
	Scheduling	No
Delivery	Delivery forecasting	Yes
	Logistics planning	No
	Satisfaction evaluation	Yes
Risk evaluation		No
Monitoring		Partially

Table 3.1-3: *Summary of the marketplaces gap analysis*

Category	Expectations	Gaps
VE management support	Support for VE creation, recommendation for VE formation, evaluation for potential suppliers to form a VE, management as if participants were a single company	There is no model to support VE in digital platforms, where initial efforts are limited to supplier selection (buy-sell relationship), but not team selection, i.e. business partner selection for inter-collaboration purposes
Logistics management	Availability of capacity planners, contract support, production planners, operational and delivery tools, with resilient, scalable, automated solutions	Logistics management, including delivery details, are approached separately, out of the digital platforms, or even without IT interaction
Monitoring	The main expectation is to monitor in real-time with connection to physical items, such as sensors, PLCs, etc.	Monitoring is carried out mainly by manual updates. No IoT for supply chain monitoring is available integrated within a collaboration platform
Risk evaluation	Risk evaluation will be an inherent functionality of the supply chain management, automated and efficient	Risk evaluation if any, are most of the times done outside digital platforms with separated and isolated technological tools

3.1.5 Discussion and Future Directions

The main goal of the current study was to identify existing gaps within digital marketplaces towards enabling future initiatives for industry, especially those focusing on supply chain management. Although there are research outcomes available to support Industry 4.0 characteristics (Community Research and Development Information Service (CORDIS) 2006; European Factories of the Future Research Association (EFRA) 2013; Helo and Szekely 2005; IAM Research Group 2006) we evaluate the extent to which existing digital marketplaces are already involved with those developments and identify those areas that require focus towards enabling a working Industry 4.0 solution to support the whole supply chain management processes.

The first question in this study sought to determine what Industry 4.0 concepts, techniques and services are available in current marketplace tools to support Industry 4.0 collaborative supply chain systems. Industry 4.0 represents a new approach in the value chain, integrating an organisation and control merged with technologies and digitalisation (Gilchrist 2016). This paper has found that generally, Industry 4.0 requirements are not fully supported in existing platforms. IoT is not implemented in the majority of the value chain stages of the surveyed platforms, cyber-physical-systems (CPS) are not present, and digitalisation is limited only to the online identification of products or services facing the customer, but not for communication between any of the factories' elements. We also identified that actions are triggered based on manual updates, rather than automated information sharing.

With respect to the second research question, it was found that digital marketplace platforms can address the gaps of traditional approaches in a collaborative supply chain by developing protocols and models to cover the gap in the integration of IoT with Industry processes, and developing unified technologies that might support the complete digitalisation of the physical factory and machinery, for which CPS communication and IoT are important parts. We believe industries will need to begin the path to digitalisation underpinned by cloud services, machine-to-machine (M2M) communication standards, embedded systems, and the introduction of new business models. In a separate layer, governance and security issues will arise linked with the new architectures, including challenges in handling Big Data.

The third question driving this research was how digital marketplace tools can impact the business, organisational, architectural and technology approaches within collaborative supply chains. Industry 4.0 will support the development of new business models and new methods of creating value chains and will widen the marketplace for SMEs by adopting a model in which small-scale batches of products and custom products and services will be competitive against larger enterprises (Gilchrist 2016). These benefits will be enabled because of the increased levels of control, micro-work specification and customisation from Industry 4.0 approaches (Geissbauer et al. 2014).

An example of how digital marketplaces can impact business models is when the information details obtained from a product distribution is at a new deeper micro-work specification level compared to the information that could be obtained before marketplaces from Industry 4.0; this information could provide value when shared among the organisational structures and roles of the companies or collaborators, generating a change in the processes carried out. Organisational aspects will change due to the increased dynamism of the industry, both within and across companies, and new information could be obtained in real-time. Together, these developments provide important insights into the steps ahead for Industry 4.0. Making use of the most innovative and recent technologies might not be enough without assuring the business and organisational models reflect the most effective way of doing business.

The industry of the future will reduce the burden involved in traditional supply chain processes, and will also create new opportunities to provide a highly dynamic environment with substantial benefits for businesses. The Industry 4.0 for the supply value chain required platform will support IoT, CPS, and smart technologies (i.e. Semantic Web Standards) that can enable M2M communications within supply chain systems and provide Industry 4.0 solutions. Future research will concentrate on the investigation of Industry 4.0 use cases, with a particular interest in the challenges, benefits and drawbacks.

3.1.6 Conclusion

This paper presented an overview of a representative set of marketplace platforms available to support supply chain processes underpinning Industry 4.0, and a gap analysis of existing marketplaces assessing their ability to support Industry 4.0 requirements, positioned in the context of the EU's Digital Automation call topic addressing the theme of collaborative manufacturing and logistics. Results of this paper revealed digital marketplace platforms have not yet moved completely from supporting simple collaboration approaches, where, for example, B2B models are formed by only one company on each side, and although there is research covering different aspects of more elaborated collaborations, such as VE formations and SMEs clusters, we believe there is still significant work to be done in relation to digital marketplaces to incorporate more advanced virtual organisation capabilities such as dynamic search, assessment, selection, and formation of coalitions. The limitations in existing digital marketplaces arise primarily due to a considerable gap between VE research adoption and its dissemination into commercial practice.

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3.2 Digital Services for Industry 4.0: Assessing Collaborative Technology Readiness

Ramzan A., Cisneros-Cabrera S., Sampaio P., Mehandjiev N., Kazantsev N. (2020) Digital Services for Industry 4.0: Assessing Collaborative Technology Readiness. In: Themistocleous M., Papadaki M. (eds) Information Systems. EMCIS 2019. Lecture Notes in Business Information Processing, vol 381. Springer, Cham. https://doi.org/10.1007/978-3-030-44322-1_45

Abstract. Collaborative technologies, such as peer-to-peer (P2P) communication systems, information sharing technologies, and online team meeting facilities have long been available to support the daily operation of businesses. We investigate how collaborative technologies can adapt to further underpin emerging business paradigms, namely the "Industry 4.0" trend. Our purpose is to contribute to the understanding of what characteristics would maintain a collaborative technology current and ready to be part of the digital services available to support the fourth industrial revolution demands. To fulfil this purpose, we propose a taxonomic solution for assessment of collaborative technologies readiness for Industry 4.0; the analysis obtained using this classification scheme serves as an indicator to elicit what is required to be addressed to meet Industry 4.0 goals. We also present details about the taxonomy development and validation using a benchmarking approach. Finally, we exemplify how our taxonomy can be applied to assess a collaborative technology.

Keywords: Digital Services, Collaborative Technologies, Industry 4.0, Technology Readiness.

3.2.1 Introduction

Industry 4.0 (I4.0) refers to an emerging trend which revolutionises the way manufacturing domains carry out their operations (Alcácer and Cruz-Machado 2019; Lasi et al. 2014). I4.0 involves the use of cyber-physical systems and transdisciplinary approaches to automate processes and enable services innovation fostering an agile business environment (Almada-

Lobo 2016; Möller 2016; Oesterreich and Teuteberg 2016). Approaches underpinning the I4.0 revolution include the digitalisation of processes to enable agility and costs reduction, new models of business collaborations and the development and implementation of Information and Communication Technologies (ICTs) to support operations (Cisneros-Cabrera et al. 2017; Heng 2014). In these approaches, collaboration appears as a core enabler (Camarinha-Matos et al. 2017; Shih et al. 2015). Digital services supporting collaboration provide the process "glue" that enable cross-organizational links across the supply chains that are core to the I4.0 paradigm.

Despite recent advances in the understanding of enablers for I4.0 (Havle and Ucler 2018; Trotta and Garengo 2018), there are still limitations towards assessing processes, technology features, use cases, functional capabilities, standards, and data security features of current collaborative technologies. There is also limited guidance on how these technologies align with the I4.0 vision (Heng 2014).

We contribute to bridging this gap by specifying what characteristics would enable a collaborative technology to support the operations of businesses towards the fourth industrial revolution, guided by the following research questions:

1. What are the key features and capabilities supported by collaborative technologies in the digital services domain?
2. What are the existing gaps in existing domain-specific collaborative technologies towards enabling the Industry 4.0 vision?

We present the specification of these key features and capabilities in a taxonomic solution that also enables the assessment of collaborative technologies readiness to support I4.0 goals and principles, such as interoperability, modularity, service orientation and information transparency (Hermann et al. 2016). The taxonomy proposed is applicable to available digital services which offer collaborative technologies in the form of applications, systems and tools, and is a first step towards the development of a comprehensive I4.0 digital services readiness assessment framework, focused on the collaborative technologies service offering.

The remainder of this paper is structured as follows: Section 3.2.2 presents the background information on collaborative technologies within digital services. Section 3.2.3 details the research method used for taxonomy development for collaborative technologies assessment. Section 3.2.4 presents the taxonomy developed, and Section 3.2.5 specifies the validation approach. Section 3.2.6 illustrates how to use the taxonomy with a sample of real-world domain-specific digital services with collaborative technologies functionalities. Finally, Section 3.2.7 presents conclusions and future directions of the research.

3.2.2 Collaborative Technologies Overview

The existing classification of collaborative technologies includes the division into two main categories: Horizontal and Vertical (Erhun and Keskinocak 2011; Shih et al. 2015). Horizontal collaborative technologies usage includes personal, educational and business communications (Erhun and Keskinocak 2011). They can be further divided into four sub-categories: (1) peer-to-peer (P2P) communication systems, (2) social media tools, (3) information sharing and (4) team meeting support (Erhun and Keskinocak 2011). On the second classification, vertical collaborative technologies are relevant to a specific industry domain to which such digital services are specifically designed (Erhun and Keskinocak 2011); an example of this is the AirSupply[21] Tool specifically supporting the aerospace industry by providing communication services that are secure and traceable between companies in the Aerospace supply chain. Another example is the FREIGHTQUOTE[22] tool which is used mainly to support processes of logistics to reduce freight costs by optimisation approaches.

The number of users and industries also serve as criteria to differentiate vertical and horizontal collaborative technologies (Shih et al. 2015). For example, a social media tool such as Twitter[23] can be considered a horizontal domain-independent digital communication technology used for broadcasting and one-to-one interaction for both personal and commercial purposes. In contrast, AirCollab[24] is a domain-specific communication technology used for collaboration in the aerospace industry on a “many-to-many” approach.

Our work further classifies the collaborative technologies. We aim to systematise the variety of concepts through a taxonomy classification by unifying terminologies and characteristics of collaborative technologies into a single structure. As a basis for developing the initial structure of the taxonomy, we departed from the European Union’s I4.0 vision articulated in the Horizon 2020 (H2020) vision document (European Commission 2015). The next section presents the development of a taxonomy of collaborative technologies supporting I4.0 capabilities.

3.2.3 Collaborative Technologies for Industry 4.0: Taxonomy Development Method

The taxonomy development method adopted for this research is based on Nickerson’s method (Nickerson et al. 2013). Nickerson et al. presented a comprehensive literature review of existing methods to develop a taxonomy in different domains; the method proposed focuses on

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[21] https://www.boostaerospace.com/airsupply/
[22] https://www.freightquote.com/define/what-is-transportation-management-system-tms
[23] https://twitter.com
[24] http://www.boostaerospace.com/aircollab/

taxonomy development applicable in Information Systems research (IS) based on the design science paradigm (Rummler and Ng 2010). The method follows a three-level measurement model (Bailey 1984) with some modifications and also considers meta-characteristics and ending conditions for taxonomy development. Nickerson's method employs two approaches for the development of taxonomies: (1) inductive and (2) deductive. This approach also guides the logic for conceiving new dimensions or uses of collaborative technologies. The method also prescribes the interleaving application of inductive and deductive approaches, which we used for understanding and organising the concepts associated with the term "collaborative technology".

The steps followed in the development included the selection of a convenience sample of collaborative technologies available in the literature (Rummler and Ng 2010) from which we extracted its potential applications. We identified the characteristics of user interaction from the extracted applications (e.g. the application of collaborative technology for audio or video communications involves the user in audio and video conferencing). We also determined the multiplicity dimension of the features such as a sole company user and a group of companies of users who can have privileges to use the application. In this activity, we employed the deductive approach to ensure alternative perspectives were considered and represented in the taxonomy. For example, some collaborative technologies (e.g. Microsoft Lync[25]) are designed to support general interactions between people.

In contrast, certain collaborative technologies (e.g. AirSupply) are developed for individuals who work for a given company. Similarly, some collaborative technologies cannot be used in certain locations of the world; for example, some countries have blocked Skype services due to security threats (Green 2018). Our deductive approach, thus, leads us to identify the former feature as access rights of using the application and the latter feature as user location identification characteristics. In the following section, we present the taxonomy developed using this approach.

3.2.4 The Industry 4.0 Collaborative Technologies Taxonomy

The taxonomy depicted in Figure 3.2-1 illustrates the broad range of conceptual constructs to classify collaborative technologies offering digital services enabling I4.0. The key features and capabilities concepts present the novelty in the designed taxonomy; both supported in defining a concept of "collaborative technology". The designed taxonomy encompasses six major

[25] https://products.office.com/en-us/microsoft-lync-2013

categories (i.e. Industries, Types, Uses, Applications, Features and Services) and many sub-categories.

We start by presenting the different industries for which such digital service can be available, from the heavy machinery manufacturing industries, such as aerospace, railway and automotive domains, to healthcare industries. Secondly, we conceptualise the different roles a collaboration technology can take within an organisation, e.g. to support decision making, as an e-commerce platform, or to support e-learning. Next, we classify the concepts of horizontal and vertical collaborative technologies (see the details in Section 3.2.2), and also the different uses a collaborative technology can take: business-to-business (B2B), business-to-consumer (B2C) or consumer-to-consumer (C2C). In the fifth branch of the collaborative technologies taxonomy, we present the features that make a collaborative technology, which includes conferencing, screen-sharing, document-sharing, information-sharing, audio and video coordination, online communication, web browsing and multiple language support.

On the conferencing feature, for example, we consider the use of calendars for conferences or meetings, with invite features, reminders, and alert functionalities. The time tracker functionality, for example, helps to interact with others on an exact given time (e.g. a German user needs to consider the time zone of other users living in the United Kingdom while inviting to an online meeting). Finally, we present the core capabilities for I4.0 that a collaborative technology may present. These capabilities are access-control, production planning[26], matchmaking[27], team creation[28], governance rules support, requirements analysis[29], risk evaluation[30], tender-decomposition[31], scheduling, security, adaptation and predictions. In this branch, we also present the access control capability of the application, which determines that the services may be of use for business or personal purposes.

[26] Production planning service is used to plan products, materials and resources (Jiru and Harcuba 2017)
[27] Matchmaking is a service that provides suggestions of best potential partners for a given business opportunity (Kazantsev et al. 2018a)
[28] Team creation is a kind of temporary alliance that is developed for short-term to share skills or core competencies and resources in order to better respond to business opportunities (Luis M. Camarinha-Matos and Afsarmanesh 1999; Kazantsev et al. 2018a)
[29] These are customers' requirement analysis that can be in the form of tracing individual customer order specification from the shop floor and monitoring their order execution and may involve forecasting item delivery and evaluating customer satisfaction (Maguire and Bevan 2002)
[30] Risk evaluation is a process to compare the estimated risk against the given risk criteria (Refsdal et al. 2015)
[31] Tender-decomposition is a business opportunity that supports tenders breakdown into sub-tenders (Cisneros-Cabrera et al. 2018)

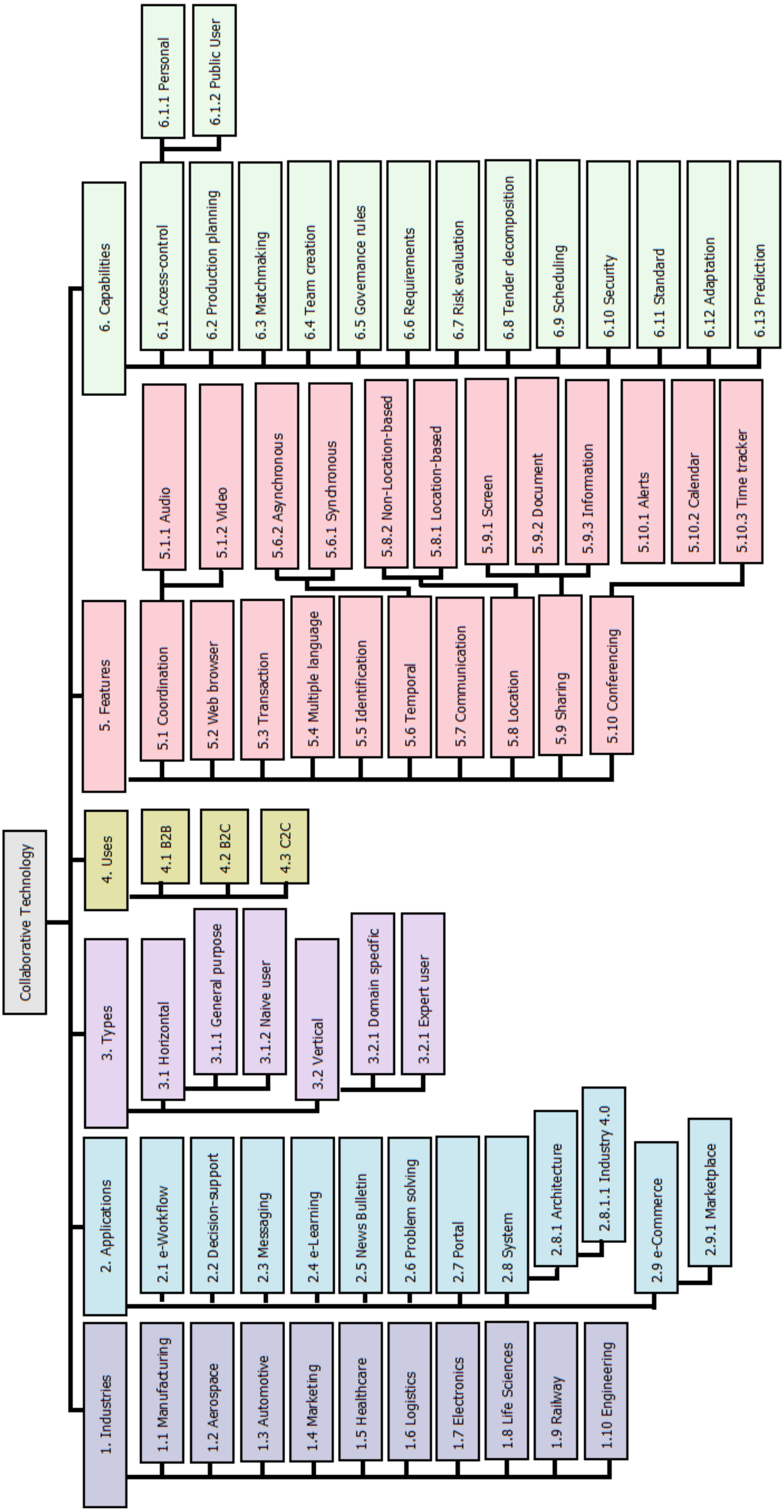

Figure 3.2-1: Collaborative technology taxonomy towards Industry 4.0 support

Following this branch of core capabilities, we also have the production planning and scheduling capabilities to support the planning of the production and manufacturing materials and allocation of the resources. Also, the concept of matchmaking derives from the context of alliances, or business teams, where different companies or suppliers work together to achieve a goal where their selection is made based on some criteria and governance rules (Petersen 2007). The risk evaluation, tender-decomposition security, adaptation and predictions capabilities are added to the taxonomy to test if a collaborative technology can support secure interoperability across the supply chain with the ability for adaptation (Hermann et al. 2016). These concepts were added to the taxonomy by employing the deductive approach, as specified in Section 3.2.3 above.

3.2.5 Validation of Collaborative Technology Taxonomy

There are various types of taxonomy validation techniques such as Delphi card sorting (Soranzo and Cooksey 2015), orthogonality demonstration, utility demonstration, and benchmarking (Usman et al. 2017). The Delphi card sorting is an in-person validating method, and the participants need to organise and label artefacts or concepts into relevant categories. A typical card-sorting exercise consists of four different states named planning, preparing, sorting and analysis. We have not employed this method due to limited resources. The orthogonality technique is used to extend the existing or base taxonomy by defining categories with clear classification criteria. The utility demonstration technique is also applicable to an extended taxonomy. We have not extended any taxonomy; therefore, both techniques are not suitable to validate our classification scheme.

We utilised benchmarking as an approach that also supports the comparison of taxonomies with other related classification structures. From the literature, we identified three taxonomical structures with a similar structure to our developed taxonomy: Mentzas, 1993 (Mentzas 1993), Nickerson, 1997 (Nickerson 1997) and Bafoutsou & Mentzas, 2002 (Bafoutsou and Mentzas 2002); we compared our work with those. In the comparison, we found that the first classification structure (Mentzas 1993) categorised group software in four different classes: (1) coordination model, (2) information sharing, (3) decision support and (4) organisational environment (user roles: centralised, decentralised). The second classification scheme (Nickerson 1997) explored nine different categories, out of which two characteristics are similar to the ones in (Mentzas 1993). The “characteristics” category groups other six categories, and “application” category lists “workflow management” only. The third classification structure (Bafoutsou and Mentzas 2002) organises collaborative systems in 24 different categories with 17 classes recognised as “characteristics”. Four out of 17 categories were already present in the previous taxonomies, and 13 new categories were added as “characteristics”. Figure 3.2-2 depicts the similarities found. Figure 3.2-3 presents the other seven similar categories identified as applications of collaborative technologies.

In the similarities identified, in comparison to the taxonomy we present in Figure 1, we found decision support, organisation environment and workflow management under applications category. Similarly, the bulletin boards, whiteboard, electronic newsgroups, project management, contact management and electronic workspace categories are recognised in the third classification structure (Bafoutsou and Mentzas 2002) (see Figure 3.2-3). These previous alternative classification structures (Bafoutsou and Mentzas 2002; Mentzas 1993; Nickerson 1997) also classified the artefacts in various applications (see Figure 3.2-3).

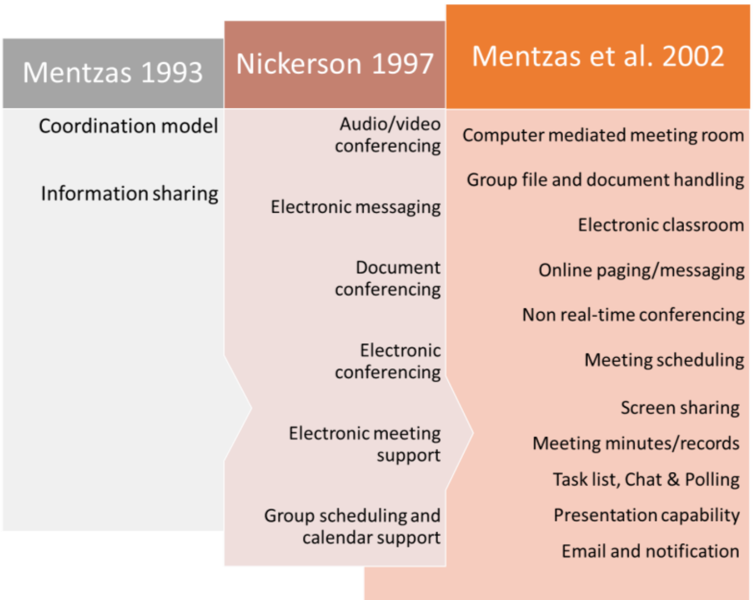

Figure 3.2-2: Similar collaborative technology taxonomies – Characteristics

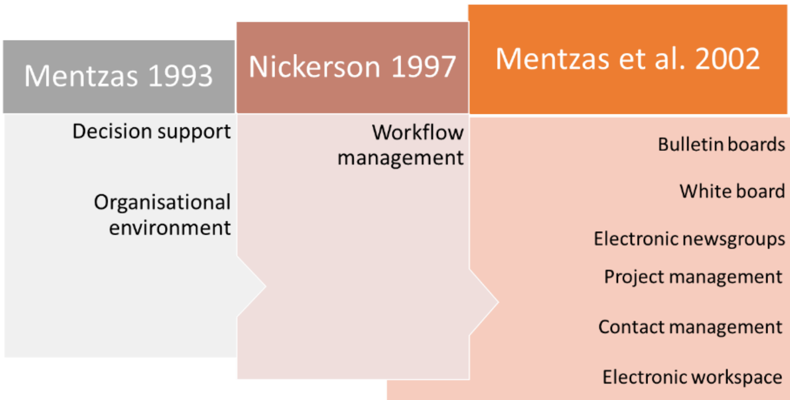

Figure 3.2-3: Similar collaborative technology taxonomies - Applications

The analysis and comparison of these previous alternative classification structures with our developed classification scheme reveal that the main focus of these previous structures seems to be only on the horizontal collaborative technologies type. For example, we found nine different examples of horizontal collaborative technologies are listed such as Novell GroupWise, Lotus Notes, DataBean FarSite, Quarterdeck WebTalk, Intel ProShare, Silicon Graphics InPerson, Ventana GroupSytems, Campbell Services OnTime and FilesNet Visual WorkFlow (Nickerson 1997). And 47 different horizontal collaborative technologies such as CommonSpace, DocuTouch, TeamNow, DOLPHIN and CVW (Bafoutsou and Mentzas 2002).

We developed a comprehensive, extensible and explanatory taxonomy which can accommodate future artefacts easily. We added the "types" artefact that has accommodated both horizontal and vertical collaborative technologies, and in future, a new type can also be listed under this category. Also, the "industries" category can accommodate more industries. We separated the application and characteristics categories in such a way it can differentiate that a collaborative technology has specific features for using some applications (e.g. decision making and problem-solving). The designed classification scheme also assists the user in the selection of a suitable tool by introducing the "uses" of an artefact which informs, for example, whether the tool should be designed for B2B or B2C activities.

The novelty in our developed taxonomy is the inclusion of the "capability" category that keeps unique artefacts which highlights the strength of the tool. For instance, tender-decomposition, machine-to-machine communication and VE creation services support to automatically execute the supply chain system and assist in creating a virtual enterprise to fulfil a task. These services indicate that the tool is suitable to execute the supply chain system of any organisation. Domain experts can add capabilities under this category associated with their specific domains such as inventory system, payroll system, or disease diagnosis system, to mention a few. Our developed taxonomy also covered the categories defined in the previous collaborative technology taxonomies (see (Bafoutsou and Mentzas 2002; Mentzas 1993; Nickerson 1997)). In the next section, we present an analysis of some domain-specific collaborative technologies assessed utilising the concepts defined in the taxonomy presented in this paper.

3.2.6 Assessing Collaborative Technologies: Representative Example

In this section, we present an example of use for the taxonomy of collaborative technologies. We assessed 10 domain-specific collaborative applications. For our analysis, we selected the following platforms: BoostAerospace[32], SAP Ariba[33], SupplyOn[34], KINAXIS[35], Quintiq[36], Generix group[37], ARTS[38], iQluster[39], Tradcloud[40] and Exostar[41]. The selection criteria included the consideration of digital services that offer collaborative technologies for supply chains and those which present information about their features, capabilities, functionalities and tools. These platforms were analysed with regards to their applications in supply chain system and capabilities to support an I4.0 solution utilising the collaborative technology taxonomy presented in Figure 3.2-1. Table 3.2-1 presents the results of the readiness assessment where the columns of the table represent the analysed domain-specific collaborative technology, and the rows of the table represent the information about the technologies' applications in different industries, features and capabilities, linked to Figure 3.2-1.

The analysis we carried out supports the identification that collaborative technologies are designed to facilitate supply chain systems of different industries but are not yet providing services (such as matchmaking and tender-decomposition) needed for an I4.0 support. Moreover, team selection and matchmaking services in these analysed tools have limited functionality and therefore provide only partial support. The collaborative team creation and governance services are also designed with limited functionalities in existing collaborative technologies consequently partially supported. For example, the Aircollab (a sub-system of Boostaerospace) platform has partial support in virtual collaboration of internal and external partners. Similarly, Boostaerospace has partial support in governance with founders, customers and service providers.

The majority of the analysed technologies do not have the capability to provide certain services (e.g. production planning and risk evaluation) and only a few tools provide full support, for example, the Quintiq platform renders full support to the production planning service, however, ARTS provides partial support and none of the other selected tools presents complete coverage regarding this service. Similarly, the KINAXIS tool supplies complete support in risk evaluation activity and SAP Ariba, SupplyOn and Exostar provide partial aid in this regard. The rest of the other six tools are not capable of measuring the risk against the

32 https://www.boostaerospace.com/
33 https://www.ariba.com/
34 http://www.supplyon.com/
35 http://www.kinaxis.com/en/
36 http://www.quintiq.com/
37 https://www.generixgroup.com/en
38 https://arts.aero/
39 https://valuechain.com/supply-chain-intelligence/iQluster/
40 https://www.tradecloud1.com/blog/topic/collaboration
41 https://www.exostar.com/

given risk criteria. The management of the scheduling service has similar issues as production planning, and risk evaluation services have in the existing tools. Quintiq and Generix group fully helps in the scheduling of resources and services involved in supply chain system; however, KINAXIS and iQluster have partial support and none of the rest of the tools has designed and managed such service.

All existing collaborative technologies are designed to connect and communicate with business communities, and customer requirements are dealt with by human experts which means that these systems are not capable of auto-analysing (parse, build internal representations and semantically understand) customer requirements and produce a workflow design accordingly. All analysed domain-specific collaborative technologies provide some level of support to communication, sharing, transaction execution, web-browsing, temporal and security features. However, remote conference calling is not possible with users needing to use ad-hoc applications for this purpose. For example, SupplyOn and Quintiq technology users use Webinar (a horizontal collaborative technology) for remote conferencing.

These analysed technologies are also used as bulletin boards to announce physical conferences, events and venues such as BoostAerospace used ISC (International Supplier Centre) Berlin and SAP Ariba conferences held at Las Vegas, Prague and Sydney in 2017 for customers and supplier’s connections. Similarly, the sharing feature is partially implemented in all analysed digital services. These technologies support only information sharing where their users need to employ some other platforms for the documents and screen sharing. The adaptability, coordination, and predicting features are missing in all of the analysed collaborative technologies.

Table 3.2-1: *Existing collaborative technologies and their readiness to support Industry 4.0 Principles. The numbered items on the table are references to the categories and subcategories of the collaborative technologies taxonomy presented in Figure 3.2-1. The notation of the analysed technologies is as follows: BoostAerospace = BA, SAP Ariba = SA, SupplyOn = SO, KINAXIS = KX, Quintiq = QN, Generix group = GX, ARTS = AS, iQluster = iQ, Tradcloud = TC and Exostar = EX. Where ✔ means the indicated characteristic is fully supported, P means partial support and* ***X*** *means the reviewed platform provides no support on the given characteristic.*

Analysed Collaborative Technologies											
No.		**BA**	**SA**	**SO**	**KX**	**QN**	**GX**	**AS**	**iQ**	**TC**	**EX**
1 Industries	1.1 Manufacturing	X	X	X	X	✔	X	X	✔	✔	✔
	1.2 Aerospace	✔	✔	✔	✔	✔	X	✔	X	X	✔
	1.3 Automotive	X	X	✔	✔	✔	X	✔	X	X	✔
	1.4 Marketing	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
	1.5 Healthcare	X	X	X	X	✔	X	X	X	X	✔
	1.6 Logistics	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔

	1.7 Electronics			X	X	X	✓	X	X	X	X	X	X
	1.8 Life Sciences			X	X	X	✓	X	X	X	X	X	✓
	1.9 Railway			X	X	✓	X	X	X	X	X	X	X
	1.10 Engineering			X	X	✓	X	X	X	X	X	X	X
2 Applications	2.1 E-workflow			X	X	X	X	X	X	X	X	X	X
	2.2 Decision-support			X	X	X	X	X	X	X	X	X	X
	2.3 Messaging			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	2.4 E-learning			X	X	X	X	X	X	X	X	X	X
	2.5 News bulletin			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	2.6 Problem-solving			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	2.7 Portal			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	2.8 System	2.8.1 Archt.	2.8.1.1 Ind. 4.0	X	X	✓	X	X	X	X	X	X	X
	2.9 e-Commerce	2.9.1 Marketplace		X	X	X	X	X	P	X	X	X	X
3 Types	3.1 Horizontal	3.1.1 General purpose		X	X	X	X	X	X	X	X	X	X
		3.1.2 Naïve user		X	X	X	X	X	X	X	X	X	X
	3.2 Vertical	3.2.1 Domain-specific		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
		3.2.2 Expert user		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
4 Uses	4.1 Business-to-business			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	4.2 Business-to-consumer			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	4.3 Consumer-to-consumer			X	X	X	X	X	X	X	X	X	X
5 Features	5.1 Coordination	5.1.1 Audio		X	X	X	X	X	X	X	X	X	X
		5.1.2 Video		X	X	X	X	X	X	X	X	X	X
	5.2 Web browser			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	5.3 Transaction			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	5.4 Multiple languages			X	✓	✓	✓	X	✓	✓	X	X	X
	5.5 Identification			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	5.6 Temporal	5.6.1 Synchronous		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
		5.6.2 Asynchronous		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	5.7 Communication			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	5.8 Location	5.8.1 Location-based		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
		5.8.2 Non-location based		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	5.9 Sharing	5.9.1 Screen		P	P	P	P	P	P	P	P	P	P
		5.9.2 Document		P	P	P	P	P	P	P	P	P	P
		5.9.3 Information		P	P	P	P	P	P	P	P	P	P
	5.10 Conferencing	5.10.1 Alerts		X	X	X	X	X	X	X	X	X	X
		5.10.2 Calendar		X	X	X	X	X	X	X	X	X	X
		5.10.3 Time Tracker		X	X	X	X	X	X	X	X	X	X
	5.10 Conferencing			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
6 Capabilities	6.1 Access control	6.1.1 Personal		X	X	X	X	X	X	X	X	X	X
		6.1.2 Public		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	6.2 Production planning			X	X	X	X	✓	X	P	X	X	X
	6.3 Matchmaking			X	X	X	X	X	X	X	X	X	X
	6.4 VE creation			P	X	X	X	X	X	X	X	X	X
	6.5 Governance rules			P	X	X	X	X	X	X	X	X	X
	6.6 Requirements			P	P	P	P	P	P	P	P	P	P
	6.7 Risk evaluation			X	P	P	✓	X	X	X	X	X	P
	6.8 Tender decomposition			X	X	X	X	X	X	X	X	X	X
	6.9 Scheduling			X	X	X	P	✓	✓	X	P	X	X
	6.10 Security			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	6.11 Standard			X	X	✓	X	X	X	X	X	X	X
	6.12 Adaptation			X	X	X	X	X	X	X	X	X	X
	6.13 Prediction			X	X	X	X	X	X	X	X	X	X

3.2.7 Conclusions

In this paper we specified key features and capabilities supported by collaborative technologies in the digital services arena and categorised them into a taxonomy of what forms a collaborative technology using Nickerson's methodology (Nickerson et al. 2013), particularly adding a category of capabilities that support the I4.0 goals. We identified the existing gaps in a sample of domain-specific collaborative technologies towards enabling the I4.0 vision utilising the taxonomy of collaborative technologies as an assessment tool. With this taxonomy, we contribute to the understanding of what characteristics collaborative technologies should address to support the fourth industrial revolution demands, and through its usage example, we presented a contribution to, for example, Research & Development (R&D) projects in the area of collaboration through technologies, where practitioners can utilise our taxonomy to systematically identify what characteristics should be developed towards an I4.0 project implementation. Finally, we also propose our work to be an initial step towards a more comprehensive I4.0 digital services readiness assessment framework.

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Chapter 4

An Approach and Decision Support Tool for Forming Industry 4.0 Supply Chain Collaborations

Cisneros Cabrera, S., Pishchulov, G., Sampaio, P., Mehandjiev, N., Liu, Z., & Kununka, S. An Approach and Decision Support Tool for Forming Industry 4.0 Supply Chain Collaborations. Submitted to Computers in Industry.

Abstract. Industry 4.0 technologies, process digitalisation and automation can be applied to support the formation of supply chain collaborations in manufacturing. Underpinned by information and communication technologies, collaborations of independent companies can dynamically pool production capacities and capabilities to jointly react to new business opportunities. These collaborations may involve a wide range of enterprises with different sizes and scope that individually would not be able to tender for such new business opportunities. To form these collaborative teams, assistive processes and technologies can underpin the effort towards exploring the tender requirements, unbundling the tender into smaller tasks and finding a suitable supplier for each task. In this paper, we present an approach and a tool to support decision making in relation to forming supply chain collaborations in Industry 4.0. The approach proposed is unique in integrating industry domain ontologies, assistive human-computer interaction tools and multi-criteria decision support techniques to form team compositions speeding-up the collaboration process whilst maximising the chances of forming a viable team to fulfil the tender requirements. We also show evaluation results involving stakeholders from the supply chain function pointing to the effectiveness of the proposed solution, available as a demo online (http://130.88.97.225:4200 username: TDMS@uniman.eu; password: uniman).

Keywords: Digitalisation, Supply Networks, Supply Chain Collaboration, Industry 4.0, Decision Support Systems.

4.1 Introduction

There is a growing body of literature recognising the vital role of enterprise collaborations in the manufacturing supply chains (Fähnrich and Kubach 2015; Ferreira et al. 2016; Lefebvre et al. 2006; Nguyen et al. 2018; Oh and Rhee 2008; Schadel et al. 2016; Wiengarten et al. 2013) where autonomous organisations combine capabilities and pool manufacturing capacities. In practice, traditional approaches for individual organisations to come together include face-to-face networking, peer referencing and reliance on companies known from past collaboration networks (Beckett and Jones 2012). Traditional approaches are time and cost consuming, often lack agility, and support a model of collaboration where organisations outside the mainstream established networks are often excluded from tender participation (Beckett and Jones 2012; Meng et al. 2019; Schadel et al. 2016).

Enterprise collaborations in the manufacturing supply chain in the form of clusters, virtual enterprises (VE), production networks, and alliances (Luis M. Camarinha-Matos and Afsarmanesh 1999; Ferreira et al. 2016; Gunasekaran et al. 2008; Mesquita et al. 2017; Trappey and Hsiao 2008) can benefit from Industry 4.0 technologies and application models (see (Chiarello et al. 2018; Dalenogare et al. 2018; Frank et al. 2019; Ghadge et al. 2020; Lu 2017) for a detailed account on such technologies and (Hofmann and Rüsch 2017) for the importance of the 4th industrial revolution application models in the context of logistics) to increase the effectiveness of collaborations (Gunasekaran and Ngai 2004).

The Industry 4.0 paradigm is changing the companies' focus towards organising production processes around the principles of interoperability between physical and cyber systems, decentralisation, real-time data analytics, service orientation, and modularity — which shall enable digital integration across the entire value chain, self-adaptation of production systems, and agile response to customer demand (Smit et al. 2016; Xu et al. 2018). Yet as large companies have already embraced the concept of such industrial revolution, its adoption by small and medium-sized enterprises (SMEs) is facing a number of challenges, such as resource constraints and lack of awareness of advanced technologies (Mittal et al. 2018; Smit et al. 2016). Still, SMEs are highly embedded in today's multi-tier supply chains, representing a vast majority of enterprises and generating a sizeable fraction of the total value added — estimated to be, for example, as large as 56.4% in the non-financial business sector of the European Union in 2018 (European Commission 2019; Smit et al. 2016).

Considering that many SMEs are tied to their existing supply-chain relationships, finding and integrating suitable suppliers into highly fragmented supply chains becomes a challenge for Original Equipment Manufacturers (OEMs) when customer demand for increasingly customised products requires an agile response in line with the demands of the emerging industrial paradigm (Smit et al. 2016). Proper tools for the dynamic formation of supply chain collaborations can help overcome this challenge and enhance the value proposition of Industry 4.0 by broadening supply opportunities for OEMs as well as market opportunities for SME suppliers. Effective collaborations in this context involve forming supply networks (teams) faster, selecting team members from a wide pool of suppliers, delivering high-quality production outcomes, higher levels of trust between collaborating organisations, and the ability to scale and adapt to highly-dynamic production requirements, product variety, customisation, and stringent manufacturing schedules (Camarinha-Matos et al. 2009; Mesquita et al. 2017).

Earlier work on decision support for team formation has been developed considering candidates based on both objective and subjective criteria (Huang et al. 2004; Petersen 2007; Petersen and Divitini 2002) usually after a process of identification of "best" suppliers followed by the evaluation of coordinating potential or team ranking based on average criteria, such as risk and costs (Huang et al. 2004; Petersen and Divitini 2002; Polyantchikov et al. 2017). Despite these advances, there is a dearth of assistive decision support approaches for agile team formation, i.e. without the need of lengthy manual pre-processing routines such as pre-selection of candidate partners and exchange of offline information previous to an invitation to join a collaboration (Nyongesa et al. 2017; Polyantchikov et al. 2017). In this paper, we explore this gap aiming at increasing agility in forming collaborative supply chains.

Our contribution to addressing this gap involves the conceptualisation, design, implementation and evaluation of an approach and an assistive decision support tool where a combination of suppliers of different items — that may belong to different levels in the supply chain — is looked for and evaluated in terms of how they all fit together *before* a collaboration is formalised. In contrast to extant approaches facilitating a single supplier selection only, our proposed team formation approach allows the composition of multiple companies aiming to collaborate as a supply network. The tool automating the team formation approach assists users in their decision process of selecting potential partners to join a collaboration by proposing group compositions of suitable partners (referred to as "teams") for fulfilling the elements of a manufacturing call-for-tenders (CfT). The approach and tool currently focus on the aviation and automotive industries, which are at the forefront of Industry 4.0 uptake (Lüke et al. 2018; Roblek et al. 2016).

Figure 4.1 presents an overview of our team formation approach and tool for supply chain collaboration in Industry 4.0. The decision support tool requires two sets of inputs: demand-side information, composed by the requirements of the manufacturing tender specification (e.g. capabilities required, product requested, certifications needed), and supply-side information (e.g. capabilities offered, certifications possessed). The approach proposed is underpinned by ontology-based knowledge representation techniques (Sowa 1999) used in the process of conceptualising and encoding supply and demand information (e.g. ontological descriptions of products demanded and supplier attributes and capabilities). The use of the attributes and relationships represented in the ontologies enable automated search and attribute matching by the decision support tool in such a way that the tool can propose sets of viable teams that can fulfil the demand side requirements; this is enabled by applying multi-criteria tender decomposition and matchmaking algorithms. We also contribute to the body of knowledge by implementing a decision-support functionality for recommending multiple compositions of teams and search for a combination of suppliers of different parts that may belong to different levels in the supply chain instead of a single-supplier single-team composition. The theoretical and practical gaps addressed by our work are further explored in Section 4.2.

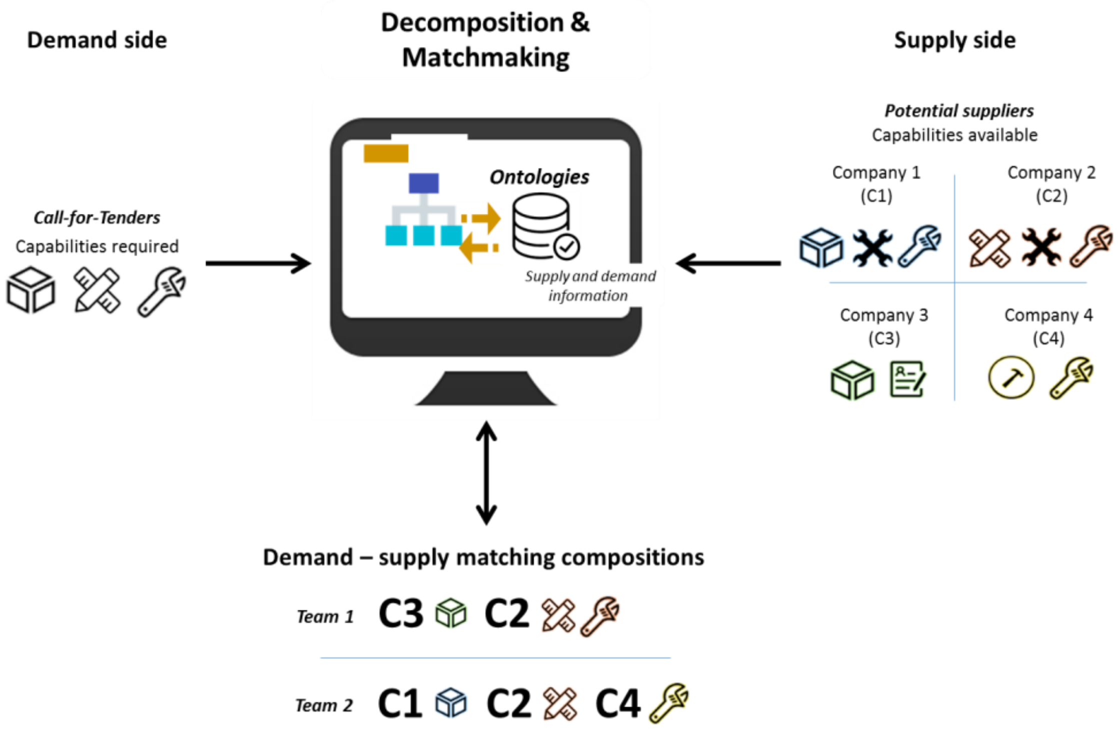

Figure 4.1: Tender Decomposition and Matchmaking tool and approach

This paper is organised as follows: Section 4.2 outlines the requirements for forming collaborations in Industry 4.0 and positions our work in the context of extant literature. Section 4.3 discusses the research method underpinning the findings reported in this paper. Section 4.4 presents the design and implementation of the team formation approach and tool for supply chain collaboration in Industry 4.0. Section 4.5 discusses the evaluation of the approach and tool. Sections 4.6 analyses key findings and managerial implications. Section 4.7 provides a summary of the work and outlines future research directions.

4.2 Background and Literature Review

Despite the supply chain automation opportunities created by Industry 4.0 technologies (Geissbauer et al. 2014, 2016; Schadel et al. 2016) traditional approaches towards collaboration in manufacturing industries are still in wide practice, such as (1) *manual identification* of the attributes required to fulfil a business opportunity, and (2) these opportunities being available for a closed select group of companies due to the lack of effective dissemination platforms (Kazantsev et al. 2018a; Schadel et al. 2016). In this sense, automating processes within the supply chain collaborations can be set to transpose collaboration barriers imposed by closed networks, traditionally faced by local or smaller suppliers (Kazantsev et al. 2018b; Schadel et al. 2016).

On the theoretical side, existing research related to Industry 4.0 technologies supporting supply chain collaboration focuses on the development of models to support the identification of suitable business partners to form a collaborative network (Camarinha-Matos 2005; Chai et al. 2013; Huang et al. 2011; Mehandjiev et al. 2009; Mikhailov 2002; Norman et al. 2004; Nyongesa et al. 2017; Vinodh et al. 2013; Wu and Barnes 2010, 2011). In that respect, one of the approaches widely researched is the *supplier selection* towards finding a one to one match (i.e. buyer-supplier), where the main body of work aims at identifying the most suitable supplier for a given business or product and the most effective criteria to evaluate the candidate suppliers (see (de Boer et al. 2001; Chai et al. 2013; Polyantchikov et al. 2017; Tahriri et al. 2008; Zimmer et al. 2016)) — commonly ranked according to different weighting techniques and criteria (known techniques include multi-attribute decision making (MCDM), mathematical programming (MP), and Artificial Intelligence (AI) oriented ones (Agarwal et al. 2011; Chai et al. 2013; Zimmer et al. 2016)). Table 4.1 presents a comparative analysis of literature describing approaches for forming supply chain collaborations (see (Huang et al. 2011; Mehandjiev et al. 2009; Mikhailov 2002; Norman et al. 2004; Nyongesa et al. 2017; Pishchulov et al. 2019; Polyantchikov et al. 2017; Wu and Barnes 2010)).

We observe that the supplier selection body of knowledge does not fully match the scope of our collaborative network problem given that, although we consider multi-criteria decisions, we propose multiple compositions of teams instead of a single-supplier single-team composition and not even multiple suppliers of the same product as the majority of the existing solutions do; instead, our approach is designed to look for a combination of suppliers of different parts that may belong to different levels in the supply chain and, in a multi-criteria approach, we evaluate how they all fit together before a collaboration is formalised.

We can observe in Table 4.1 how the extant work, to the best of our knowledge, does not fully cover the functionalities/capabilities of the approach we propose; with a noticeable gap in algorithms and approaches to multiple team compositions based on a multi-level decomposition of tender requirements. The approach proposed in this paper is particularly suitable in the context of the Industry 4.0 collaborative network formation problem involving interoperability, decentralisation, and modularity issues (Smit et al. 2016) and seeking to attain agility, accuracy, and efficiency gains (Ghadge et al. 2020). Our work contributes to enabling agility, accuracy, and efficiency in the supply chain (Ghadge et al. 2020) by shortening the team formation time and enabling higher resource efficiency by allowing suppliers to utilise their available resources better, thus, providing a solution which is both flexible to multiple players and enables integration into a dynamic value-creation network (Martinez et al. 2001).

We extend the body of knowledge by proposing an agile approach to supply and demand requirements matchmaking, where automated decomposition of tender requirements enables the widening of the team composition solution space to fulfil the demand. We also support extensibility by proposing an approach that provides ontological support for collaborative network formation across industry domains. Previous research predominantly focuses on a single vertical industry domain without developing extensible collaboration ontologies (Norman et al. 2004) (see Table 4.1). Our collaboration ontology builds on previous work on enterprise ontologies (Mehandjiev et al. 2009) proposing extensions that evolve the original ontological models from manual decomposition and single team composition (Mehandjiev et al. 2009), to support automatic decomposition and multiple team composition, as well as validating the ontological models and associated approach/tool with industrial stakeholders across two vertical domains (see Section 4.3).

Moreover, when compared to other solutions proposed in the literature, the decision support tool underpinning our approach does not advise the user about how to bargain and induce others to collaborate; its utility is in helping the user to explore the supply market, that is, all possible team compositions, and to re-evaluate these during the team formation process. Our work provides decision support through formalising selection criteria elicited from industry stakeholders and applying these to evaluate each prospective collaboration of suppliers as a whole.

Table 4.1: *Comparative analysis of team formation approaches*

	Approach (Chai et al. 2013)			Approach functionalities/capabilities								Validation				Tool	
Study	Multi-attribute decision making	Mathematical programming	Artificial Intelligence (Particle Swarm Optimisation)	Multiple team composition	Single team composition	Supplier selection	Agent-based negotiation	Manual decomposition of requirements	Multi-level decomposition of requirements	Agile selection of criteria	Semi-automatic/automatic	Technical validation (test cases)	Numerical illustrative example	Empirical illustrative example	Concept evaluation through end-user feedback	End-user tool available	Ontology enabled
(Polyantchikov et al. 2017)	X			X		X						X					
(Nyongesa et al. 2017)	X					X							X				
(Mikhailov 2002)	X					X											
(Norman et al. 2004)		X			X	X	X							X			X
(Mehandjiev et al. 2009)		X			X	X		X						X			X
(Wu and Barnes 2010)	X					X				X			X				
(Huang et al. 2011)			X		X	X						X					
(Pishchulov et al. 2019)	X					X				X		X					
This paper	**X**			**X**				**X**	**X**		**X**	**X**			**X**	**X**	**X**

4.3 Research Method

Figure 4.2 depicts the research process adopted in this study. The work presented in this paper was guided by a Design Science Research (DSR) approach (Hevner et al. 2004) to carry out a phase of exploratory research, elicit requirements, frame the design problem, and identify measures and constructs relevant to solution artefact design. We also conducted a validation stage in which we evaluated our results both from the technical and the business point of views. For this, we carried out validity tests using synthetic data reflecting usage scenarios, and we also conducted a survey to gather the view of experts in the manufacturing area. In the following subsections, we expand the details of the research process followed.

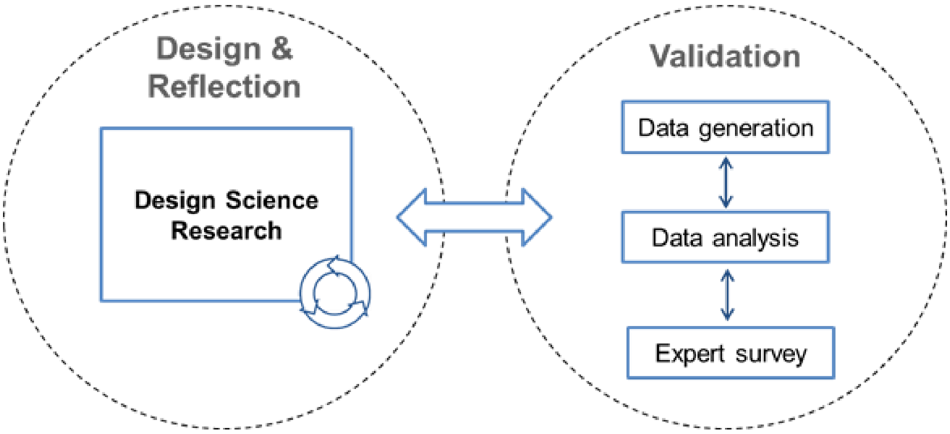

Figure 4.2: Research process utilised in the study

4.3.1 Design Science Research (DSR)

In this research, we applied DSR guidelines (Baskerville et al. 2018; Hevner et al. 2004; Hevner and Chatterjee 2010) to develop the team formation approach and decision support tool. Table 4.2 summarises the application of DSR concepts and guidelines (Hevner et al. 2004) to derive research artefacts. We held separate sessions in the form of semi-structured interviews and workshops where we collected insights from the Director and Technical Director of an automotive cluster, and from five suppliers who are also members of an aviation manufacturing association concerning their vision towards Industry 4.0 from the collaboration point of view.

Table 4.2: *Design Science guidelines and its application in the context of the research undertaken*

Design Science Guideline	How it was applied in this research
Design as an artefact	The outcome of the research requires to be "a construct, a model, a method, or an instantiation" (Hevner et al. 2004). In this stage, the artefact is the tool for selecting business partners to form a team
Problem relevance	The artefact is targeted at aiding the team formation decision process, which is a relevant and current business phenomenon in the context of Industry 4.0 (see Section 4.2)
Design evaluation	Rigorous evaluation methods have to be present when demonstrating the utility of the artefact to solve the given problem, its quality, and efficacy (Hevner et al. 2004). For this, quality measures were utilised when testing the usability and functionalities of the artefact, with practices borrowed from the Software Engineering area, such as matrix testing for quality assurance. We show the efficacy aspect of the proposed solution in the technical evaluation section of this paper (Section 4.5)
Research contributions	The research carried out must demonstrate verifiable benefits linked to the subject area in which the designed artefacts belong. End-user testing was executed to analyse the benefits of the artefacts from their perspective. We present the results of this analysis in the end-user validation section of this paper (Section 4.5)

Research rigour	Rigorous methods are demanded to be used during the whole research, from the design to implementation, as well as its evaluation and presentation of results. Standards for the design of software artefacts were utilised such as UML and Agile methods, as well as exploratory scientific methods
Design as a search process	Research iterations were made as needed to reach an effective artefact with the highest quality and fully compliment the desired ends. This includes the involvement of end-users and peer review feedback. The design was built after iterations involving requirements elicitation, system development and feedback from end-users
Communication of research	Information Technology and managerial audiences must be involved in the presentation of the results and insights obtained. For this, the project to which this study is part of has been presented in scientific conferences, as well as in industry events and workshops (https://www.digicor-project.eu/blog, https://www.digicor-project.eu/publications)

We also benefited from access to small and medium-sized enterprises (SMEs) and large Original Equipment Manufacturers (OEMs) involved in the European Union (EU)-funded DIGICOR project[42], a business-to-business (B2B) Industry 4.0 platform designed to support interoperability with other B2B supply chain platforms, from which we collected feedback and opinions to shape the decision support tool functionalities (DIGICOR 2016). Table 4.3 presents a description of the activities executed as part of the stage to explore the problem to address and summarises the main outcome obtained from each activity.

Table 4.3: *Overview of the activities included in the exploratory stage*

Description	Objective	Method	Date and Stakeholders	Outcome/Insights
Assessment of digital marketplace support for Industry 4.0 capabilities (Cisneros-Cabrera et al. 2017)	Gain a general overview of the state-of-the-art functionalities available in supply chain collaborative platforms towards enabling Industry 4.0	Survey and Gap Analysis	April 2017 Secondary research not involving stakeholders	Team formation is not yet widely supported in the most popular business-to-business (B2B) digital platforms
Discussion regarding the findings of the Survey and Gap Analysis	Gain insights and initial perspectives from end-users about the use of Information Technology (IT) support for team formation	Interview	June 2017 Welsh Automotive Cluster (2 respondents)	Results from the initial gap analysis were confirmed and aligned with the end-users' perspective

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Presentation of the initial concept and designs supporting the proposed team formation approach and tool	Gather feedback from stakeholders of the manufacturing supply chain to further shape the details of the approach and tool	Workshop	October 2017 European Aerospace corporation and European Union Project members (4 respondents)	Users want to reduce time and effort for forming teams and diminish the risk of ending without a beneficial deal or result from the collaboration, supported by a "quick" and "easy" mechanism. Users also want to maintain control over their final decisions
Presentation and feedback collection of the initial low-fi design of the proposed approach and tool	Obtain initial comments regarding the idea of the use of a tool recommending business partners to form a team and the design presented	Workshop	October 2017 German Aviation Cluster (5 respondents)	End-users value the benefits of the proposed tool; however, they have concerns about trust and information security

4.3.2 Verification and Validation of Research Artefacts

We carried out a technical experiment to verify the correctness of implementation concerning the conceptual model proposed for the artefact. Firstly, we generated synthetic data reflecting mainstream usage scenarios elicited from end-users, where we cannot disclose real company data due to privacy compliance constraints. The created data represents five hypothetical CfTs and 14 hypothetical companies. Given that the difference between the synthetic data and real data relies on the content only, e.g. a real-world company name of an existing company; we can perform an accurate, domain-relevant and privacy-preserving verification of our proposed approach based on the specified data model. Secondly, we executed the artefact (see Section 4.4.2) using the synthetic data and verified the outputs comprising teams where companies are grouped, ranked and are capable of fulfilling the CfT's specified goal(s). We aimed to verify the viability of the approach and confirm that the implemented solution works as designed. Section 4.5 shows the results of one of the test cases performed. The complete data set including all test cases are available in Appendix B.1. The results for all of the five CfTs' team compositions are available at http://130.88.97.225:4200 (username: TDMS@uniman.eu; password: uniman).

We also developed a validation study using a survey to capture experts' views and provide feedback about the proposed approach and to confirm that the artefact proposed provides a reasonable picture of a real-world system to these experts, i.e. to the people who are to be users of such system. The study was conducted in September 2018 in the *Connected Smart Factories* workshop at the 9th International Conference on Intelligent Systems in Madeira, Portugal using a questionnaire survey tool (presented in Appendix B.2). A total of 13 respondents participated in the survey; however, one survey set of responses was invalidated because the participant did not check the consent box to indicate permission for the use of their responses for research purposes. Secondly, two additional responses were collected during a demonstration of the artefact prototype at the DIGICOR project workshop held in October 2018 in Hamburg, Germany. Together, a total of 14 responses were collected.

Respondents were asked questions relating to what purposes the proposed artefact would serve in their company and were provided with several options of possible purposes. The questions in the survey focused on establishing the utility and the ability of the functionalities and purposes of the proposed artefact to produce a desired or intended result in relation to addressing the problem of collaborative team formation in supply chains. The study also offered an opportunity for obtaining information from experts that would help to refine the artefact.

It is important to highlight that the validation study constitutes primarily a formative evaluation activity in design science research, producing (1) interpretations of expectations about the utility and efficacy of the artefact; and (2) a foundation for confirming the appropriateness of decisions that led to the artefact design. On both counts, the evaluation described reached its overall objective. Further evaluation could examine the artefact deployed in an organisational operational context (a summative evaluation as stated in (Venable et al. 2016)); however, a summative evaluation requires a longer time frame and is beyond the scope of this paper. The results of the verification and validation studies are presented in Section 4.5.

4.4 The Team Formation Approach and Decision Support Tool

4.4.1 The Team Formation Approach

Informed by the analysis of the stakeholders' requirements and feedback, and the collaborative supply chain context with regard to the team formation process, we propose an approach to support team formation in support of digitalising collaborative supply chains responding to a given call-for-tenders (CfT) which represents a market demand. The proposed approach encompasses the following process steps:

Step 1: Retrieving CfT Requirements. The process starts by identifying the CfT specification of the required product or service, referred to as the target item (e.g. aircraft lavatory), and the required set of *goals* for the target item. Possible goals are “Plan & Manage”, “Design & Develop”, “Integrate Design”, “Source”, “Make”, “Assemble”, and “Deliver”, which are defined in accordance with the Supply Chain Operations Reference (SCOR) and Design Chain Operations Reference (DCOR) models (APICS Supply Chain Council 2014, 2017). The CfT further specifies characteristics which the issuer of the CfT would consider suitable for companies to provide the target item (e.g. certifications required, minimum annual turnover, minimum number of employees, and technological capabilities). We provide a detailed list of such characteristics in Appendix B.3. We note that the list of possible requirements may depend on the specific industry application; the current implementation of the approach is based on a use case in the aerospace industry (DIGICOR 2016).

Step 2: Tender Decomposition. In the next step, the process decomposes the CfT by identifying the subordinate items (parts, materials and/or services) needed to produce the target item (e.g. electric and water systems) and deriving the goals to be associated with them. For example, if the target item has a “Make” goal, then decomposing it into parts assigns goals “Make” and “Deliver” to each part, while the target goal “Make” is being replaced with “Assemble” and “Plan & Manage”. A similar decomposition rule applies to the target goal “Design & Develop”. Decomposition is then being executed further in a recursive fashion — using the information about the product structure from an ontology, thus producing a variety of different *tender decompositions* — each representing a list of specific items and goals associated with them. An item paired with one of the associated goals is called a *task*.

Step 3: Matchmaking. The tasks contained in each of the tender decompositions are then matched to the pool of available companies — whose specific capabilities and other characteristics are stored in the ontology and represent the supply side in Figure 4.1. We provide a detailed list of the available company characteristics in Appendix B.3. This step, called *matchmaking*, thus attempts to find suitable team members for each generated tender decomposition and to distribute tasks between them according to their capabilities. The matchmaking potentially gives a variety of prospective teams for each tender decomposition. Matchmaking is further guided by a number of *grouping criteria*, according to which prospective team members need to jointly meet certain CfT requirements. From the CfT requirements presented in Appendix B.3, the following ones have been identified by our study (Section 4.3) as representing grouping criteria: minimum annual turnover, minimum number of employees, and required certification.

Step 4: Evaluation. All team compositions are evaluated towards their *fit* — or overall suitability for the CfT. This is accomplished by applying a set of evaluation criteria to the team members' characteristics. As such, the following company characteristics have been identified in the course of our study as subject to evaluation (see Appendix B.3): certification, preferred contract types, target regions, location of manufacturing departments, and capabilities in terms of ATA, materials, technology, and speciality. Degree of coverage of the respective CfT requirements by the team members' characteristics is being averaged to produce the overall team fit. In addition, the team size and geographical dispersion of its members' manufacturing locations are taken into account in the way that bigger teams with more dispersed manufacturing facilities have, ceteris paribus, a weaker team fit due to coordination challenges. The final result is a list of teams, arranged in the order of the decreasing team fit, where each team comprises one or more companies associated with the tasks that they are expected to perform.

The team formation approach described above can also be executed in the "soft constraint" mode, in which the team compositions failing to meet grouping criteria of the Matchmaking step are still included in the result, yet with a reduced fit score. The team formation approach is fully automated by a decision support tool coined as the "Tender Decomposition and Matchmaking Service" (TDMS). Apart from the fully automated mode, TDMS also offers manual execution of Tender Decomposition and Matchmaking steps to permit the user to build up the team incrementally. For reasons of space and focus, formal algorithmic specifications are provided elsewhere (Pishchulov et al. 2020), however, we do include in this paper detailed steps of the approach using a flowchart diagram (depicted in Figure 4.11). The next section describes the design and implementation of the TDMS.

4.4.2 Technical Implementation of the TDMS

The TDMS tool aids end-users' decision-making process of selecting a team to jointly respond to a CfT. To design and implement TDMS, we followed a microservices architectural style (Nadareishvili et al. 2016; Namiot and Sneps-Sneppe 2014) and utilised the Angular 4 Java web-based framework ("Angular V4" 2017). The back-end decision support algorithms, including data analysis procedures, were implemented in the R programming language (R version 3.6). TDMS was designed to be deployed as a secure self-contained microservice that can be utilised on its own or integrated into third-party platforms (e.g. B2B platforms). TDMS also adopts technical designs based on RESTful and an event-driven architecture (Pautasso et al. 2008; Richardson n.d.; Richardson and Ruby 2007), as such, a TDMS Application Programming Interface (API) is provided to support platforms without event-driven capabilities. Figure 4.3 shows the TDMS architecture illustrating the internal components; the events indicated as “required” are those consumed by the TDMS, and the events indicated as “provided” are those that the TDMS generates when integrated to a B2B platform. A detailed account of the events and REST calls is included in the supplementary data (Appendix B.4).

As part of the tool’s back-end, we implemented the TDMS domain ontology (Guarino 1998) to support data interoperability between TDMS and integrated third-party platforms such as DIGICOR (see Section 4.3). Figure 4.4 presents an overview of the TDMS ontology in terms of a UML class diagram (Roussey et al. 2011); we provide further details in the remainder of this section.

The TDMS ontology describes the entities participating in the team formation considering the demand and supply sides. The ontological constructs encode three main sets of data, named the CfT data, the Company data, and the Team data where three types of attributes can be found: identifiers (e.g. IDs, CfT title, name of a company), characteristics (e.g. capabilities of a company, certifications accredited) and requirements (e.g. target item, type of contract). A detailed list of the data used in the TDMS ontology is provided in Appendix B.3. The TDMS utilises the internal ontological database model to store the required input data (“call for tender” data, and “company information” data) to avoid the communication costs that would incur if the approach was to request data from the “data owner” every time it is needed (i.e. every time a user utilises the TDMS). The ontology can be manipulated using Protégé[43] and needs to be supplied in the Web Ontology Language (OWL) format.

Using the ontology for knowledge base representation in the TDMS provides considerable advantages in terms of the flexibility in defining its main concepts, which facilitates portability of the TDMS to different application domains as well as its adaptability to future changes in the same domain. Such advantages are described below in the ontological implementation of *characteristics* — a central concept for representing the supply and demand sides in the TDMS (Figure 4.4).

The ontological implementation of characteristics is organised hierarchically in terms of classes and instances, as shown in the ontology class diagram in Figure 4.5; classes, as well as subclasses, may comprise specific instances of characteristics, as illustrated in Figure 4.6 for the *Material* subclass. As explained earlier, an instance of the *Specialty* characteristic refers to an item–goal combination (Section 4.1). *Items*, in turn, are represented by *Products* and *Services* (Figure 4.4). For brevity, and without loss of generality, in this paper we focus on the Products subtree.

[43] https://protege.stanford.edu/

Products in the ontology are organised into classes (product categories); the instances of those represent specific product variants. The classes are hierarchically structured, representing a classification of products in terms of categories, sub-categories, and so forth. Any product class may have specific products as its instances, which is represented by the relationship "has individual" (see Figure 4.7). This kind of relationship (between product classes and product instances) provides a core construct to support matchmaking algorithms, allowing companies to specify their capabilities in terms of broader categories than just specific product variants, and enables the TDMS to perform approximate matching of CfT requirements against companies' capabilities. E.g., when the requested item–goal task cannot be fulfilled by any of the companies then the search for suppliers is widened using the ontological relationships as a basis for identifying companies capable of dealing with products of the same class, or that class as a whole (DIGICOR 2019a).

Furthermore, if one product is an immediate component of another, then the latter is related to the former through the relationship "contains". Utilizing such relationships, the ontology captures all products in terms of their structure; this is essential for identifying team compositions that would be able to fulfil the tender (i.e. by manufacturing the components and assembling them to the final product). Relationships between products and product classes are illustrated in Figure 4.7: the product class hierarchy originates from *Product* as the root class, which has *Fixations* as one of the subclasses ("has subclass" relationship). *Fixations* has its own subclasses, such as *Lateral_Fixation* and *Upper_Fixations*. The latter subclass has an individual product *upper_fixations1* ("has individual" relationship) that contains other products as immediate components — which belong to their own product classes ("contains" relationship) (DIGICOR 2019a).

Appendix B.5 presents an extract of the OWL ontology representation of a hypothetical company named AirFrames Ltd. We finally note that updating the hierarchy of product categories and adding new products to it is fairly flexible in such an ontology-based data model and does not require making changes in the programme code because the above relationships among products and product classes are automatically respected when querying the ontology.

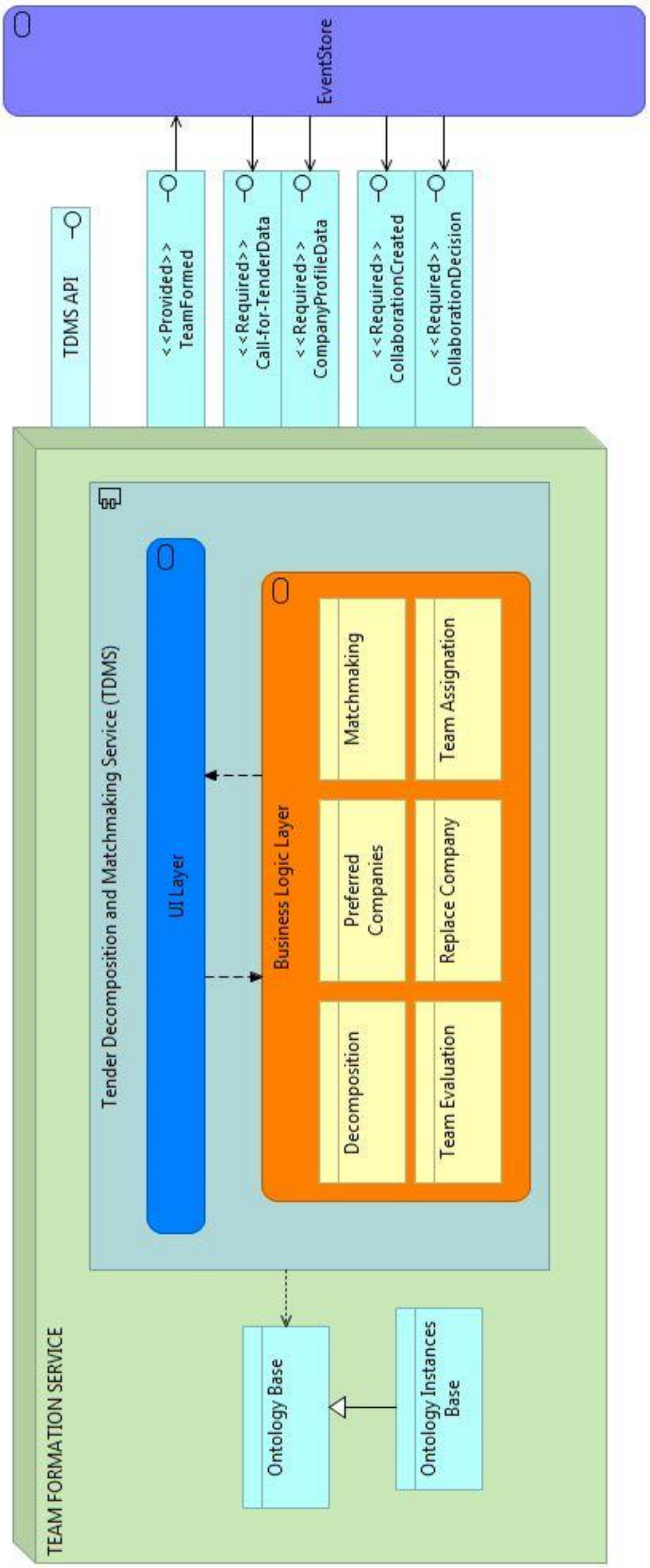

Figure 4.3: TDMS architecture depicting the events consumed (indicated as “required”) and produced (indicated as “provided”) for the communication with other services

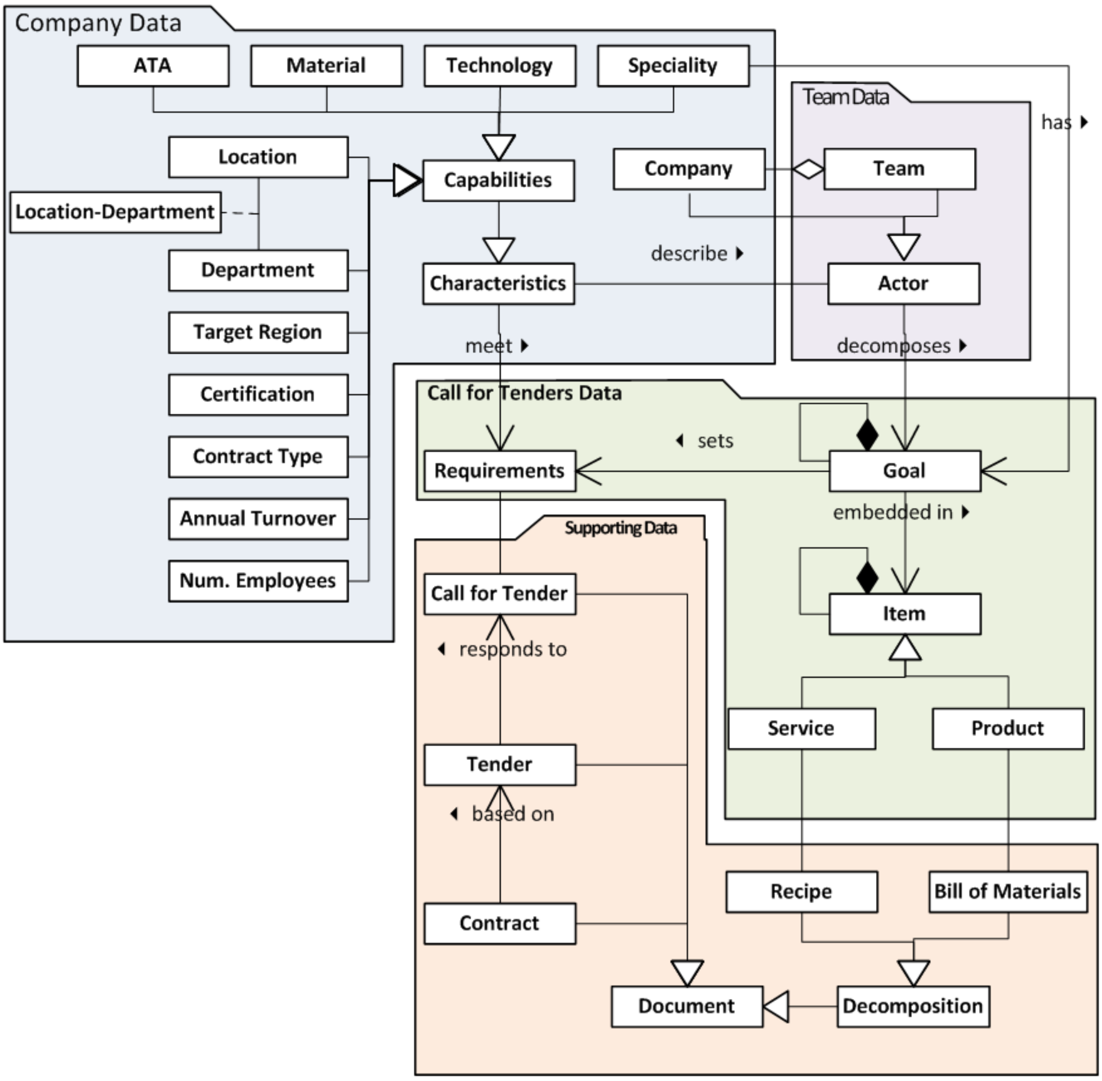

Figure 4.4: UML class diagram representing the TDMS ontology components and their relationships

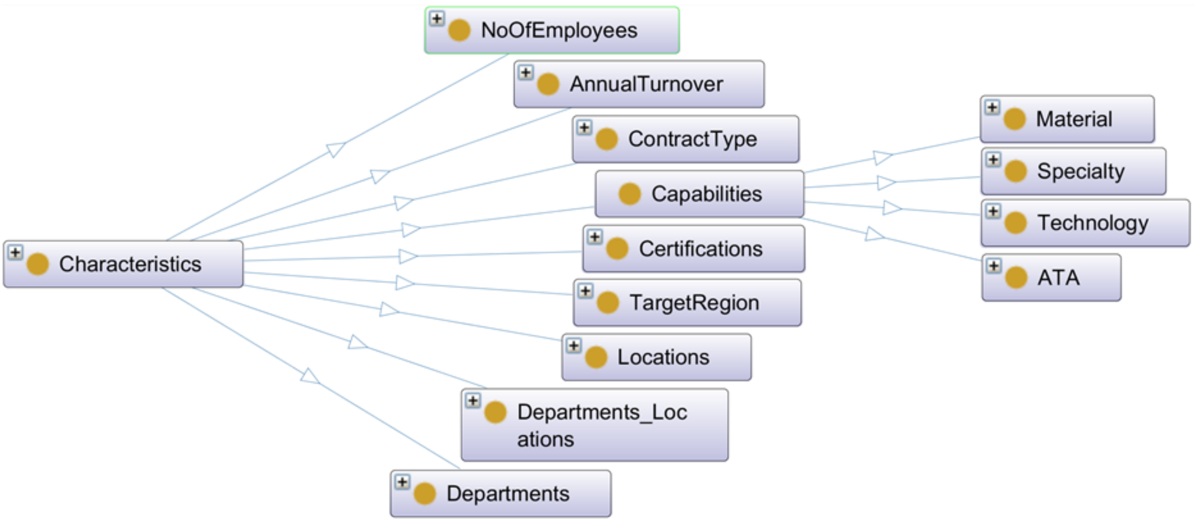

Figure 4.5: First and second levels of the class hierarchy of characteristics in the TDMS ontology

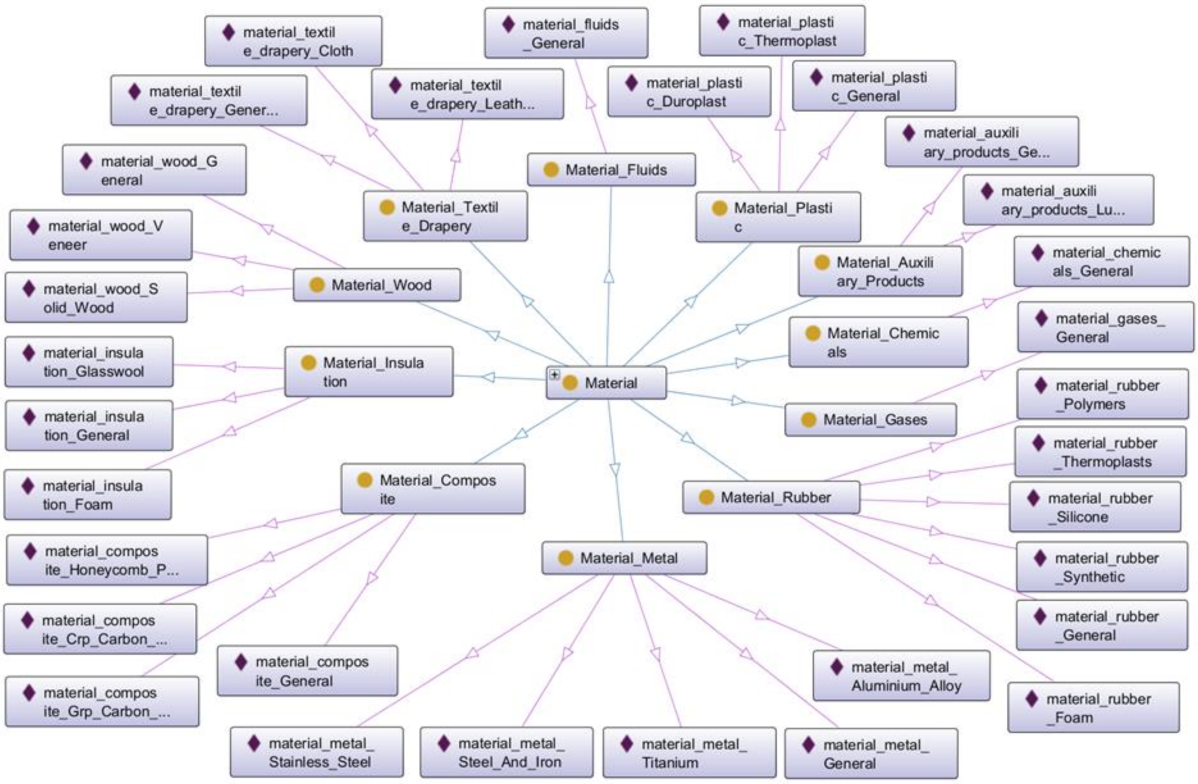

Figure 4.6: Subclasses of the Material characteristic in the TDMS ontology, and their instances

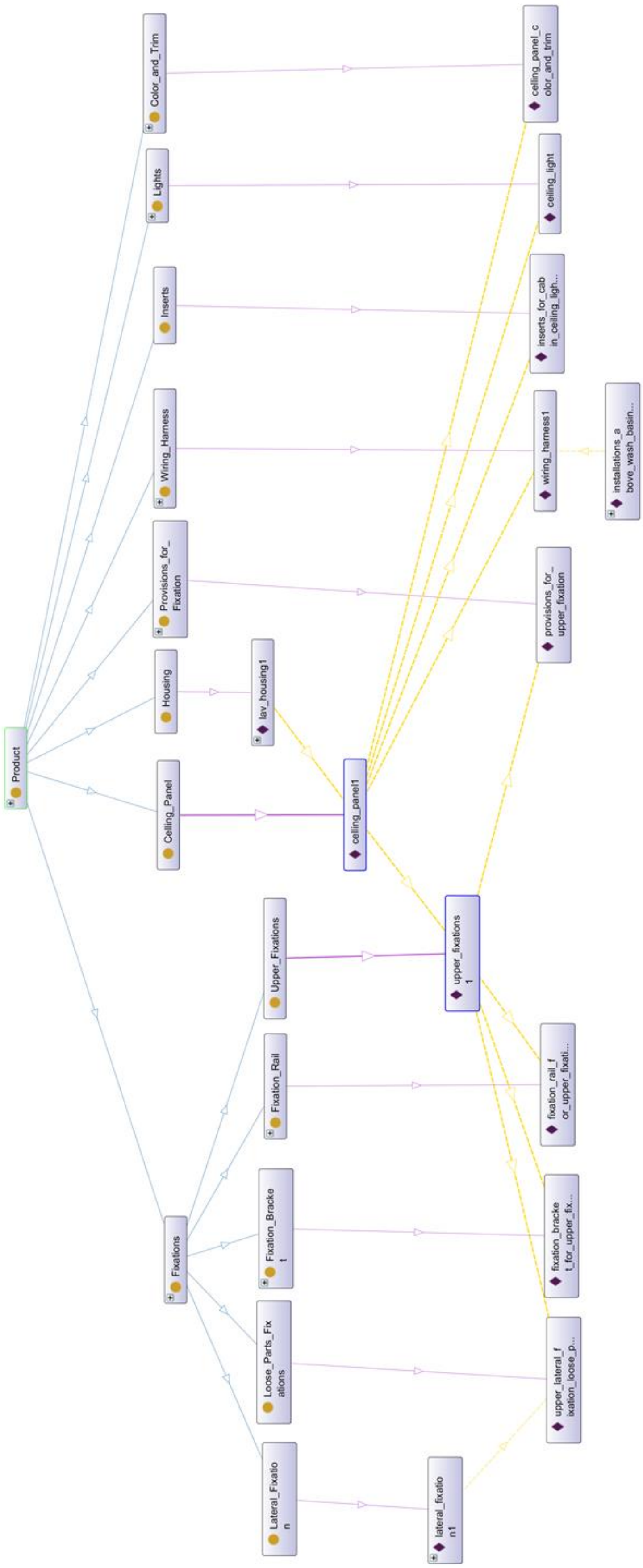

Figure 4.7: Example of relationships between products and product classes in the TDMS ontology

4.4.3 TDMS User Interface

In the tendering process, once the user selects the CfT to which he/she would like to respond to, the next step is to use the TDMS tool to find suitable business partners with who to jointly respond to the selected CfT. Figure 4.8 presents the initial screen shown to the user. Before the user starts interacting with the user interface (UI), the tool's back-end has received information regarding which item (that could be a product or service) is required as specified in the selected CfT; therefore, the front-end is able to present to the user the corresponding item structure as a hierarchical ontology composed of parts/sub-parts/services needed to produce the selected item. The TDMS UI shown in Figure 4.8 divides the interaction with the user into three screens according to the following workflow: (1) Search prospective teams, (2) Review teams & replace members, and (3) Review assignments.

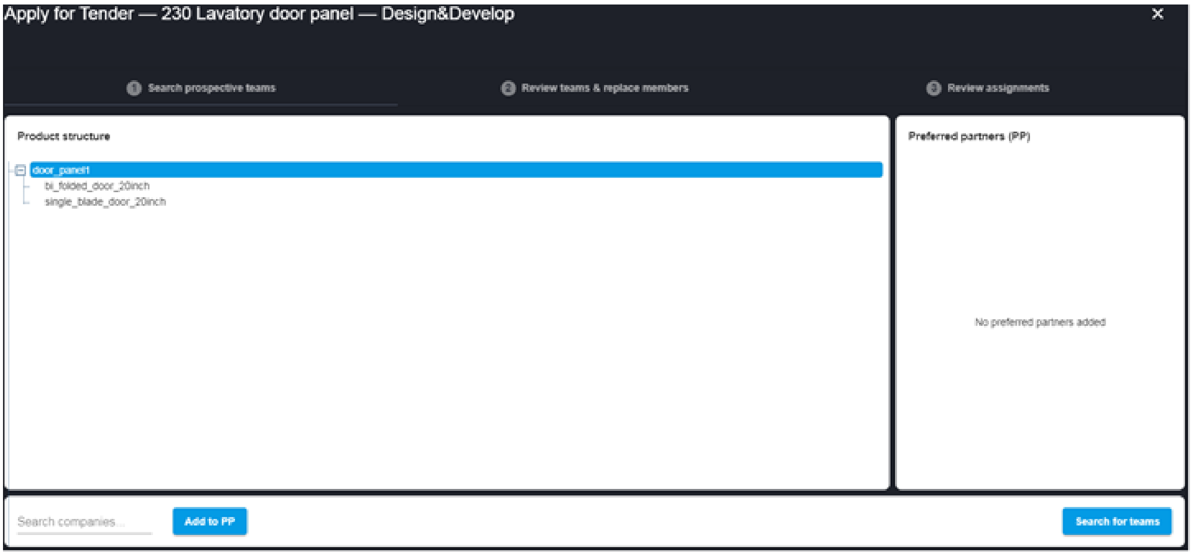

Figure 4.8: Example of the TDMS UI, showing its first screen "Search prospective teams" with a specific element of the product structure highlighted

In the UI screenshot depicted in Figure 4.8, we use an example of a CfT requesting work on a lavatory door panel to be included as a part of an aircraft's lavatory. The TDMS shows the decomposition tree of such product in the "Search prospective teams" screen. Figure 4.9 shows what is displayed if the user clicks on the "Search suppliers" button, where the tool looks for matching teams of suppliers that are able to provide the part/service selected by the user. Finally, in Figure 4.10, a screenshot is included showing the UI screen after the user has selected the preferred suppliers to be invited to form a team to jointly apply for and collaborate on a tender. Tasks for the items for which no supplier was found, will be shown as open positions without an assigned supplier. After confirming the selection, the user can click on the "Proceed" button to continue to the next step which is part of a service that would manage the collaboration process once a collaborative team is formed. The TDMS can also be used during the collaboration process if it is necessary to replace a supplier in a team.

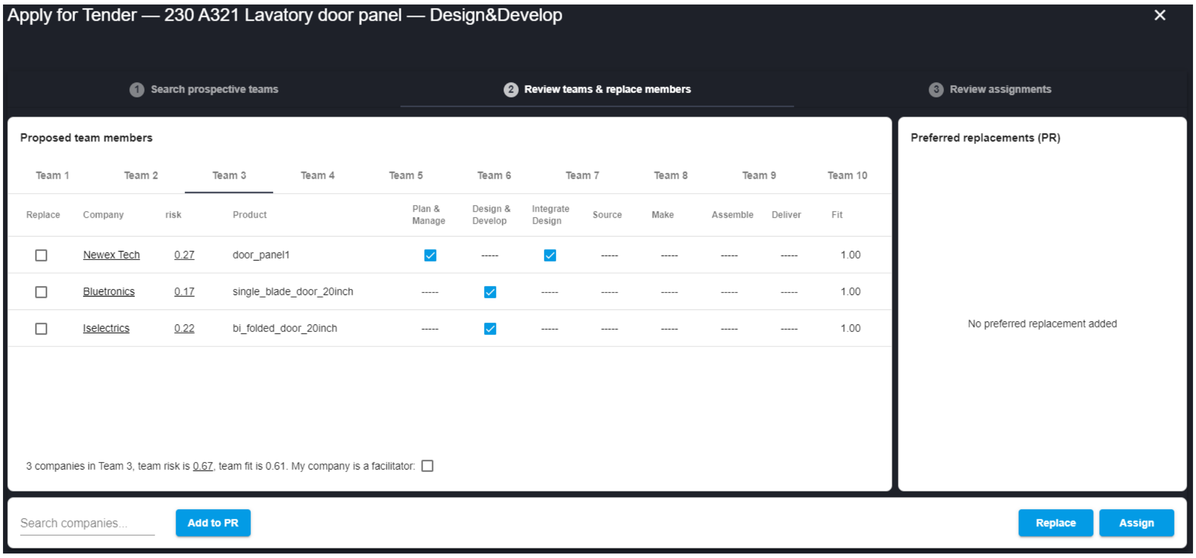

Figure 4.9: Example of the TDMS UI, showing its second screen "Review teams & replace members" with search results displaying a three-company team composition. Note: risk indicators were supplied by an external service hosted by DIGICOR (DIGICOR 2016)

Figure 4.10: Example of the TDMS UI, showing its third screen "Review assignments" with the team selected by the user in the previous screen

4.4.4 The Decision Support Approach and Tool Functionality: Users' Perspective

Our approach involves two major supply chain network analytical functionalities: (A) decomposition, (B) matchmaking; and three decision support functionalities: (C) team evaluation, (D) specification of preferred companies, replacement of a company, and (E) team assignment. Table 4.4 provides an overview of the functionalities provided by the TDMS, and Figure 4.11 presents a flowchart of the process including the use of the functionalities described in Table 4.4. The functionalities included were derived from the requirements and understanding captured from the exploratory activities carried out (see Table 4.3) and the gaps described in the background section of this paper. These functionalities were designed to cover the gaps identified, such as the need for enabling higher resource allocation efficiency (decomposition), forming semi-automated teams operationalising the agile formation of collaborations (matchmaking), supporting means to promote trust between collaborating organisations (team evaluation, specification of preferred companies), the ability to scale and adapt to market needs (replacement of a company), and the possibility to compose teams of multiple companies aiming to collaborate (team assignment).

The first part of the overall approach (revolving around item decomposition) is shown in section A of Figure 4.11. The user can request matchmaking for the entire product or individual parts of the product and, thus, build a team incrementally. If the selected item is part of the target product, then the associated goals are derived from the goals specified in the CfT through their decomposition.

Section D1 of Figure 4.11 shows that before applying the matchmaking functionality, the user can search and add preferred partners. The matchmaking algorithm respects the indicated preferred partners; therefore, the team compositions containing preferred partners are listed first, ordered by decreasing team fit.

The functionality shown in section B of Figure 4.11 corresponds to the matchmaking. By executing the matchmaking algorithm, the TDMS returns recommended team or teams able to provide the item selected by the user.

If there are several recommend teams, the user can select a given one to be shown in the UI and check its details; this corresponds to section C of Figure 4.11.

If the user wishes to replace a team member on a particular item, then he or she can use the replace function as depicted in section D2 of Figure 4.11. The tender decomposition and matchmaking algorithm will look for prospective subteams that can fulfil the goals associated with the given item, and will automatically pick the one with the highest team fit. As mentioned previously, they could search for the target item directly or decompose the target item and search the sub-items one by one.

Section E of Figure 4.11 shows the last part of the approach in the flow diagram, which is to select the final team composition. This is done by the user assigning the tasks to a company. Finally, the user can invite all assigned supplier(s) to join the team and allow them to decide whether to accept joining the collaboration. If there is any declined invitation, the user can select to search for alternatives by using TDMS again. The user can also examine the team completeness for specific gaps and/or redundancies in the team composition and address outstanding team formation issues by iteratively applying TDMS functionalities (DIGICOR 2019b).

Table 4.4: *Overview of the functionalities included in the TDMS tool. See Figure 4.11 for the visualization of the scope in relation to the decision support approach*

Scope	Functionality	Description	User action	TDMS action
A	Product/service decomposition (tender decomposition)	Supports the granular decomposition of a service/product demanded in the CfT. This component uses a view of a decomposition of service/products with interaction from the user to decompose to the required abstraction level	Select CfT	
			Select item to search	Show corresponding decomposition tree
B	Match providers to tasks (item–goal pairs) (matchmaking)	The tool proposes teams of partners (suppliers) that match the requirements of the required tasks. If no provider is found suitable for a specific task, the task can be further decomposed or left as a vacant position		Search suitable suppliers
C	Evaluate the matching of teams to a task (item-goal pairs) (team evaluation)	The tool proposes teams of suppliers that can fulfil the required tasks and evaluate the proposal by scoring against a set of criteria		Evaluate teams
D	Update the recommended teams (preferred companies, replace company)	The user is able to update and replace the partners proposed in the team. This can be done indicating which partner is preferred both for the initial proposition or when the tool looks for a replacement on a given item-goal pair	Add preferred partners	
			Select companies for replacement	
E	Select the final team composition (team assignation)	Once the user has gone through the process and is satisfied with the team composition built, the members are indicated to be the final assignment, therefore the tool allows the user to save this information for future usage, e.g. if a replacement of one of the suppliers is to be done at a later point in time due to the selected partner not accepting to join the team, or quitting from it	Select team to be invited	

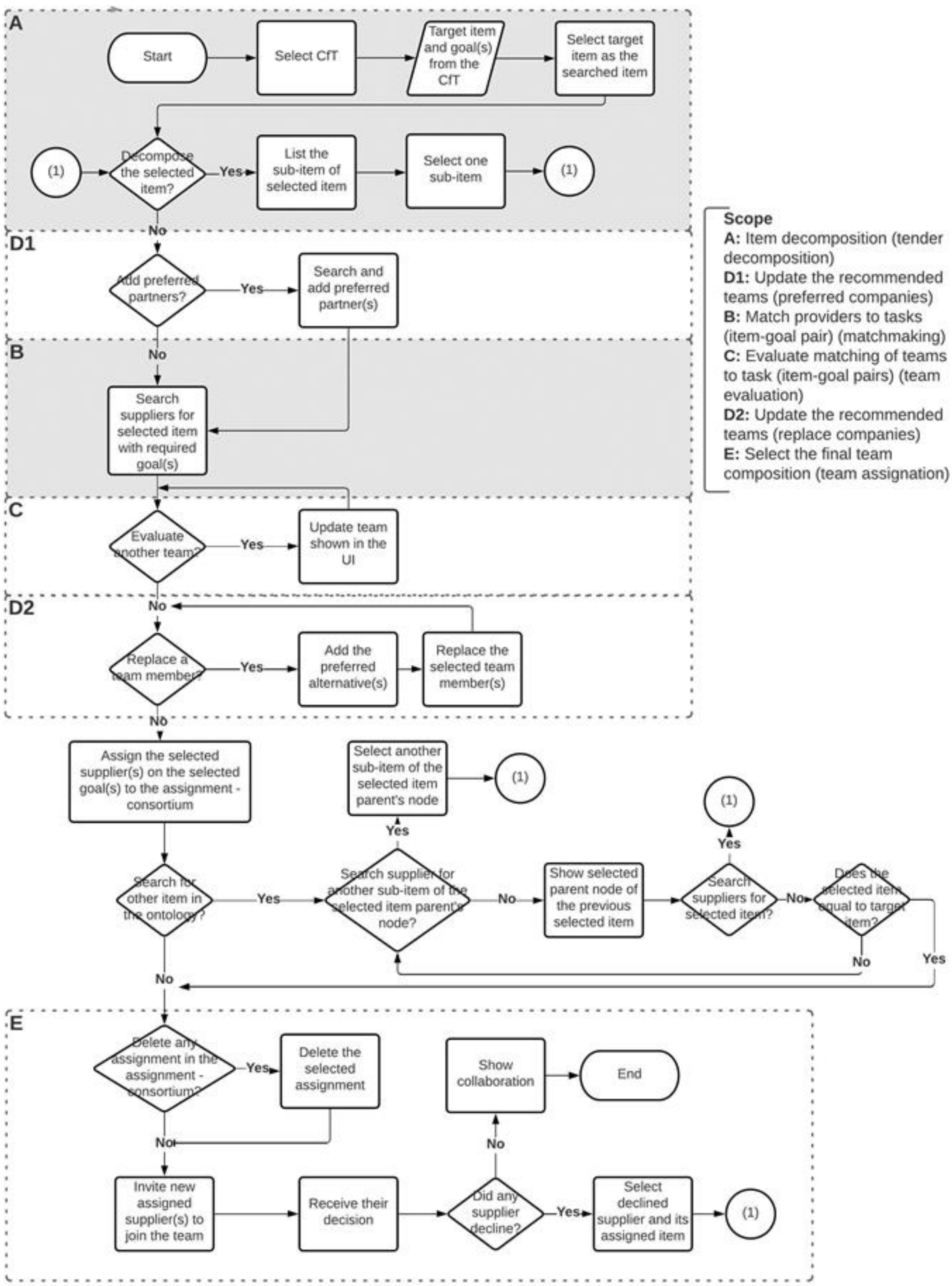

Figure 4.11: Overall decision support approach. The functionalities of matchmaking (A) and decomposition (B) are highlighted

4.5 Evaluation and Results

4.5.1 Verification

We carried out test cases to verify the correctness of the TDMS in proposing team compositions to respond to a CfT as described in Section 4.4. Following the procedure stated in Section 4.3.2, for our illustrative example, we utilise a CfT that hypothesises an OEM requesting to *Make* and *Source aircraft lavatory door handles*. Figure 4. depicts the decomposition tree used for this target item.

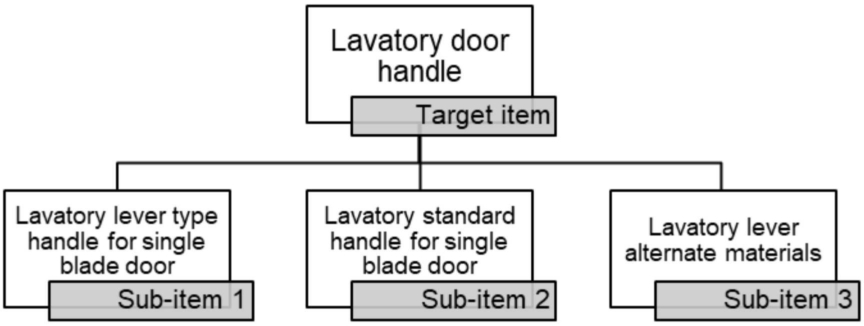

Figure 4.12: Decomposition tree for the CfT requiring a lavatory door handle

Analysing the expected results, considering the CfT data and the 14 companies' data (see Appendix B.1), no suitable company can fulfil the item–goal pair of "lavatory door handle – Make"; in this case, one possible solution is to leave this task as a vacant position and wait for a new company which can fulfil this task to register in later in the B2B marketplace. Another solution is to decompose the task and therefore, based on the corresponding item decomposition tree, the target item we obtain as sub-items are "lavatory lever type handle for single blade door" (i.e. handle lever on the inside) (sub-item 1), "lavatory standard handle for single blade door" (i.e. handle lever on the outside) (sub-item 2), and "lavatory lever alternate materials" (i.e. fixings) (sub-item 3), which means those are the elements required to successfully fulfil a Make goal for a lavatory door handle. In this example, the tool needs to find companies which can make these three sub-items respectively, deliver, and assemble them, considering that when a Make goal is decomposed, a new goal named Assemble is added for the overall target item and a Deliver goal is also added per each sub-item. Furthermore, a company to Plan & Manage this supply chain process is also needed.

Table 4.5 presents the results for the example CfT (Make and Source aircraft lavatory door handles), where three possible teams are shown. Figure 4.13 shows the teams formed by the decision support tool.

Team 1 presents an option where the company "Openlane Plc" is recommended to Plan & Manage the required item, i.e. the target item for the CfT, as well as to fulfil the Source goal. As mentioned earlier, there is no single company capable of fulfilling the Make goal for lavatory door handles on its own; therefore, the position is proposed as "not available" in this team.

Table 4.5: *The team formation tool's expected teams for Make and Source aircraft lavatory door handles CfT. Key: "not available" (NA), Plan & Manage (PM), Design & Develop (DD), Integrate Design (I), Source (S), Make (M), Assemble (A) and Deliver (D)*

Tender description: lavatory door handle (target item) — Make, Source (goals)								
Company	**Category**	**PM**	**DD**	**I**	**S**	**M**	**A**	**D**
Team 1								
Openlane Plc	target item	✓	–	–	✓	–	–	–
NA	target item	–	–	–	–	✓	–	–
Team 2								
Openlane Plc	target item	✓	–	–	✓	–	✓	–
CoUK coop	sub-item 1	–	–	–	–	✓	–	–
ABC Aviation	sub-item 1	–	–	–	–	–	–	✓
ABC Aviation	sub-item 2	–	–	–	–	–	–	✓
NA	sub-item 2	–	–	–	–	✓	–	–
Design Vital Ltd	sub-item 3	–	–	–	–	✓	–	✓
Team 3								
Openlane Plc	target item	✓	–	–	✓	–	✓	–
CoUK coop	sub-item 1	–	–	–	–	✓	–	–
ABC Aviation	sub-item 1	–	–	–	–	–	–	✓
ABC Aviation	sub-item 2	–	–	–	–	–	–	✓
NA	sub-item 2	–	–	–	–	✓	–	–
CoUK coop	sub-item 3	–	–	–	–	–	–	✓
Design Vital Ltd	sub-item 3	–	–	–	–	✓	–	–

Team 2 proposes "Openlane Plc" to fulfil the three overall associated goals to the target item – Plan & Manage, Source, and Assemble – where the Assemble goal appears because of the Make goal being decomposed. Thus, to fulfil the Make goal for the lavatory door handle, Team 2 proposes a decomposition according to the corresponding tree (see Figure 4.12) and shows companies whose capabilities include the goal Make for the required sub-items; the associated Delivery goal for each sub-item is also taken into account. In this team, the sub-item 2, lavatory standard handle for single blade door, lacks a company, from within the 14 companies set, able to fulfil the Make goal.

Finally, Team 3 proposes a different assignment of the required tasks to fulfil the CfT. The difference between Team 2 and Team 3 is that the latter presents the tasks associated with sub-item 3 (“lavatory lever alternate materials – Make” and “lavatory lever alternate materials – Deliver”) to be fulfilled by two different companies, instead of a single one as it is in Team 2. TDMS enables the decomposition and assignment of CfT goals using what is called “a contracting function” which helps to identify the best fitting partner or a set of partners for forming a team to fulfil a CfT.

Team 1

Replace	Company	risk	Product	Plan & Manage	Design & Develop	Integrate Design	Source	Make	Assemble	Deliver	Fit
☐	Openlane Plc	0.21	lavatory_door_handle1	☑	-----	-----	☑	-----	-----	-----	1.00
☐	<not available>	1.00	lavatory_door_handle1	-----	-----	-----	-----	☐	-----	-----	0.00

Team 2

Replace	Company	risk	Product	Plan & Manage	Design & Develop	Integrate Design	Source	Make	Assemble	Deliver	Fit
☐	Openlane Plc	0.21	lavatory_door_handle1	☑	-----	-----	☑	-----	☑	-----	1.00
☐	CoUK Coop	0.30	lavatory_lever_type_handle_for_single_	-----	-----	-----	-----	☑	-----	-----	1.00
☐	ABC Aviation	0.27	lavatory_lever_type_handle_for_single_	-----	-----	-----	-----	-----	-----	☑	1.00
☐	ABC Aviation	0.27	lavatory_standard_handle_for_single_b	-----	-----	-----	-----	-----	-----	☑	1.00
☐	Design Vital Ltd.	0.27	lavatory_lever_alternate_materials1	-----	-----	-----	-----	☑	-----	☑	1.00
☐	<not available>	1.00	lavatory_standard_handle_for_single_b	-----	-----	-----	-----	☐	-----	-----	0.00

Team 3

Replace	Company	risk	Product	Plan & Manage	Design & Develop	Integrate Design	Source	Make	Assemble	Deliver	Fit
☐	Openlane Plc	0.21	lavatory_door_handle1	☑	-----	-----	☑	-----	☑	-----	1.00
☐	CoUK Coop	0.30	lavatory_lever_type_handle_for_single_	-----	-----	-----	-----	☑	-----	-----	1.00
☐	CoUK Coop	0.30	lavatory_lever_alternate_materials1	-----	-----	-----	-----	-----	-----	☑	1.00
☐	ABC Aviation	0.27	lavatory_lever_type_handle_for_single_	-----	-----	-----	-----	-----	-----	☑	1.00
☐	ABC Aviation	0.27	lavatory_standard_handle_for_single_b	-----	-----	-----	-----	-----	-----	☑	1.00
☐	Design Vital Ltd.	0.27	lavatory_lever_alternate_materials1	-----	-----	-----	-----	☑	-----	-----	1.00
☐	<not available>	1.00	lavatory_standard_handle_for_single_b	-----	-----	-----	-----	☐	-----	-----	0.00

Figure 4.13: The proposed teams obtained in the team formation tool (TDMS) for the Lavatory door handle CfT. Note: risk indicators have been supplied by an external service hosted by DIGICOR (DIGICOR 2016)

4.5.2 Validation

As indicated in Section 4.3.2, the expert feedback study aims to capture expert views about the expected utility and effectiveness of the tool in facilitating team formation decisions in a digitalised context. The study confirms whether or not the idea of a system such as TDMS is the right artefact to support the formation of collaborative supply chains, and validates that the TDMS as designed is a suitable approach to address such formation, as claimed in this paper. Section 4.3.2 shows the details of the procedure for this validation study.

The survey used three questions to capture the 14 respondents' background: (i) field of work, (ii) level of expertise in smart manufacturing/Industry 4.0, and (iii) role or position held. The number of respondents for the various fields is presented in Table 4.6, where the sum of responses for the role or position held exceeds the total number of participants because some of them hold more than one position within their fields.

Table 4.6: *Expert feedback survey. Respondents' background results*

Field		Expertise		Role / position	
academic	5	basic	28.6%	academic	3
professional	8	intermediate	42.9%	IT developer / systems engineer / architect	4
both	1	expert	28.6%	business / IT consultant	1
				executive / manager	2
				operations / supply chain professional	5
				others	3

The number of responses corresponding to the different purposes is indicated in parenthesis following each option: (a) Forming a team/finding partners (12), (b) exploring/understanding the supplier market (4), (c) finding alternative team compositions (5), (d) replacing team members (4), (e) diversifying the supplier base (7) and, (f) other (1): i.e. applying for current and future EU projects.

The study then explored the most frequently used method for collaborative tender preparation with answers showing the use of "existing networks such as professional and personal contacts" as the most commonly used method at 78.6%, followed by "finding partners through industry events/fairs" at 14.3% with the least used method being the use of "IT-assisted solutions such as the TDMS" at 0%; however, 7.1% did not indicate any method. Further, based on the respondents' experience, they were required to rate the effectiveness of the methods used for collaborative tender preparation. The rating was based on a five-point Likert scale: ineffective (1), slightly effective (2), rarely effective (3), effective (4), and very effective (5). The findings show that on average, the use of "existing networks such as professional and personal contacts" was rated highest at 4.2, then "finding partners through industry events/fairs" at 2.9 which was closely followed by the use of "IT-assisted solutions such as the TDMS" at 2.8.

Next, respondents were required to indicate the expected benefits from using a system such as the TDMS and were able to select multiple choices. The results of the expected benefits were as follows: (a) Reduced time and cost to fulfil related tasks (11), (b) Broaden access to supplier market (8), (c) Increased number of successful call-for-tender submissions (5), (d) Improved manufacturing capacity utilisation (6) and, (e) Other (2): i) Cash and carry – other branches, automotive suppliers, and ii) Broader view for collaboration. In addition, based on their experience, respondents were requested to rate the expected benefits, on the scale from 1 to 5: not beneficial (1), slightly beneficial (2), rarely beneficial (3), beneficial (4), and very beneficial (5).

The results indicate that on average the benefits of using a tool such as the TDMS (see Figure 4.14) were rated as follows: the "reduced time and cost to fulfil related tasks" was rated as the most beneficial at 3.86, followed by "broadening access to supplier market" at 3.79, then improved "manufacturing capacity utilisation" at 3.5, and the least beneficial as the "increased number of successful call-for-tender submissions" at 3.36. The top three benefits gauged from the survey provide clear indicators of the value derived from tools such as TDMS in addressing challenges relating to finding and integrating suitable suppliers into highly fragmented supply chains, moreover doing so at speed and scale (for reference see the problem framing and gap identification articulated in the introduction and literature review sections of this chapter).

The study then explored the concerns that might prevent respondents from using the TDMS tool. Respondents were allowed to select from multiple choices, and the following results were obtained: (a) System security and integrity (8), (b) Data privacy (7), (c) Industry regulatory compliance (6), (d) System training costs (3), (e) Auditability of the system (6), (f) Other (1): i.e. system complexity should be an issue/ease of use (see Figure 4.15). Furthermore, an assessment of the respondents' likelihood to recommend the use of the TDMS to their organisation or business partners was conducted by asking respondents to indicate the likelihood on the scale from 1 (very unlikely) to 10 (very likely). The following likelihood was indicated: Likelihood of 8 (6 responses), likelihood of 7 (4 responses), likelihood of 6 (3) and likelihood of 2 (1). To conclude the study, respondents' views were sought on several general aspects about the TDMS' functionality which they had to rate using a Likert scale from 1 to 5: strongly disagree (1), disagree (2), neither agree nor disagree (3), agree (4), and strongly agree (5).

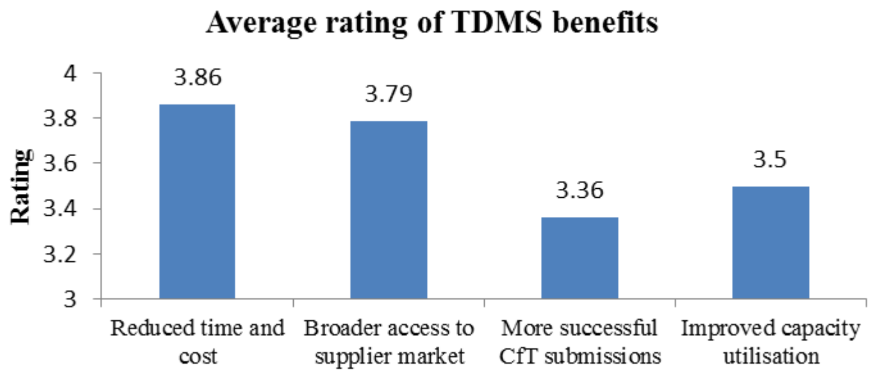

Figure 4.14: Average user rating of TDMS benefits

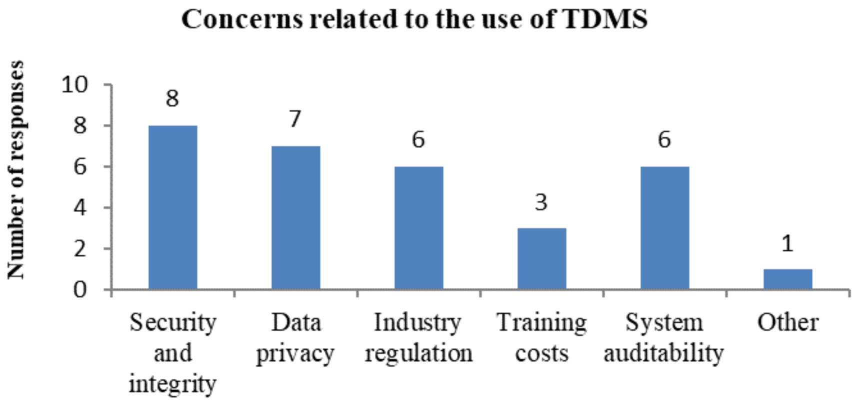

Figure 4.15: Concerns related to the use of the TDMS

The findings show that the average level of agreement to the general statements asked was as follows: I find the tender decomposition useful (4.29); I find the TDMS suitable for composing a team (3.79); I find the use of ontologies in the description of products useful to support tender preparations (3.36); I find that the specification of goals supported by the TDMS is suitable for tender preparation (3.86), and I find that the TDMS matchmaking criteria are suitable for tender preparation (3.64).

4.6 Impact and Managerial Implications

The proposed approach and decision support tool applied to the formation of collaborative supply chain networks increases the likelihood of complex production requirements specified as digital CfTs to be fulfilled by a wider pool of enterprises joining capacities/capabilities and forming temporal supply chain collaborations and virtual enterprises (Camarinha-Matos et al. 2017; Cisneros-Cabrera et al. 2018). This also *facilitates SME integration into the manufacturing supplier pool*, allowing SMEs to bid for large-scale business opportunities involving dynamic and complex tasks as part of a collaborative supply network, with benefits to supply chain and B2B market efficiency (Mehandjiev et al. 2010). TDMS can be used by companies of any size, however, it is particularly suitable for SMEs because they often lack capacities and capabilities to fulfil CfTs alone (Hong and Jeong 2006; Macpherson and Wilson 2003). A larger pool of suppliers searchable and integrated into the digital platform matchmaking algorithms also *allows OEMs and Tier-1 enterprises to rapidly react to supply chain disruptions* and opens the marketplace by adding more transparency and visibility to both the supply and demand sides. There is also more *flexibility towards selecting suppliers* by rapidly assessing several team combinations with different risk/quality/cost trade-offs.

Based on feedback from supply chain experts analysed previously, "reduced time and cost to fulfil related tasks" came on top of the list of expected benefits pointing to a positive impact of TDMS in *increasing organisational agility* by speeding up the collaboration formation process, e.g., from months to weeks or days. Most of the benefits derived from adopting the proposed approach and tool can be positioned within the scope of the identification, selection and evaluation stages of the supplier relationship management process (Mehandjiev et al. 2010). This is a field of growing importance to the efficient and effective functioning of increasingly disperse, fragmented and global supply chains (Brun et al. 2019; Min et al. 2019). Being able to rapidly form teams and search for replacements in scenarios of supply disruptions from a wide pool of suppliers also has the indirect benefit of *increasing supply chain resilience*.

In contrast to other approaches that form collaborations after a phase of pre-selection of suppliers individually (see (de Boer et al. 2001; Chai et al. 2013; Polyantchikov et al. 2017; Tahriri et al. 2008; Zimmer et al. 2016)), our approach supports "on-the-fly" team formation, with a holistic multi-tier view of the supply chain collaboration design problem. This facilitates the *search for global suitable team combinations* to respond to a call for tenders.

Finally, the digitalisation of the tendering and team formation process advances the state-of-the-art towards the notion of forming contractual team collaborations, defining, settling and enforcing contractual obligations providing an important step towards the implementation of "Smart Contract" (Korpela et al. 2017) solutions for global supply chains.

4.7 Conclusions and Future Work

The fourth industrial revolution (Lasi et al. 2014; Liao et al. 2017) is increasing the pace of automation with offline business processes replaced by digitalised versions based on human-machine collaborations. Digitalisation has reached a tipping point where high-value-added processes involving decision-making traditionally carried out offline by managers are being digitalised using assistive decision support technologies (Brettel et al. 2014; Kagermann 2015; Lasi et al. 2014).

In this chapter, we have discussed the design, implementation and validation of an approach and decision-support tool allowing search, matchmaking, team composition and multi-criteria decision support (with regard to the CfT requirements) towards assessing candidate teams regarding suitability to collaborate as a supply network by sharing and combining capabilities and production capacities.

The tool automating the team formation approach applies domain knowledge codified as machine-readable ontologies to assist users in their decision process of selecting potential partners to join a collaboration; this is done by proposing group compositions of suitable partners (teams) for fulfilling the elements of a CfT. In this way, the ontologies used by the tool represent a conceptualisation of the real-world products and relationships between them, companies' capabilities, CfT requirements, and other terms essential for forming and maintaining supply-chain collaborations. The top-level concepts in the ontology and their structural relationships presented here are a part of a wider effort which also covers the process coordination aspects of team collaboration using the Coordination Theory (Malone and Crowston 1994; Mehandjiev et al. 2010, 2009), and explores the potential of ontological relationships and axioms to support reasoning and to enable automated inference about team, product, and process composition alternatives, exploring the relationships between parts and products and suitability of prospective suppliers for fulfilling specific tasks.

The decision support capabilities of the tool include recommendations to business users regarding candidate sets of companies considered best suited towards forming a collaborative team. The recommendations are based on multiple attributes capable of addressing the tender requirements leveraging a broad range of companies and their collective capabilities. The validation based on expert feedback indicated the usefulness and acceptance potential of the proposed approach and tool. Our proposed solution to forming Industry 4.0 supply chain collaborations is unique in integrating industry domain ontologies, assistive human-computer interaction techniques, and multi-criteria decision support to address the issue of semiautomating the process. Our work contrasts with current practices of forming collaborative supply chains that are reliant on manual processes, networking via face-to-face sector-specific events and peer referencing.

Future work will involve understanding and theorising for the motivations of end-users in the manufacturing domain to accept high-valued added automated B2B advice from decision support systems, particularly addressing trust and security issues (Hoff and Bashir 2015; Hoffman et al. 2013) and also investigate algorithm aversion in B2B supply chain decision making support (Cisneros-Cabrera et al. 2020; Dietvorst et al. 2015).

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Chapter 5

Computers as Advisors for Inter-organisational Partner Selection: What makes People take Business Advice from a Computer System?

Cisneros Cabrera, S., Mehandjiev, N., Rossi, M., & Sampaio, P. Computers as Advisors for Inter-organisational Partner Selection: What makes People take Business Advice from a Computer System? Unpublished Manuscript.

Abstract. Computers as advisors are already in use to support high impact decision-making; however, there is a limited understanding of why and when users act upon computer-generated advice in such complex scenarios. To contribute to this understanding, we present our "Computer Advice Utilisation" (CAU) theory, applicable when the advice is provided by a computer in support of business partner selection in manufacturing industries. We have developed CAU within the Action Design Research (ADR) method engaging with a network of manufacturing companies to improve their partner selection process. ADR allowed us to match our theory-derived propositions to empirical results from practitioners within the network, thus using an iterative pattern-matching theory development process integrated with the iterative artefact development within ADR. In this paper, we present our CAU theory and explore its predictive capabilities using a Bayesian network to reason using probabilities. We then compare the resultant predicted outcomes with those captured from our practitioners. In doing so, we demonstrate the validity of CAU. The results in this paper contribute to the Information Systems (IS) theories by offering new insights into the factors impacting computer-generated advice taking by professionals acting on behalf of organisations when establishing inter-organisational collaborations. CAU theory propositions can also support management practice by enhancing the likelihood of users taking advice for business decision-making.

Keywords: Computer advisory systems, Computerised Advisor, Theory Development, Advice Utilisation, Inter-organisation Partner Selection, Mid-range theory.

5.1 Introduction

Computers have been used as advisors for nearly half a century (Dzierzanowski et al. 1989; Smith and Eckroth 2017; Timmreck 1966, 1967, 1968), yet little is known about the factors that make people utilise the advice received from computers (Prahl 2018). Advice utilisation refers to the extent to which the recipient of an advice follows the recommendation (Bonaccio and Dalal 2006). When the advice is given by a computerised advisor, we refer to "Computer Advice Utilisation", and we define such utilisation as "*the decision of the advice-recipient, a human, to integrate advice given by a computerised advisor into her/his decision-making*".

Investigating how humans take advice from a computer is identified as an interesting research direction (Sniezek 1999); however, as shown in this chapter, research has yet to answer this research call. Indeed, there is a good understanding of user acceptance and use of technologies (Bright et al. 2012; Burton-Jones et al. 2017; Lee et al. 2003), including computerised advisors (Shibl et al. 2013; Wang et al. 2012). However, research on the computerised advice utilisation differs in its focus on whether humans follow the advice received, rather than on their intention of using the advisory technology, where such research has only explored a few examples (Bonsall 1992; Chow et al. 2015; Gasparic and Ricci 2015; Köhler et al. 2011; Lourenço et al. 2020; Westin et al. 2013; Ye and Johnson 1995). None of these works establishes an explicit theoretical model linking the main influencing factors with users using or not computer-generated advice. Also, the majority of these works focus on low business value decisions such as choice of movies (Köhler et al. 2011), music selection (Jin et al. 2017), or museum route selection (Takahashi et al. 2007), with a very few exceptions in higher business value decisions, such as health (Chow et al. 2015), and air traffic management (Westin et al. 2013). Furthermore, broad research into advice utilisation factors remains focused on human-to-human advice utilisation (MacGeorge and Van Swol 2018).

This lack of theory motivates our work aiming to explain what influences people to utilise computer-generated advice. Our theory of *Computer Advice Utilisation (CAU)* identifies and describes the factors that influence people to take advice from computerised advisors regarding *inter-organisational partner selection*, particularly focused in the cases of the aerospace and automotive application domains. Selecting business partners for collaborative bidding, for example, is a high-value decision where businesses still rely on previous interactions with existing partners and even database searches are frowned upon — mainly because of the richness of the information to be considered before a rational decision can be taken. Producing sound advice recommending suitable partners is a complex task (Cisneros-

Cabrera et al. 2018), and ensuring businesses trust this advice is paramount to achieve the full transformational effect of such automation.

The CAU theory proposed here establishes a contribution in the theoretical realm of computer-generated advice utilisation, allowing others to extend this knowledge to different application domains and target problems. In the practical realm, CAU can inform the design of inter-organisation partner selection systems to increase their advice utilisation.

5.2 Computer Advice Utilisation: Previous Work

There is a paucity of research into what leads users to follow advice from computerised advisors, with the few studies reviewed below focusing on individual factors and, to the best of our knowledge, lacking a connection of these factors into a theoretical model.

Research in recommenders for leisure activities (Bonsall 1992; Köhler et al. 2011; Takahashi et al. 2007) and leisure services (Jin et al. 2017; Köhler et al. 2011) suggests that the **processing time** of a computerised advisor has an impact on the utilisation of the advice and that such utilisation is mediated by the **transparency of the advice** (Köhler et al. 2011). This finding is also supported in research from finance (Ye and Johnson 1995), and health (Chow et al. 2015) where **transparency**, **trust**, and **perceived levels of the system's credibility** are identified as relevant factors in the acceptance of the advice coming from a computerised advisor (Chow et al. 2015; Ye and Johnson 1995).

Research in finance (Ye and Johnson 1995), and border control management (Giboney et al. 2015) has identified that **explaining the rationale of the advice** also impacts the computer-generated advice utilisation (Ye and Johnson 1995) with the most efficient influencer being the justification ("why") type of explanation. Research in these contexts and in air traffic management (Westin et al. 2013) has identified explanations' influence on a decision is proportionate to the time user spends reading those explanations; this appears to happen mainly when the user-explanation **cognitive style is met** (Giboney et al. 2015; Westin et al. 2013), for example, when the computerised advisor's advice generation process matches the decision-making process of the end-user.

In research of vehicle navigation (Bonsall 1992), programming (Gasparic et al. 2017), and leisure services recommendation (Jin et al. 2017), the factors identified as influencing computer advice utilisation are (a) the **quality of both the advice and the system**, (b) the existence of any corroborating or conflicting **evidence** to support the advice (Bonsall 1992;

Gasparic and Ricci 2015; Jin et al. 2017), and (c) the chosen **advice presentation** (UI) **approach** (Gasparic and Ricci 2015).

Table 5.1 summarises the factors believed to impact the utilisation of computer advice. These factors appear without a unified model of their relationships and influence on computer-generated advice utilisation. As such, further research is needed to specify the antecedents to advice utilisation, their relationship, and to diversify the context where the phenomenon is studied. Indeed, the dominant type of advice taking studied is of personal recommendations, with the business' context somewhat neglected, i.e. advice taking on behalf of an organisation.

Table 5.1: *Summary of factors influencing computerised advice utilisation*

What influences the utilisation of advice coming from an advisory system?	Context	Reference
Transparency	Leisure activities recommendation, finance, health	(Chow et al. 2015; Köhler et al. 2011; Ye and Johnson 1995)
Quality of the advice and the system	Vehicle navigation, programming tools, leisure services recommendation	(Bonsall 1992; Gasparic and Ricci 2015; Jin et al. 2017)
Trust	Finance, health	(Chow et al. 2015; Ye and Johnson 1995)
Cognitive style alignment	Border control management, air traffic management	(Giboney et al. 2015; Westin et al. 2013)
System's response time	Leisure activities recommendation, leisure services recommendation	(Köhler et al. 2011)
System Credibility	Leisure activities, health	(Chow et al. 2015; Takahashi et al. 2007)
Explanations	Finance	(Ye and Johnson 1995)
Advice presentation style	Programming	(Gasparic et al. 2017)

In this chapter, we address the lack of (1) theory formulating a model of computer advice utilisation, and (2) theory considering advice-taking on behalf of organisations. To achieve this, we draw on theories within the areas of human-to-human advice acceptance and inter-organisational collaborations partner selection.

The academic literature on human-to-human advice utilisation hosts the "Judge Advisor Systems" (JAS) body of research (Bonaccio and Dalal 2006; Sniezek and Buckley 1995). JAS studies decision-making situations where the advice may influence the final decision (Sniezek and Van Swol 2001), differentiating between the "judge" (the decision-maker, recipient of the advice), and the "advisor" (the advice-giver) (Bonaccio and Dalal 2006). This differentiation contrasts with other decision-making situations such as group decision making, where the roles are not differentiated and the participants can be both advisors and judges (Bonaccio and Dalal 2006). In a JAS, one member is solely responsible for making the final decision supported by the input of the advisor or advisors (Bonaccio and Dalal 2006; Sniezek and Buckley 1995).

We use JAS since it fits well our research scenario, where an individual (the judge) is deciding on behalf of an organisation with input from an advisor (the computerised advisor). We, therefore, conceptualise our research using the terms of "judge" and "advisor" from the JAS.

5.3 Research Method

This theory development work emerged out of a 36-month partnership with manufacturing practitioners from a Welsh automotive cluster and a German aerospace cluster. The partnership took place within the Decentralised Agile Coordination Across Supply Chains (DIGICOR)[44] EU-funded research project. DIGICOR developed a technology platform to support the creation and operation of manufacturing collaborative networks. The development included a computerised advisor to support the business partner selection process and DIGICOR provided the context to support practice-inspired research; this, through inquiring about the requirements and problems faced by manufacturing industries collaborating through a technological platform.

The interest of the participating organisations lies in seeking for the alignment of their businesses with the emerging industrial paradigms, particularly the Industry 4.0, and DIGICOR offered an opportunity to address the need of developing digital solutions that would support the innovation and updated services level to fulfil the demands of the industry (Dalmarco and Barros 2018; DIGICOR 2016; Heng 2014; Kannan et al. 2017).

We use Action Design Research (ADR) (Sein et al. 2011) to support the organisation's aim of developing such digital solutions. Through this ADR intervention, we developed our theory of computer advice utilisation. ADR enables us to integrate the development of a computerised advisor and our theorising process within its iterations. ADR is recognised as suitable when there is access to practitioners (as in our case) and considered to encourage both research rigour and practitioners interaction with such research (Sein et al. 2011). ADR is structured in four iterative stages (Sein et al. 2011): Stage 1: Problem formulation, Stage 2: Building-intervention-evaluation *(BIE)*, Stage 3: Reflection and learning, and Stage 4: Formalisation of learning.

[44] https://www.digicor-project.eu/

In Stage 1 of ADR (Sein et al. 2011), we liaise with the involved practitioners to gather such requirements and conceptualise the problem to address within our research. For this, we look at two of the DIGICOR use cases, involving the aviation domain, and the automotive domain, respectively. We also develop a gap analysis of existing collaborative platforms in the manufacturing domain (see (Cisneros-Cabrera et al. 2017) presented in Chapter 3 of this thesis). From these initial activities, we identify that, within a manufacturing collaboration, one key aspect is the process of inter-organisational partner selection (Beckett and Jones 2012; Camarinha-Matos et al. 2009; Lau and Wong 2001; Mesquita et al. 2017; Polyantchikov et al. 2017). We also capture the requirements to support such process and conceptualise the need of a computerised advisor supporting inter-organisational partner selection; our problem-inspired research is set to understand what makes end-users follow such advice.

On the theoretical realm informing the research, we review the literature from inter-organisational partner selection to understand the phenomena and identify the factors relevant in the context of this domain. We also review the literature from computer advice utilisation to understand the background of our research. Further, we use the *Judge Advisor System (JAS)* (Bonaccio and Dalal 2006; Sniezek and Buckley 1995) to support the structuring of our problem in a system where the computer advisor is the "advisor", and the person utilising the advice is the "judge".

We also use the *Expectancy-Value Theory (EVT)* (Edwards 1954; Fishbein 1963; Fishbein and Ajzen 1977) to support the formalisation of our theory propositions and model the relationships among the identified factors. The EVT informs how to model a behaviour (e.g. follow the computer-generated advice), motivated by beliefs (expectancy) and evaluations (value) (Fishbein and Ajzen 1977). The EVT theory can be phrased as "the strength of the expectancy (beliefs) and the value (evaluations) attributed to the outcome will determine the strength of the tendency to act" (Bradley 2012). We support the modelling and structuring of our identified factors following the EVT understanding of behaviour.

In Stage 2 of ADR, and following the ADR principles of reciprocal shaping and mutually influential roles (Sein et al. 2011), we develop a series of data collection interventions with the practitioners. These interventions explore the computerised advisor concerning the inter-organisational partner selection and include workshops, a laddering interview study (Reynolds 1988), and questionnaires. Chapter 2 presents the details of these activities.

The iterative nature of ADR enables us to evaluate the data collected in light of the theoretical influencing realm using a pattern matching process (Sinkovics 2018), and the outcomes of the pattern matching inform the work in the parallel Stage 3 of ADR. In Stage 3, we conceptualise our theory propositions at the time that the computerised advisor was also updated, this, progressively and parallel to Stages 1 and 2.

Finally, in Stage 4, we formalise our theory informed by the EVT to structure and model the relationships among the identified factors of our CAU theory. We also empirically assess our propositions through a Bayesian Network (BN) (Holmes and Jain 2008; Korb and Nicholson 2010; Tosun et al. 2017) simulation which builds upon the outcomes of the previous stages to support the BN validity guidelines (see (Pitchforth and Mengersen 2013)).

A Bayesian Network (BN) enables us testing the predictive power of our theory (Charniak 1991). BNs are popularly used to model complex systems, usually in scenarios that lack data (Pitchforth and Mengersen 2013), in contrast to scenarios that can draw conclusions based on existing corresponding datasets, e.g. historical data of a phenomenon. Methods related to models of factors include the Structured Equations Modelling (SEM) (Hoyle 2012; Maruyama 1998), however, we do not use SEM given that its purpose does not fit ours; SEM is used to measure dependencies between factors and output variables in terms of correlations (Hoyle 2012; Maruyama 1998), whereas BNs enable the probability of an event occurrence (i.e. in this research, a person utilising computer-generated advice) given the probability of preceding events (i.e. the calculated levels of the advice utilisation factors) (Holmes and Jain 2008; Niedermayer 2008).

BNs consist of a directed acyclic graph (DAG) formed by variables represented in nodes (Pollino et al. 2007) where each node has a set of states (e.g. true or false, or low, medium, and high), for our research and in the absence of datasets regarding the states of our interest, we utilised expert elicitation to inform the called "prior probabilities" (Pitchforth and Mengersen 2013; Pollino et al. 2007), we then validated the predictive validity of our BN through a sensitivity analysis (Pitchforth and Mengersen 2013) and an assessment of the expected results from our CAU theory, compared with the obtained results from the BN.

Figure 5.1 depicts our process within the four stages of ADR (Sein et al. 2011) as described in this section, and Table 5.2 lists a summary of the mentioned activities within each ADR stage.

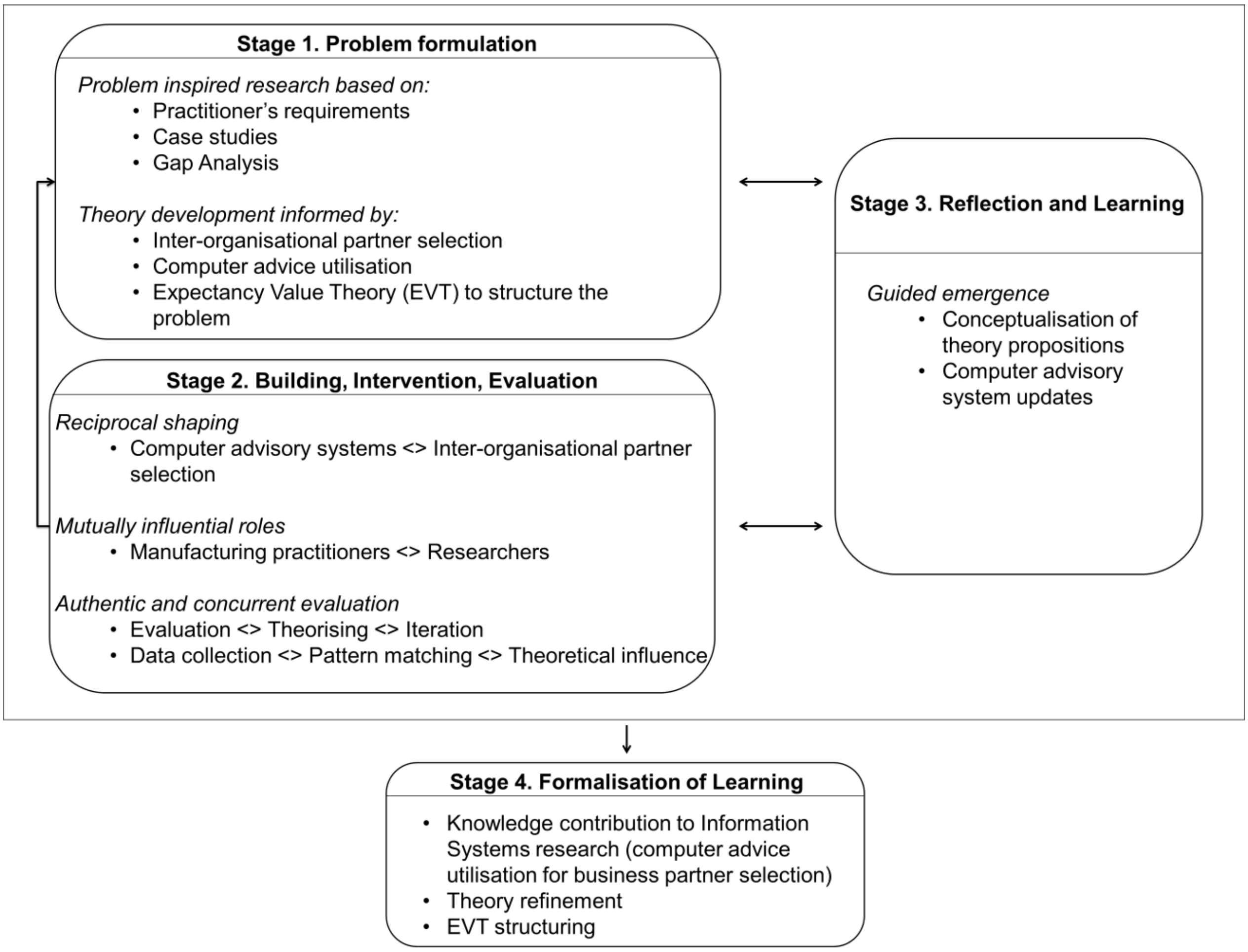

Figure 5.1: ADR Stages and Principles as applied in the theory development for the Computer Advice Utilisation theory. Adapted from (Sein et al. 2011)

Table 5.2: *Summary of activities carried out in the theory development for the CAU theory*

Description	Objective	Date and Stakeholders
ADR Stage 1: Problem formulation		
Literature review: inter-organisational partner selection and advice acceptance	Understand the extant literature and influence our research through existing theory	February – March 2017 and iteratively across the research (Stakeholders not required)
Survey and gap analysis: assessment of extant manufacturing collaborative platforms	Gain a general overview of the state-of-the-art functionalities available and required in manufacturing in the supply chain collaborative platforms	April 2017 (Stakeholders not required)
Interview: discussion of the findings of the Survey and Gap Analysis	Gain insights and initial practitioners’ perspectives on the use of a computerised advisor	June 2017. Welsh Automotive Cluster (2 people)
ADR Stage 2: Building, Intervention, Evaluation		
Workshop: initial concept of a computerised advisor: Mock-ups	Gather initial requirements to shape a computerised advisor and start exploring the advice utilisation factors	October 2017. European Aerospace corporation and European Union Project members (4 people)
Feedback session: initial demo of a computerised advisor	Obtain initial comments regarding the idea of the use of a computerised advisor	October 2017. German Aviation Cluster (5 people)

Laddering interview: first version of the computerised advisor (live and running)	Understand insights of what would make end-users follow computer-generated advice to shape the design further	April 2019. Expo Air show (Germany) (25 people)
Paper-based questionnaire: updated version of the of a computerised advisor	Inquiry about the perceived usability and desired functionalities of a computerised advisor	June 2019. Paris Air Show (France) (36 people)
Task-based questionnaire and paper-based questionnaire: updated version of the of a computerised advisor	Further explore the insights obtained in the laddering interviews and analyse if such results apply as well with other practitioners and domains	June 2019. German aviation cluster (5 people) & Oct 2019, Welsh automotive cluster (18 people)
ADR Stage 3: Reflection and learning		
Pattern matching: conceptualisation of theory propositions	Compare the theoretical (literature review, gap analysis, theory influence) and empirical (workshops, interviews, questionnaires) patterns from the data collected for theorising	Iteratively across the duration of the project (Stakeholders not required)
ADR Stage 4: Formalisation of learning		
EVT structuring: theory refinement	Structure the theory propositions guided by an appropriate theory	November 2019 – March 2020 (Stakeholders not required)
Vignette online survey: Bayesian simulation	Test the predictive power of our theory and refine the propositions	December 2019 – April 2020. Manufacturing practitioners (Online) (14 people)

5.4 Computer Advice Utilisation for Business Partner Selection

This subsection presents the CAU theory and the rationale for its proposal. These first paragraphs present a summary of the theory-building process, followed by a detailed account of it. The CAU theory proposes four core factors that intervene in the dynamics of end-users utilising computer-generated advice when selecting business partners: (a) trust in the advice, (b) potential benefits expectation, (c) transparency of the advising process, and (c) the quality of the information presented in the advice.

Our theory-building process follows a pattern-matching approach, and moves from theoretical sources to empirical studies and then back to theoretical sources. This dynamic allows us to deepen into some factors identified during Stage 3 of ADR (i.e. Reflection and learning) by pattern matching the empirical and theoretical realms (Sinkovics 2018), i.e. a comparison of what is known and expected from theory knowledge, and what is observed from empirical data (Sinkovics 2018). Indeed, factors like "trust in suggested partner" were identified as quite important during the empirical study; therefore, we needed to go into the domain of inter-organisational collaboration to explore these factors in depth. This iterative process enabled us to derive a model of these factors and their interactions. Figure 5.2 depicts a general overview of our pattern matching approach, and Figure 5.3 details the process followed.

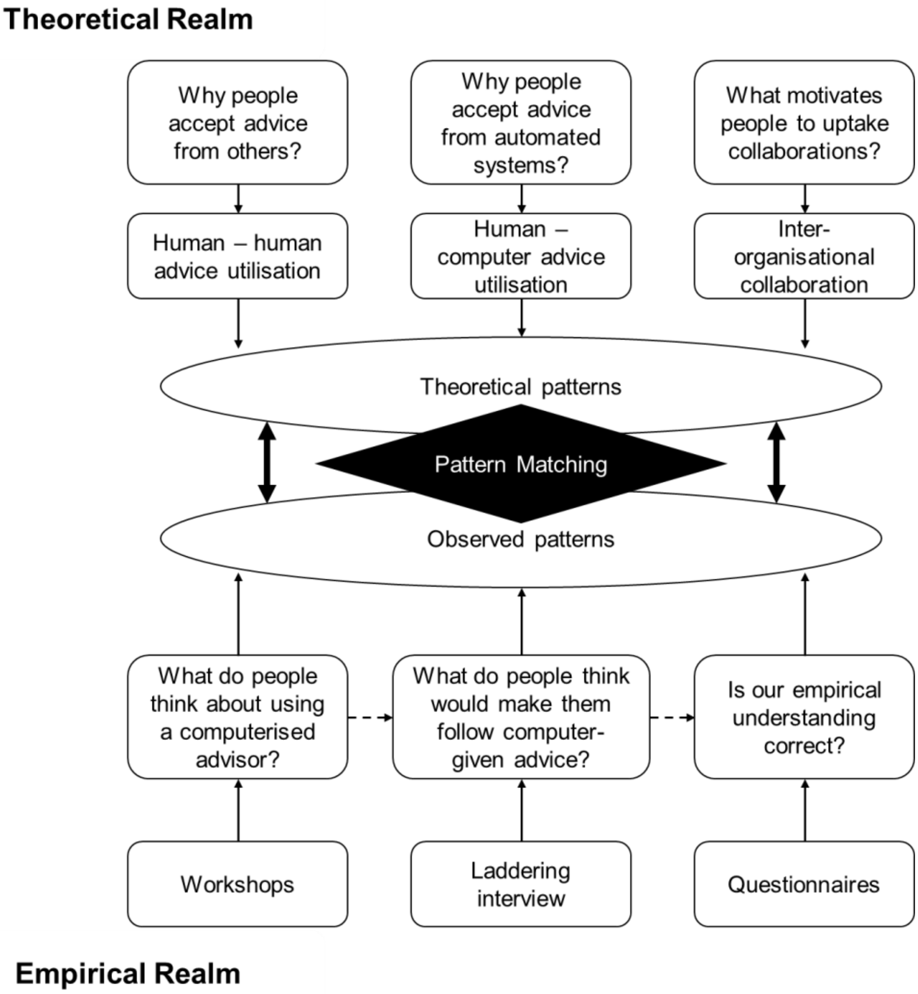

Figure 5.2: Conceptualisation of the theory-building process following a pattern-matching approach. Diagram adapted from (Sinkovics 2018)

To identify the core factors of our CAU theory, we then first analyse the literature on human-to-human advice utilisation to understand the factors influencing people to follow advice from other people (Part A in Figure 5.3). Then, we contrast our findings with the literature of human-computer advice utilisation and select those factors that apply to such scenario; this is reflected in Part B in Figure 5.3. We then collect and analyse our empirical data matching the theoretical results (Part C in Figure 5.3). Finally, we explore literature from inter-organisational collaboration and match the relevant factors with our built-up knowledge (Part D in Figure 5.3).

In the following subsections, we expand the understanding of the factors identified within each realm of enquiry and present how these contribute to the formulation of the CAU theory.

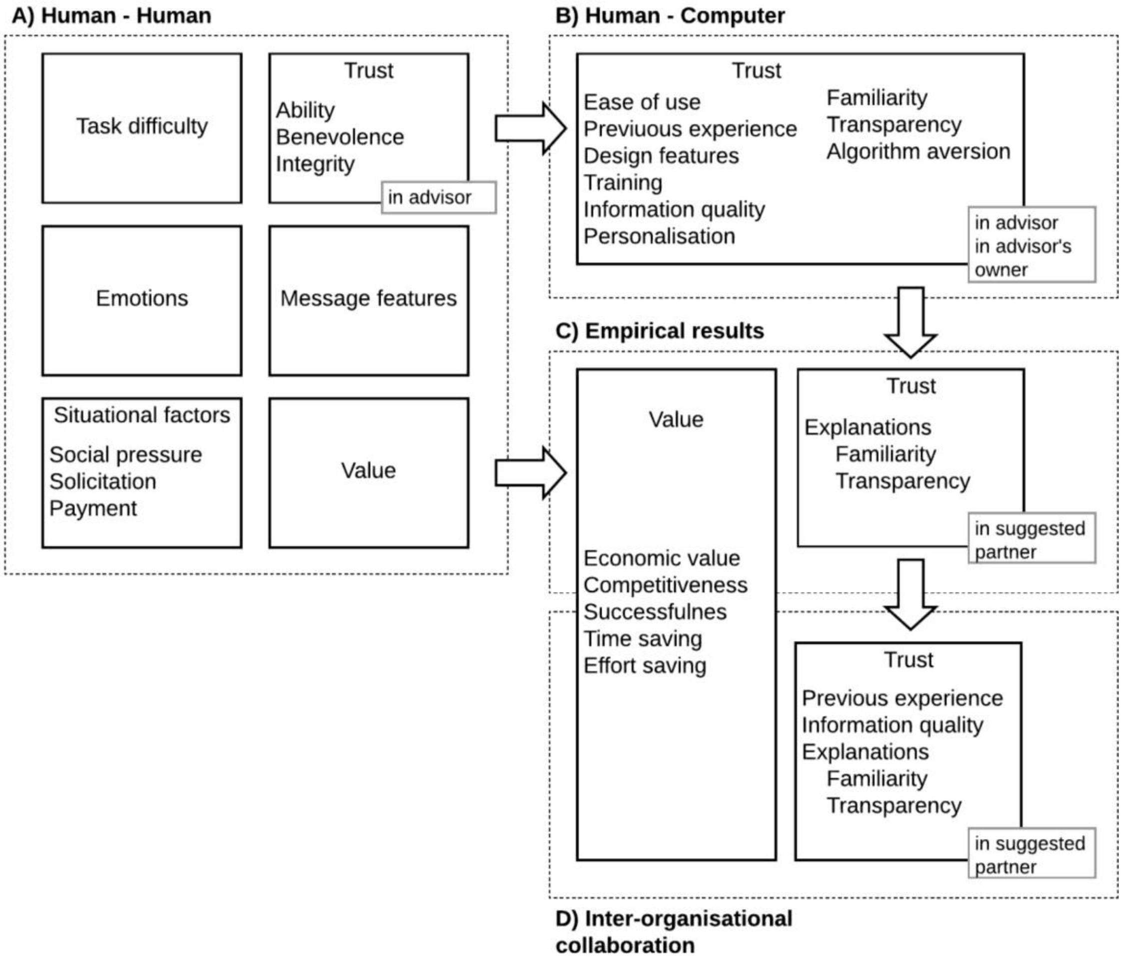

Figure 5.3: Theorising process for the computer advice utilisation theory representing the built-up knowledge from the different areas explored

5.4.1 Human-Advice Utilisation

Trust. In the literature, we find that trust is one of the most important influencers of advice utilisation (Green et al. 2001). Recipients of advice (i.e. judges) are taking a risk dependent on the advice, and trust links risk and uncertainty (Sniezek and Van Swol 2001). The importance of trust for advice utilisation increases for value-judgement tasks, i.e. "tasks that do not have a demonstrably correct answer" (Handgraaf et al. 2012; van Swol 2011), such as the task of selecting a partner for inter-organisational collaboration.

From the perspective of affect and cognition-based trust (McAllister 1995), trust can be conceptualised as comprising the dimensions of "ability", "integrity" and "benevolence" (Ba and Pavlou 2002; Pavlou et al. 2007; Pavlou and Fygenson 2006; Xiao and Benbasat 2007). The *ability* dimension indicates that trust-building is more likely to be developed when (a) the advisor is perceived as confident (Sniezek and Van Swol 2001; van Swol and Sniezek 2005), (b) the advisor has provided successful advice (van Swol and Sniezek 2005), and (c) the advisor is perceived as an expert (Dalal and Bonaccio 2010). *Benevolence* and *integrity* dimensions stipulate that trust depends on the judge perceiving the advisor as credible (van Swol and Sniezek 2005), with honest intentions to help the judge (MacGeorge and Van Swol 2018); and with low uncertainty of their motivations (MacGeorge and Van Swol 2018).

Value. Business advice is better accepted when the advisor manages to show the value of his/her advice in such a way that when the value of an advice is demonstrated and understood by the judge, the likelihood of advice utilisation increases (MacGeorge and Van Swol 2018).

Emotions. Researchers have explored the influence of emotions in human-to-human advice utilisation, finding that judges that feel angry are less likely to utilise advice, whilst gratitude increases advice utilisation (Gino and Schweitzer 2008). Positive self-directed emotions (e.g. high self-confidence) decrease advice utilisation (Yaniv and Choshen-Hillel 2012; Yaniv and Kleinberger 2000), whilst negative self-directed emotions increase advice utilisation. The negative emotions seem to increase the need to share the responsibility of a decision (MacGeorge and Van Swol 2018), and also decrease judge's self-esteem regarding expertise and thus increase the reliance on the advisor as the expert (Gino et al. 2012; Harvey and Fischer 1997).

Situational Factors. Advice utilisation is known to be high in certain situations, *e.g.* under social pressure (Cialdini 2006; Harvey and Fischer 1997), when the task is difficult (Gino and Moore 2007; Schrah et al. 2006), and when the advice is solicited or paid for (Gino 2008).

Message Features. The advice response theory (ART) (Bo Feng and MacGeorge 2010; MacGeorge et al. 2016) claims that advice message features (including message content and message politeness) have more influence on advice outcomes than characteristics of the advisor (Bo Feng and MacGeorge 2010) and that the influence of advisor characteristics is largely mediated through perceptions of message features (Bo Feng and MacGeorge 2010).

The "human-to-human" advice utilisation literature shapes our initial understanding of advice utilisation factors shown in Section A in Figure 5.3.

5.4.2 Human-Computer Advice Utilisation

Trust. In the research area of human-computer interaction, *trust* in computers is deemed the main factor influencing computer-generated advice utilisation (MacGeorge and Van Swol 2018). Several efforts formulate models of trust in advisory systems (van Dongen and van Maanen 2013; Hoff and Bashir 2015; Hoffman et al. 2013; Logg et al. 2019; Madhavan and Wiegmann 2007; Seong and Bisantz 2000; Wærn and Ramberg 1996). Studies propose that trust in advisory systems depends on the ease of use (Davis 1989, 1993), previous experience working with a system, system design features, training on the use of the system (Hoff and Bashir 2015), information quality (Bonsall 1992; Gasparic and Ricci 2015; Han et al. 2015; Jin et al. 2017), personalisation possibilities and familiarity (Komiak and Benbasat 2006), and the system's transparency or feedback means (Ba and Pavlou 2002; Gregor and Benbasat 1999). Transparency influences the perceived reliability of the computerised advisor and allows the users to evaluate the advice (Hoff and Bashir 2015).

Trust is often seen as an antecedent of technology usage, including using recommendation systems (Dietvorst et al. 2015; Hoff and Bashir 2015; Önkal et al. 2009; Prahl and Van Swol 2017). That research is focused on the usage of such systems and not on utilising their advice. Trust in advisory systems is seen as a proxy for trust in the owner or designer of such system (Hoff and Bashir 2015; Parasuraman and Riley 1997; van Swol 2011). This links to the credibility factor in computer advice utilisation (Chow et al. 2015).

Computer and algorithmic advice is often considered to be of higher quality than human judgement and is becoming more common for highly consequential decisions (Logg et al. 2019). Nevertheless, judges are less likely to use it (Prahl and Van Swol 2017); this is explained by "algorithm aversion" (Dietvorst et al. 2015; Prahl and Van Swol 2017), indicating that people tend to lose confidence in an algorithm faster than in a human (Dietvorst et al. 2015) because they expect computers to be perfect (Dzindolet et al. 2002; Hoff and Bashir 2015; Prahl and Van Swol 2017).

The literature on computerised advice acceptance confirms the key position of trust found in the human-to-human advice field. It also brings forth a number of trust antecedents; trust in the owner/developer of the computerised advisor, and the transparency of the advisor operationalised as explanation functionalities.

In Section B in Figure 5.3, we depict the build-up of our understanding of advice utilisation, based on extending the concept of trust through the findings from the computer advice utilisation literature.

5.4.3 Empirical Results

Our theory-building process took place in parallel with several ADR iterations, and we used the interventions and interactions of the BIE stage to gather empirical evidence. This empirical evidence concerns the influencers of our end-users to accept advice from a computer system when selecting a business partner. At one of these stages, using a laddering technique (Reynolds 1988), we interviewed 25 manufacturing professionals at the Hamburg Aircraft Interiors Expo 2019, April 2 - 4, 2019 (see Chapter 2). Manufacturing aircraft interiors is a key element of aircraft manufacturing, with more flexible supply chains to respond to new materials and trends. All participants were involved in forming collaborative supply chains since this is the core aim of the event.

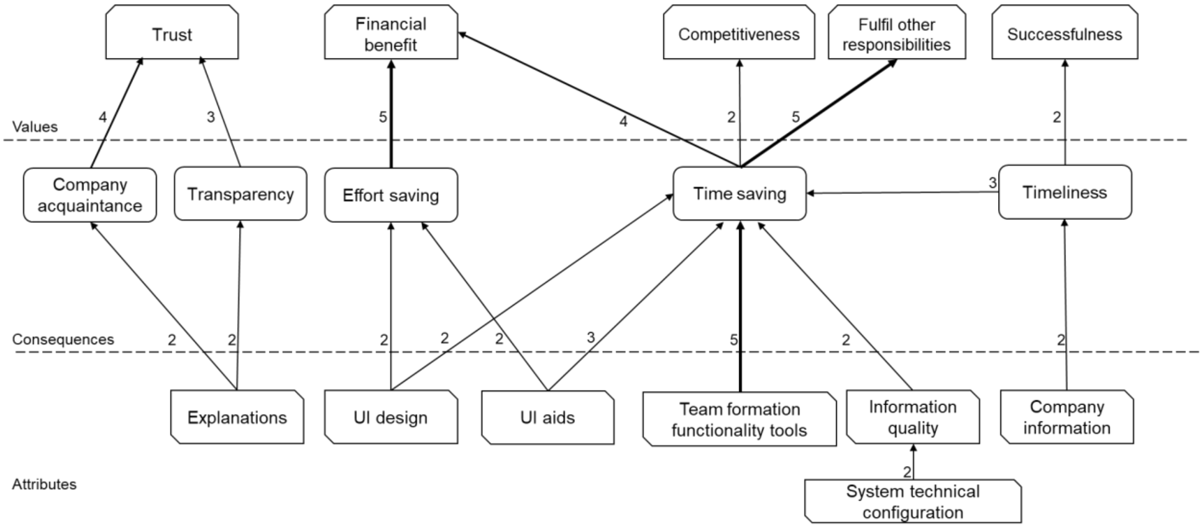

Figure 5.4: HVM of end-users following advice from a computer to select a business partner. The numbers indicate the count for repeated Attribute – Consequence – Value "ladder" links found in the interviews

From the 25 participants, 20 interviews were deemed valid based on completeness criteria for the data analysis (i.e. at least one complete chain of attribute-value-mean known as "ladder" within the laddering interview technique) (Phillips and Reynolds 2009). From the 20 valid respondents, there were 2 females (10%) and 18 male respondents (90%) which is a sample consistent with the known female minority of the aerospace industry (Halleran 2019). 40% of our respondents were 31-40 years old, followed by 30% in the 51–60 group, and 20% in the 41 – 50 group. We had one respondent younger than 30 and one older than 60 years. The respondent's domain of expertise was indicated as Aerospace for 75% of the answers and one each in "Industrial", "Research & Consulting", and "Logistics". From those, 20% of the participants are CEOs, 15% Logistics Professionals, 10% Managing Directors, 10% Sales Managers, and the rest were an Aviation Journalist, a Cabin Project Manager, a Chair, a Corporate Manager, a Head of Design, an Operations Director, a Product Manager, a Project Manager and a Research professional. 35% have more than 10 years of experience in the forming collaborative teams. 45% declared to have no experience using computerised systems, and 20% declared having more than 10 years of experience using them. More details and insight of this study can be found in (Cisneros-Cabrera et al. 2020).

Using the laddering interview to obtain the Hierarchical Value Map (HVM) (Reynolds 1988) presented in Figure 5.4, we observe the motivators of judges to follow advice (Figure 5.4, values level), the attributes within the computerised advisor that judges consider can lead them to meet the desired values (Figure 5.4, attributes level), and the meaning judges link to the presence of a given attribute (Figure 5.4, consequences level).

For example, to analyse what seems to make a judge follow an advice for partner selection, we look at the value of trust in Figure 5.4. Firstly, we observe judges look for trusting the partner being recommended, secondly, for them to achieve such trust, explanations appear useful, and thirdly, explanations for judges represent transparency, which for them, at the same time, support trust-building. Following the analysis, we obtain that trust in the partner, the expectation of obtaining different benefits including financial benefits, benefits of competitiveness, time-saving and successfulness increased rates are what drives judges to follow the computer-generated advice. From the HVM, we also gain an understanding of what functionalities could lead to increase the trust and build a sense of benefits expectation.

At a consequent BIE stage, we explored further the findings from the interviews with a task-based questionnaire (see Chapter 2, Appendix A.6), obtaining 23 responses. In the questionnaire, 70% of the respondents agree that a computerised advisor for inter-collaboration partner selection enables them to develop a sense of trust in the partners (Table 5.3, question 1a). With this response, we support that it is feasible to obtain trust through such a system. Further, we asked about the benefits that they think could be obtained through such advisory system; 70% agree that benefits of success could be obtained, 61% agree that financial benefits can be obtained, 78% agree that the competitiveness of the company can be supported, and 77% agree that time-saving is also a benefit that can be obtained (Table 5.3, questions 1b – 1e respectively). This understanding is relevant to confirm that the concepts that emerged from the HVM are existent components in a system that advises on business partner selection.

The questionnaire explored the impact of explanations in building trust and transparency, with 87% of participants consider trust in the advice given would increase the likelihood for them to utilise it (Table 5.3, question 2a). Results also indicate that judges would follow the system's advice if they believe that by doing so, they would obtain benefits of the economic type (78%), time reduction (83%), competitiveness (83%), or increased likelihood of successfulness (96%) (Table 5.3, questions 3a – 3c respectively).

Table 5.3: *Summary of the results found in the task-based questionnaire. Key: strongly agree (SA), agree (A), neither agree nor disagree (N), disagree (D), strongly disagree (SD)*

	SA	A	N	D	SD	Agreement percentage (SA + A)
1. Using the system would help me to achieve the following:						
a. Trusting the proposed partners	2	14	4	3	0	(16/23) 70%
b. Being successful in the tender	3	13	6	0	1	(16/23) 70%
c. Obtaining financial benefits	2	12	9	0	0	(14/23) 61%
d. Increasing competitiveness of the company	4	14	4	1	0	(18/23) 78%
e. Enabling the fulfilment of other responsibilities (e.g. by saving time in the team formation process)	6	11	5	0	0	(17/22) 77%
2. I will follow the system's advice if …						
a. I trust the partners being proposed	9	11	1	2	0	(20/23) 87%
3. I will follow the system's advice if I think that by doing so…						
a. I can obtain financial benefits	8	10	1	4	0	(18/23) 78%
b. I will free time to fulfil other work tasks	7	12	4	0	0	(19/23) 83%
c. our competitiveness will be increased	8	11	3	1	0	(19/23) 83%
d. the likelihood of a successful tender increases	13	9	1	0	0	(22/23) 96%
4. Arguments explaining why a given team is proposed would…						
a. give me a sense of transparency of the process	9	11	3	0	0	(20/23) 87%
b. increase my trust in the companies being proposed	9	11	3	0	0	(20/23) 87%
5. For the system to save my time and effort in forming a collaborative team, it needs to…						
a. Ensure the quality of the information presented	18	5	0	0	0	(23/23) 100%

We also explore the roles of explanations in building trust and transparency based on the previous understanding of the relevance for advice utilisation and the insights gathered from the laddering interviews. We find that 87% agree that explanations of the advising process would give them a sense of transparency (Table 5.3, question 4a), and 87% agree that it would help increase the trust in the advice given (i.e. the companies being proposed) (Table 5.3, question 4b). We ask about the concept of the quality of the advice, given that we found a few mentions in the HVM, and it appears relevant from the theoretical realm of advice utilisation. In the task-based questionnaire, 100% agreed that the quality of the information would contribute to the expectation of obtaining benefits if the advice is followed (Table 5.3, question 5a). Within the empirical results, information quality does not appear directly linked to trust.

From these interviews, we observe that (a) our "judges" need to trust the partners being recommended by the system; (b) such trust can be supported by explanations; and (c) explanations provide transparency, supporting trust-building. The analysis of data supports the following antecedents of utilising computer-generated advice: trust in the partner, the expectation of obtaining (financial) benefits, competitiveness, time-saving, and increased success rate.

Our empirical findings help us update our theory-derived understanding of factors impacting the utilisation of computer-generated advice for inter-collaboration partner selection, and this is presented in Section C in Figure 5.3. This includes a new interpretation of trust as trusting the suggested partner, rather than the advisor, and extending the concept of value through the findings from our empirical results.

5.4.4 Inter-organisational Collaboration

To refine our understanding of advice utilisation in the context of our research, we explore the business domain to understand if there is another influential concept involved in the uptake of collaborations and if some of the findings from our empirical results matched this domain. We focused on the context of business domains, differentiating from research including advice that suggests which movie to watch and advice suggesting which business partner to form a team. The latter requires reliance on the advice of others in the pursuit of direct economic value (e.g. immediate profit), or subjective economic value (e.g. building business alliances) (MacGeorge and Van Swol 2018).

Value. In business domains, computerised advice often targets ill-defined and complex, or "wicked", problems, usually impacting multiple stakeholders (Bonner and Cadman 2014; Calcagno and Monticone 2015; Garfagnini et al. 2014; MacGeorge and Van Swol 2018). We find, not surprisingly, that the value of showing the benefits of following an advice is one of the main factors to accept it within the business domain (Bonner et al. 2018; MacGeorge and Van Swol 2018). These findings are aligned to the knowledge that judges increase the tendency to utilise advice if they believe that the advisor has intentions to help them succeed (Schrah et al. 2006), and it is also aligned to the trust-building dimension of benevolence (Ba and Pavlou 2002; Pavlou et al. 2007; Pavlou and Fygenson 2006; Xiao and Benbasat 2007)

Trust. As exposed in the background section of this paper, trust is also highly relevant for the decision-making of partner selection, and it acts as an enabler for the inter-organisational collaboration (Kazantsev et al. 2018b). Among the trust builders in this context, we find that knowledge of the other company increases both the willingness of collaborating and the trust in the companies (Nooteboom 2003; Whitford and Zeitlin 2004). The information quality is thus important and should be a key feature of our computerised advisor. Information quality also provides a mean to decide on the grounds of the partner selection criteria, which differ from company to company (Whitford and Zeitlin 2004).

Section D of Figure 5.3 depicts the work done at this final stage of understanding the factors for computer-generated advice utilisation, consolidating our findings from the previous stages with the relevant work of inter-organisational collaboration.

5.4.5 CAU Propositions

As seen in the previous sections, Trust and Value emerge from our theorising process as the main concepts relevant across the explored aspects of computer advice utilisation for business partner selection; Figure 5.5 presents their constituents.

We group the trust-builders of *previous experience* and *explanations* in a concept of "*transparency of the advising process*". To capture the variety of demonstrable value to obtain after utilising computer-generated advice, we group *successfulness expectancy, competitiveness expectancy, demonstrability* and *effort expectancy* into a concept of "*expectation of potential benefits*". We thus obtain four concepts influencing advice utilisation: (1) Trust; two trust-builders named (2) Transparency of the advising process, and (3) Quality of the information from the advice; and (4) Potential benefits expectation, integrating the elements of Value.

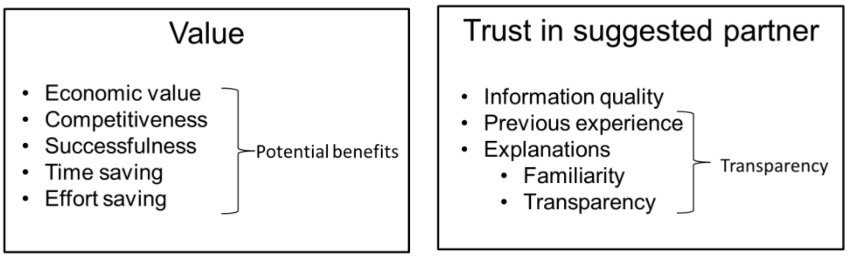

Figure 5.5: Computer Advice Utilisation theory concepts

Trust in the Suggested Partner. We found our end-users placing importance on trusting the potential partner recommended by the system (i.e. trust in the advice), rather than trusting the advisor. Indeed trust is found in inter-organisational collaboration as a mechanism to control risk (Andersen and Kumar 2006; Campbell et al. 2010; Lambert et al. 1996; Li and Rowley 2002; Wilkinson et al. 2005) and in literature of both advice utilisation given by a computer or a human (van Dongen and van Maanen 2013; Green et al. 2001; Hoff and Bashir 2015; Hoffman et al. 2013; Logg et al. 2019; Madhavan and Wiegmann 2007; Seong and Bisantz 2000; Wærn and Ramberg 1996). Our empirical results also focus on trust, with comments such as "I want to know about the products and services of a company because I want to develop trust in their capabilities and experience", and "It is important for me that the system gives me information that allows me to know the intention of the company so I can trust the company".

These comments confirm trust as a key driver for advice utilisation; however, this is a trust in the advice not in the system providing the advice (see Section 1.1.3). This reflects the nature of the business collaboration domain. We therefore propose:

> Proposition 1a: *If the judge trusts the advice, then the likelihood of utilising the advice will increase.*

Potential Benefits Expectation. We learned that people are motivated to utilise an advice given if such decision would offer them a benefit, compared to not utilising the advice. This situation is known as demonstrability in the advice utilisation domain (MacGeorge and Van Swol 2018), and as a general rule that drives the business domain where particularly benefits of the economic type are expected if reliance is to be encouraged (Bonner and Cadman 2014; Calcagno and Monticone 2015; Garfagnini et al. 2014; MacGeorge and Van Swol 2018). In our research, practitioners mentioned they would follow the advice if "it allows me to have more successful projects because we are making money out of it and we want to make money", and "if the system would allow me to reduce useless work, at the end of the day, we are working for money, and the company also needs to earn money, and if you are more efficient, you earn more money". We observed that the theoretical realm matched with our empirical data in terms of the expected benefits as a factor. We conceptualise benefits to include the reduction in effort, costs, time and the increasing likelihood of support to the competitiveness and successfulness for the companies, and we propose:

> Proposition 1b: *If the judge has high expectations of obtaining benefits from utilising the advice, then the likelihood of utilising the advice will increase.*

Following the EVT (Edwards 1954; Fishbein 1963; Fishbein and Ajzen 1977), and based on the understanding obtained, we position trust in the advice as a value assigned to the advice itself (Inglehart et al. 1998), and the expectation of obtaining benefits as a belief (the expectancy in the model) (Fishbein 1963), in alignment to the EVT model. We, therefore, propose:

> Proposition 1: *If the judge trusts the advice and has high expectations of obtaining benefits from utilising the advice, then the likelihood of utilising the advice will increase.*

Transparency of the Process. Models of trust related to technology mention three dimensions of trust. Each dimension refers to different reasons why trust is built. The ability dimension, also known as the competence-based trust, refers to the "fit-for-purpose" and expertise level (Pavlou et al. 2007; Pavlou and Fygenson 2006); the integrity dimension forms the evaluation of ethics level and honesty (Pavlou et al. 2007; Pavlou and Fygenson 2006); and the benevolence level is related to a recognition of a non-opportunistic behaviour on the part that needs to be trusted (Pavlou et al. 2007; Pavlou and Fygenson 2006). These dimensions are also known to be supported by the use of explanatory functionalities in software modules and feedback facilities (Ba and Pavlou 2002; Gregor and Benbasat 1999). The participants in our study also referred to the transparency as a relevant driver to the advice utilisation through trust, for example: "I think a user who can have a chance to get more information will develop more trust in the system because all information is open and no information is behind the scenes", and "If transparency is not given, I don't know if the proposed company is capable of doing what I need. Trust is the most important, and transparency...". Another comment mentioned the importance of explaining the recommendation process as "I need to know if the companies are being perfectly assessed. Otherwise, the recommendation will never work". In our propositions, we refer to the process' transparency to the open disclosure of the procedures of how the system achieved the given results. This openness includes presenting the details of the companies being proposed to support the benevolence and integrity dimensions of trust; this, providing the required information to allow users make a judgment on those dimensions. We, therefore, propose:

> Proposition 2a: *If the advising process is transparent, then the judge will more likely trust the advice.*

Information Quality. The importance of the transparency is linked to the information presented, and therefore the quality of it becomes relevant, as it is known that information quality has an impact on decision making quality (Gao et al. 2012; Raghunathan 1999). Previous research on computer-generated advice utilisation has found the quality of both the system and the advice is related to users behaviour of following the advice (Bonsall 1992; Gasparic and Ricci 2015; Jin et al. 2017). However, these are investigated in different domain areas and in contexts of advice different to business advice, as presented in the Previous Work section of this chapter. Also, models of trust indicate that information quality supports trust-building (Han et al. 2015). From our study participants, we also found mentions to the quality of information leading to trust in the advice, for example, one participant mentioned that “I would trust the advice if I take for granted that the data inside the system is already verified”. Also, we found that the quality of the information helps to develop an expectancy of possible benefits, such as “if the database [of the system] is correct, you will save a lot of time by defining the teams and defining your possible suppliers and finding the correct supplier for your challenges”. We, therefore, propose:

> Proposition 2b: *If the quality of the information contained in the advice is high, then the judge will more likely trust the advice.*

Because both transparency of the process and information quality were found to influence trust in the advice, we propose:

> Proposition 2: *If the advising process is transparent and the quality of the information contained in the advice is high, then the judge will more likely trust the advice.*

In our propositions, we conceptualise the quality of the data in the dimensions of correctness, completeness and timeliness as discussed earlier. We therefore propose:

> Proposition 3: *If the quality of the information contained in the advice is high, then the judge will more likely increase the level of expectations of obtaining benefits from utilising the advice.*

In general, we observed a stronger match of our empirical findings with the literature in the inter-organisational collaboration, where the criteria that apply in offline selection seem to be the driving factors for users to take advice. We depict a representative model of our CAU propositions in Figure 5.6 which show the theorised relationships among the concepts.

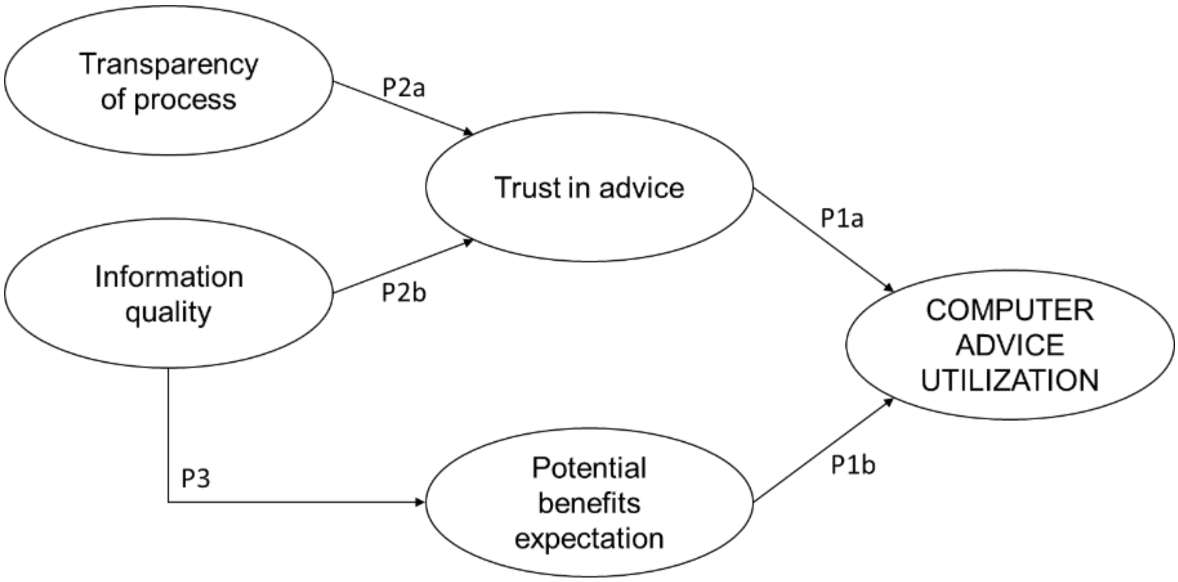

Figure 5.6: Model of the Computer Advice Utilisation Theory

5.5 Simulation

The Bayesian Networks (BNs) represent the likelihood that each node adopts a given state and the causal link between the likelihood of such state and the likelihood of a given outcome as the outcome node (Korb and Nicholson 2010; Niedermayer 2008; Pearl 1988; Pitchforth and Mengersen 2013; Pollino et al. 2007). Internal nodes are dependent on the probabilities of the preceding nodes, and the associated probabilities on the given combinations of states are presented in conditional probability tables (Pitchforth and Mengersen 2013; Pollino et al. 2007). In our study, we utilised the graphical model of the CAU theory (shown in Figure 5.3) as a BN aiming at validating the findings and formalise them in a predictive model.

To implement a BN simulation, we utilised "SamIam[45]" as the software to model our BN (Darwiche et al. 2017). In SamIam, the terminology defines as "root nodes" those with no preceding nodes, "internal nodes" those with preceding nodes, and "leaf" is the outcome node. Firstly, we define the initial probabilities for the root nodes on an expert elicitation asking for the probability of information quality and transparency in the states of low, medium, and high, found in similar computer systems in their experience; we consulted 5 experts in the use of systems and academics of the IS area.

[45] http://reasoning.cs.ucla.edu/samiam/

Secondly, we define a *prior set* of Conditional Probability Tables (CPT) based on the elicited probabilities. Table 5.4 shows the reference key that is used in our CPTs. Table 5.5 shows the initial probabilities for the root nodes defined with expert elicitation. Table 5.6 shows the prior CPT calculated for the internal nodes, and the leaf node calculated based on the elicited probabilities shown in Table 5.5.

In all of the tables presented the notation is as follows: P(X) indicates the probability of event X, and P (X | Y, Z) indicates the probability of event X, given event Y or Z respectively, *e.g.* low trust in the advice (TA) given low transparency (TP) and low information quality (IQ) is defined as P(TA(low) | TP(low), IQ(low)). With these initial CPTs, we model the first BN as our *prior BN*.

Thirdly, we develop an online end-user study to gather the data for the *posterior CPT*. For this, we use an online vignette scenario study aimed at placing the participants in the contextual situations that would allow them to respond accurately (Hughes and Huby 2004). Four scenarios were developed based on the root nodes (see Table 5.4).

Table 5.4: *Key acronyms for the defined probability tables in our BN*

Type	Node	ID
Root	Transparency of the process	TP
Root	Information quality	IQ
Internal	Trust in the advice	TA
Internal	Potential benefits expectation	PB
Leaf	Computer Advice Utilisation	CAU

Table 5.5: *Initial elicited probabilities for transparency, and information quality nodes*

	P(TP)	*P(IQ)*
Low	*0.76*	*0.52*
Medium	*0.18*	*0.30*
High	*0.06*	*0.18*

Table 5.6: *Prior CPTs of TA, PD, and CAU nodes*

	P(TA | TP, IQ)									
	TP	*Low*			*Medium*			*High*		
	IQ	*Low*	*Medium*	*High*	*Low*	*Medium*	*High*	*Low*	*Medium*	*High*
TA	Low	0.82	0.65	0.51	0.74	0.40	0.33	0.46	0.26	0.18
	Medium	0.15	0.24	0.37	0.18	0.35	0.25	0.31	0.34	0.32
	High	0.03	0.11	0.12	0.08	0.25	0.42	0.23	0.40	0.50

	P(PB | IQ)			
	IQ	*Low*	*Medium*	*High*
PB	Low	0.60	0.47	0.15
	Medium	0.35	0.36	0.23
	High	0.05	0.17	0.62

	P(CAU | TA, PB)									
	TA	*Low*			*Medium*			*High*		
	PB	*Low*	*Medium*	*High*	*Low*	*Medium*	*High*	*Low*	*Medium*	*High*
CAU	Low	0.74	0.66	0.59	0.43	0.31	0.27	0.19	0.11	0.07
	Medium	0.24	0.27	0.30	0.37	0.46	0.55	0.45	0.16	0.10
	High	0.02	0.07	0.11	0.20	0.23	0.18	0.36	0.73	0.83

In the study, the participants read a situation in which the levels of the root nodes vary (low, medium, or high), and they select their preference on what state would the participants assign for the intermediate and leaf nodes. The four scenarios were presented to each participant in a random order to address order-effect bias (Schuman and Presser 1996; Serenko and Bontis 2013). Table 5.7 shows one example of such scenario and Figures A.7-7 to A.7-11 in Appendix A.7 show the rest of the scenarios within the study. We selected four scenarios for the study to reduce the time required from the participants.

Table 5.7: *Example of the scenario used in the vignette study*

Scenario presented	Please read the scenario below and in the questions select the option that reflects more closely your opinion given the scenario: You find a tender opportunity suitable for your organisation; however, on a closer inspection, it appears that the requirements cannot be met by your organisation alone. To participate, you will need to find partners to team-up with. You then remember about this new tool which can recommend potential partners for the team. Now, you are logged into the tool and...
Scenario type	Scenario 1: Information quality (high), Transparency of the process (medium)
Scenario detail as presented	You notice the information about the recommended partners is of very high quality, for example, it is updated, accurate and all of the information you require to know is available. Also, there is some, but not detailed information about the process the tool used to come up with the recommendation. Given the circumstances described above, to which level you would...
Options as response	…trust in the recommended partners? (low, medium, high) …expect to obtain benefits by following the recommendations? (low, medium, high) …follow the recommendation given by the tool? (low, medium, high)

The first scenario presents both information quality (IQ) and transparency of the process (TP) as low (Scenario 1: IQ-L, TP-L). The second scenario presents both high IQ and TP (Scenario 2: IQ-H, TP-H). The third and fourth scenarios present a high IQ and a medium level of TP (Scenario 3: IQ-H, TP-M) and vice versa (Scenario 4: IQ-M, TP-H). The decision of which scenarios to select is based on the ordered results of the prior BN (i.e. using the values of the prior CPTs) for the CAU value and the observation of the breaking points (i.e. where the order inverses), as well as our interest in the extreme states (both nodes in low and both nodes in high states). Figure 5.7 presents the ordered computer advice utilisation values form the prior Bayesian Network.

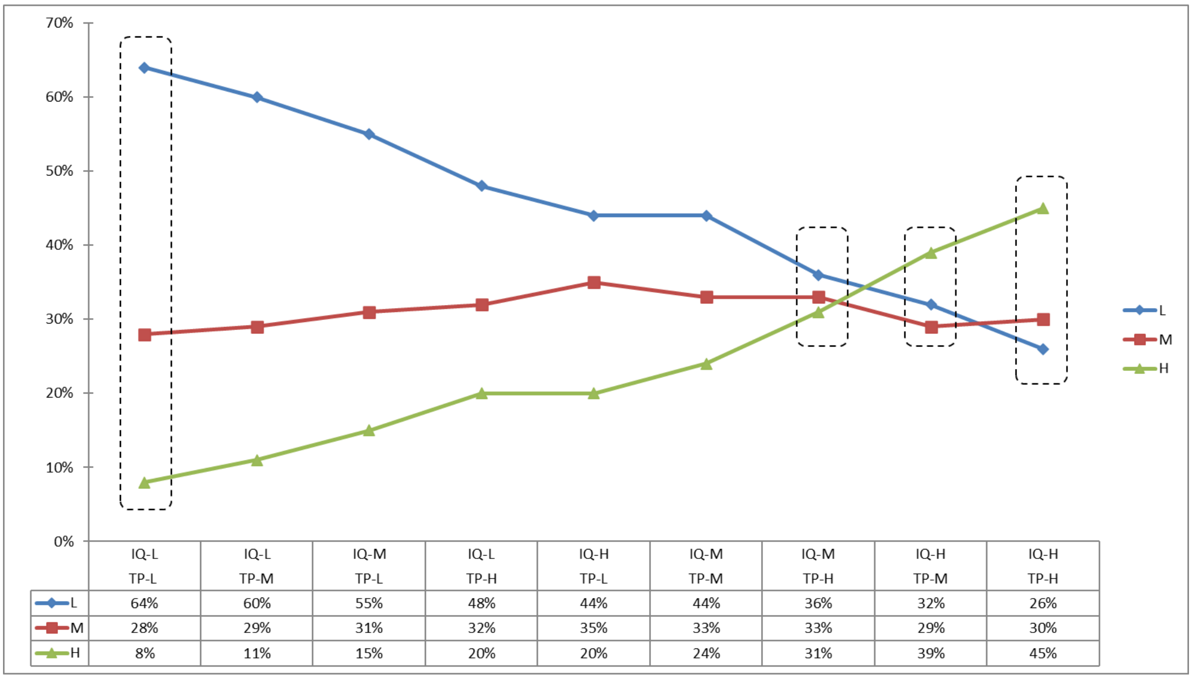

Figure 5.7: Ordered values for the computer advice utilisation (CAU) node, where low (L), medium (M), and high (H) states are represented based on the root nodes of transparency of the process (TP), and information quality (IQ). The selected scenarios are outlined

5.5.1 Results

We obtained 14 responses where 36% of the participants are in the 51-60 age group, 29% in the 31-40, 21% in the 41-50, and 7% each in the 21-30 and 61-70 age groups. From these, 29% are females. The main industries where the participants work vary, with 50% from the aerospace domain, 7% from the automotive domain, and 43% from "other". Among the category of "other", we find: "Service, Systems, Industrial Electronics, Information technologies, Food, and Construction". Among the roles of the respondents, 21% are Project Managers, 14% are CEOs, 14% Directors of Operations, and 7% each are diversified in the positions of managing director, cluster manager, purchasing manager, systems engineer, business developer, safety advisor, and researcher.

Our respondents also indicated their experience in years using computer systems for their jobs, where 71% indicated more than 10 years, 21% between 7 to 10 years, and 7% between 5 and 7 years. The experience in partner selection ranged from 29% with experience of more than 10 years, 1 CEO and 2 Directors of Operations indicating no experience (21%), 21% with experience between 3-5 years, 14% with experience of less than a year, and 7% each with experience between 5-7 years, and 7-10 years. The results are presented in Table 5.8.

Table 5.8: *Results of the scenario-based study. Key: Low (L), Medium (M), and High (H)*

Factor	Trust in the Advice			Potential Benefits			Computer Advice Utilisation		
State	*Low*	*Medium*	*High*	*Low*	*Medium*	*High*	*Low*	*Medium*	*High*
1: IQ-H, TP-M	7%	50%	43%	7%	64%	29%	7%	64%	29%
2: IQ-L, TP-L	86%	14%	0%	93%	7%	0%	79%	21%	0%
3: IQ-H, TP-H	0%	36%	64%	0%	36%	64%	0%	36%	64%
4: IQ-M, TP-H	21%	71%	7%	14%	79%	7%	7%	50%	43%

5.5.2 Validation of Theory Propositions

The results of the study provide support to validate the propositions of our theory. To validate the theorised relationships of the elements from the CAU theory we compare the propositions with the data obtained. For example, Proposition 1a (*If the judge trusts the advice, then the likelihood of utilising the advice will increase*) is reflected in the results if Table 5.8 shows that TA influences CAU. The same comparison is made for the rest of the propositions, where we found those to be held true within the results obtained.

For this, firstly, we identify in Table 5.8 the scenario presenting the desired state or the highest percentage for the desired state (high, medium or low state). For example, Scenario 3 presents the highest percentage for TA in a high state (64%), compared to how likely it is to obtain such state in the other scenarios (43%, 0%, and 7%). We call this a comparison per column. Secondly, we look at the row in the identified scenario and identify which one is the most likely status to obtain. For example, in Scenario 3, CAU is more likely to present a high state (64%) compared to how likely it is to obtain low (0%) and medium (36%) in the selected scenario. We call this a comparison per row. To summarise, we validate the theorised relationships within the data by performing a comparison per column to identify the target state, followed by a comparison per row in the identified scenario to check the expected state given the target state. Tables 5.9 to 5.15 present the results obtained from the assessment of the theory propositions against the data obtained from our study.

One case each is marked with (*) in Table 5.12, Table 5.13, and Table 5.15 from propositions 2a, 2b, and 3 respectively. These marked cases present one result as expected (e.g. Proposition 2a presents TA high when TP is high, as expected), and a second result within the same assessment different to what is expected (e.g. Proposition 2a presents TA with medium value when TP is high, where the expected result was TA being high).

The common situation for the marked results is found in the scenarios, as follows: the scenarios that validate the propositions in the assessment criteria present mixed-value levels (i.e. low, medium, high) of the factors involved, and although the mentioned propositions might look at only either factors IQ or TP, their assessed scenarios present different levels for each, contrary to other scenarios where both IQ and TP are in the same level. We consider these results are evidence that the involved elements present a relationship with the other elements as theorised, given that indeed variability in the elements involved is also reflected in the results.

Table 5.9: *Results of the assessment of Proposition 1a*

Proposition 1a (If the judge trusts the advice, then the likelihood of utilising the advice will increase) is reflected in the results if TA shows an influence in CAU, as follows:		
Assessment criteria	**Result**	**Analysis**
CAU is high when TA is high	True	In Table 5.8, the highest likelihood of obtaining a high TA appears in Scenario 3 (64%). In this scenario, CAU also presents the highest likelihood for high (64%)
CAU is low when TA is low	True	In Table 5.8, the highest likelihood of obtaining a low TA appears in Scenario 2 (86%). In this scenario, CAU also presents the highest likelihood for low (79%)
CAU is medium when TA is medium	True	In Table 5.8, the highest likelihood of obtaining a medium TA appears in Scenario 4 (71%). In this scenario, CAU also presents the highest likelihood for medium (50%)

Table 5.10: *Results of the assessment of Proposition 1b*

Proposition 1b (If the judge has high expectations of obtaining benefits from utilising the advice, then the likelihood of utilising the advice will increase) is reflected in the results if PB shows an influence in CAU, as follows:		
Assessment criteria	**Result**	**Analysis**
CAU is high when PB is high	True	In Table 5.8, the highest likelihood of obtaining a high PB appears in Scenario 3 (64%). In this scenario, CAU also presents the highest likelihood for high (64%)
CAU is low when PB is low	True	In Table 5.8, the highest likelihood of obtaining a low PB appears in Scenario 2 (93%). In this scenario, CAU also presents the highest likelihood for low (79%)
CAU is medium when PB is medium	True	In Table 5.8, the highest likelihood of obtaining a medium PB appears in Scenario 4 (79%). In this scenario, CAU also presents the highest likelihood for medium (50%)

Table 5.11: *Results of the assessment of Proposition 1*

Proposition 1 (If the judge trusts the advice and has high expectations of obtaining benefits from utilising the advice, then the likelihood of utilising the advice will increase) is reflected in the results if TA and PB show an influence in CAU, as follows:		
Assessment criteria	**Result**	**Analysis**
CAU is high when TA and PB are high	True	In Table 5.8, the highest likelihood of obtaining a high TA and a high PB appears in Scenario 3 (64% for both). In this scenario, CAU also presents the highest likelihood for high (64%)
CAU is low when TA and PB are low	True	In Table 5.8, the highest likelihood of obtaining a low TA and a low PB appears in Scenario 2 (86% and 93% respectively). In this scenario, CAU also presents the highest likelihood for low (79%)

CAU is medium when TA and PB are medium	True	In Table 5.8, the highest likelihood of obtaining a medium TA and a medium PB appears in Scenario 4 (71% and 79% respectively). In this scenario, CAU also presents the highest likelihood for medium (50%)

Table 5.12: *Results of the assessment of Proposition 2a*

Proposition 2a (If the advising process is transparent, then the judge will more likely trust the advice) is reflected in the results if TP shows an influence in TA, as follows:		
Assessment criteria	**Result**	**Analysis**
TA is high when TP is high	True*	Scenarios 3 and 4 present TP as high. In Table 5.8, Scenario 3, TA presents the highest likelihood for high (64%). In Scenario 4, TA presents the highest likelihood for medium (71%)
TA is low when TP is low	True	Scenario 2 presents TP as low. In this scenario in Table 5.8, TA presents the highest likelihood for low (86%)
TA is medium when TP is medium	True	Scenario 1 presents TP as medium. In this scenario in Table 5.8, TA presents the highest likelihood for medium (50%)

Table 5.13: *Results of the assessment of Proposition 2a*

Proposition 2b (If the quality of the information contained in the advice is high, then the judge will more likely trust the advice) is reflected in the results if IQ shows an influence in TA, as follows:		
Assessment criteria	**Result**	**Analysis**
TA is high when IQ is high	True*	Scenarios 1 and 3 present IQ as high. In Table 5.8, Scenario 1, TA presents the highest likelihood for medium (50%). In Scenario 3, TA presents the highest likelihood for high (64%)
TA is low when IQ is low	True	Scenario 2 presents IQ as low. In this scenario in Table 5.8, TA presents the highest likelihood for low (86%)
TA is medium when IQ is medium	True	Scenario 4 presents IQ as medium. In this scenario in Table 5.8, TA presents the highest likelihood for medium (71%)

Table 5.14: *Results of the assessment of Proposition 2*

Proposition 2 (If the advising process is transparent and the quality of the information contained in the advice is high, then the judge will more likely trust the advice) is reflected in the results if TP and IQ show an influence in TA, as follows:		
Assessment criteria	**Result**	**Analysis**
TA is high when TP and IQ are high	True	Scenario 3 presents TP and IQ as high. In this scenario in Table 5.8, TA presents the highest likelihood for high (64%)
TA is low when TP and IQ are low	True	Scenario 2 presents TP and IQ as low. In this scenario in Table 5.8, TA presents the highest likelihood for low (86%)
TA is medium when TP and IQ are medium	NA	We don’t have a supporting scenario presenting both TP and IQ in medium states

Table 5.15: *Results of the assessment of Proposition 3*

Proposition 3 (If the quality of the information contained in the advice is high, then the judge will more likely increase the level of expectations of obtaining benefits from utilising the advice) is reflected in the results if IQ shows an influence in PB, as follows:		
Assessment criteria	**Result**	**Analysis**
PB is high when IQ is high	True*	Scenarios 1 and 3 present IQ as high. In Table 5.8, Scenario 1, PB presents the highest likelihood for medium (64%). In Scenario 3, PB presents the highest likelihood for high (64%)
PB is low when IQ is low	True	Scenario 2 presents IQ as low. In this scenario in Table 5.8, PB presents the highest likelihood for low (93%)
PB is medium when IQ is medium	True	Scenario 4 presents IQ as medium. In this scenario in Table 5.8, PB presents the highest likelihood for medium (79%)

5.5.3 Predictive Power

Our results also provide the data to update our BN through a sensitivity analysis (Laskey 1995). For the sensitivity analysis, we design the BN using the values as shown in the prior CPTs (see Table 5.6); Figure 5.8 presents an excerpt of the prior BN with the states of “low” for both TP and IQ. Secondly, we update the prior CPTs through adjusting the BN to reflect the values obtained in the study; Figure 5.9 shows an excerpt of the adjusted BN with the states of “low” for both TP and IQ. We adjust the values for TA and PB and observe the values in CAU, which reflect a trend as theorised, and as obtained in the data collected. Finally, Table 5.16 presents the updated CPTs; these CPTs are the result of the sensitivity analysis through the use of the values obtained from the study.

The results of the adjusted CPTs allow us to elaborate predictions on the likelihood of end-users (i.e. judges) accepting advice from a computerised advisor (i.e. advisor) based on the concepts of the CAU theory. For example, from the CPT table of CAU in Table 5.16, we predict that the highest likelihood of people accepting advice is when both TA and PB are high (83%). We can also predict that a high likelihood of end-users accepting advice is higher when TA is high and PB is low (36%) than when TA is low, and PB is high (11%). Further combinations can be analysed considering Table 5.16. The following section discusses the implications of these results and the CAU theory.

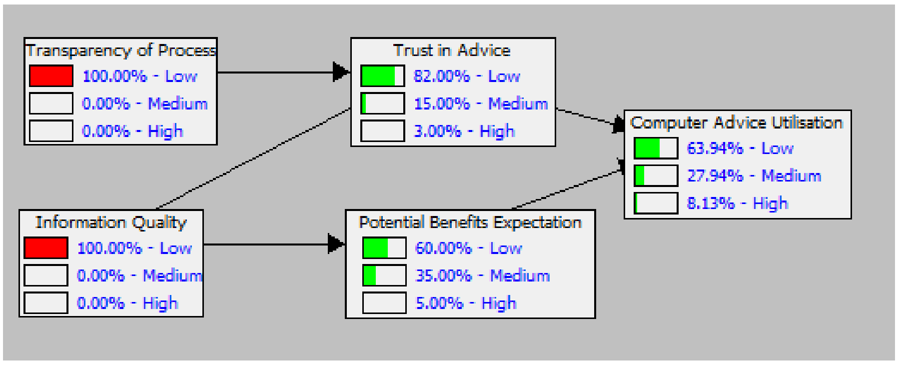

Figure 5.8: Scenario showing the values with prior CPTs

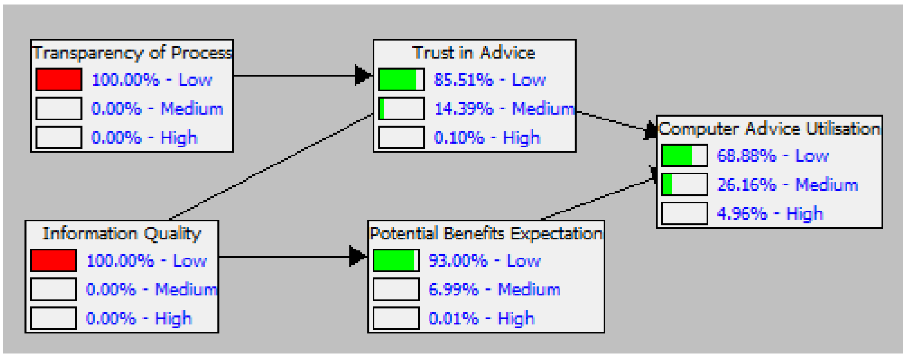

Figure 5.9: Scenario showing the values adjusted in the CPTs through a sensitivity analysis

Table 5.16: *Adjusted CPTs of TA, PD, and CAU nodes*

	P(TA | TP, IQ)									
	TP	*Low*			*Medium*			*High*		
	IQ	*Low*	*Medium*	*High*	*Low*	*Medium*	*High*	*Low*	*Medium*	*High*
TA	Low	0.86	0.65	0.51	0.15	0.40	0.07	0.46	0.20	0.00
	Medium	0.14	0.24	0.37	0.59	0.35	0.49	0.31	0.71	0.36
	High	0.00	0.11	0.12	0.26	0.25	0.44	0.23	0.09	0.64

	P(PB | IQ)			
	IQ	*Low*	*Medium*	*High*
PB	Low	0.93	0.14	0.00
	Medium	0.07	0.78	0.36
	High	0.00	0.08	0.64

	P(CAU | TA, PB)									
	TA	*Low*			*Medium*			*High*		
	PB	*Low*	*Medium*	*High*	*Low*	*Medium*	*High*	*Low*	*Medium*	*High*
CAU	Low	0.74	0.66	0.59	0.43	0.31	0.27	0.19	0.11	0.07
	Medium	0.24	0.27	0.30	0.37	0.46	0.55	0.45	0.16	0.10
	High	0.02	0.07	0.11	0.20	0.23	0.18	0.36	0.73	0.83

5.6 Conclusion

In this paper, we present our CAU theory. Guided by an ADR strategy, we explain the phenomena of computer advice utilisation and, using theory and empirical results, we explain why judges follow advice given by computerised advisors. Among the theories informing our work, we use (1) JAS to conceptualise a computer as the advisor, and a human decision-maker as the judge, and (2) EVT to give form to the theorised relationships of the elements involved. We contextualise our research in computers advising business partner selection, and we extend the knowledge to theorise about advice given by computers when high business value decisions are at hand. Our theory formulates an answer to the question of why computerised advice is utilised by users and extends the knowledge by providing a new block of understanding regarding advisory systems within organisations. Below, we further discuss the implications of our work, its limitations and future research directions.

5.6.1 Contributions to Knowledge

Our CAU theory proposes to focus on four factors which determine how judges react to computer-generated advice in business collaboration settings: trust, information quality, transparency, and expectation of benefits. These factors have indeed been identified before as relevant to technology acceptance (Lai 2017), information systems use (Burton-Jones et al. 2017)**,** advice acceptance (MacGeorge and Van Swol 2018), and inter-organisational collaboration (Bonner et al. 2018); however, their relationship and a quantified measure of their influence on computerised advice utilisation has until now remained unclear. Research literature identifies trust as one of the main influencers in advice utilisation, from the advice taking domain (Green et al. 2001; MacGeorge and Van Swol 2018), the inter-organisational domain (Andersen and Kumar 2006; Campbell et al. 2010; Kazantsev et al. 2018b; Lambert et al. 1996; Li and Rowley 2002; Wilkinson et al. 2005), and the IS domain (Chow et al. 2015; Ye and Johnson 1995). We add to the knowledge further evidence that bridges the understanding of trust into a relationship of how trust from the offline settings is applied to digital contexts in the view of advice utilisation. We also offer a novel insight in relation to trust considering that trust, as described in the literature, refers to trust in the advisor (Chow et al. 2015; Green et al. 2001; MacGeorge and Van Swol 2018; Ye and Johnson 1995). Our novel insight is that the relevant trust component influencing advice appears to be not the trust in the advisory system, but the trust in the partner being recommended, reflecting findings from human-to-human advice literature (Nooteboom 2003; Whitford and Zeitlin 2004).

Further, our research adds the expectation of benefits as a second example of how an influential offline element (Bonner and Cadman 2014; Calcagno and Monticone 2015; Garfagnini et al. 2014; MacGeorge and Van Swol 2018) reflects in the digital contexts for computerised advice utilisation. The elements of transparency of the advising process and information quality represent two aspects widely researched in the IS domains, and the literature presents them as primarily linked to trust (Ba and Pavlou 2002; Gregor and Benbasat 1999), or individually linked to computerised advice utilisation (Köhler, Breugelmans, and Dellaert 2011; Ye and Johnson 1995). However, we theorise about the explicit relationship of transparency and information quality to trust, this, in relation to computerised advice utilisation. We also theorise about the relationship of information quality influencing the expectation of benefits to favour computerised advice utilisation. These are novel insights to the computerised advice utilisation literature.

Previous to this work, computer advice utilisation research was also limited to only proposing some factors identified in specific contexts, such as health (Chow et al. 2015), finance (Ye and Johnson 1995), air traffic management (Westin et al. 2013), leisure activities and services (Bonsall 1992; Jin et al. 2017; Köhler et al. 2011; Takahashi et al. 2007), and border control management (Giboney et al. 2015), and we add a new domain not reviewed before, and theorise about the relationships of the identified factors. Our research also extends the JAS research borders by adding to the knowledge a case of a JAS when the computer is the advisor, and formulating an example of how to include JAS in the arena of IS, expanding JAS beyond its usual application in organisational and psychology settings (Bonaccio and Dalal 2006; Sniezek and Van Swol 2001).

5.6.2 Implications to Practice

Our CAU theory brings to the theoretical knowledge a model explaining what would influence advice utilisation, and this explanation impacts managerial practice. Emerging industrial trends (Liao et al. 2017) mean inter-organisational networks need flexibility (Camarinha-Matos et al. 2017; Cisneros-Cabrera et al. 2017) and invite digital transformation (Bowersox et al. 2005). The use of computerised advisors is expected to grow in such settings (Cisneros-Cabrera et al. 2017, 2018; Pishchulov et al. 2020). In such scenarios, practitioners can use our theory to aid the design of computerised advisors supporting high business value decision-making. We demonstrate this use through the application of an ADR strategy, having fed our findings in the eventual development of an impactful advisory system prototype. Also, our theory can be used to predict the behaviour of end-users when exposed to the context of computer advisors, by considering the results of our theory in the BN and adjusting the predictions as needed (Laskey 1995), and thus helping to develop more effective systems.

5.6.3 Future Research Directions and Limitations

Our research does not intend to be an exhaustive theory of elements involved in the utilisation of advice, but rather to propose relevant elements and demonstrate the influence of these relevant factors to the explored issue. Furthermore, as demonstrated, CAU's context of applicability is narrowed to when the advice is given by a computer in support of business partner selection in manufacturing industries.

Our study can serve as a start to develop a stream of IS research devoted to the understanding of computers as advisors for a range of roles traditionally executed by humans, and could also investigate how our findings can be transposed to domains such as group decision making, with more fluid roles than in JAS, also, more research is needed to test the generalisability of CAU in domains beyond the context in which it was developed. Such research should potentially extend CAU. Results from research building upon our theory are expected to offer valuable insights to keep developing the knowledge around the phenomena and further extend the IS domain. Limitations of this research include the comparatively narrow target domain and hence the narrow professional profile of our users, and expanding this should also be explored in further research.

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Chapter 6

Conclusions

6.1 Summary

The research presented in this thesis identifies the factors that decision-makers consider when selecting business partners to form collaborative networks, conceptualises, designs and implements a computerised advisor supporting such decision-makers towards digitalising the business partner selection process, and identifies the factors that influence users to utilise the computer-generated advice from that kind of computerised advisors within the context of inter-organisational collaboration and digitalisation.

Such context has grown in importance with the adoption of Industry 4.0, an industrial trend towards efficient and flexible manufacturing systems augmenting the current levels of automation of industrial processes (Lasi et al. 2014; Obitko and Jirkovsky 2015). To enable such automation, digitalisation is one of the key enablers (Alcácer and Cruz-Machado 2019; Hahn 2020; Nambisan et al. 2017). One of the core processes impacted by digitalisation appears to be the formation of collaborative networks (Arıcıoğlu and Yiğitol 2020; Camarinha-Matos et al. 2017; Keller et al. 2014; Schniederjans et al. 2020).

Leading European organisations recognise the relevance of providing support to digitalising the processes of formation and evolution of collaborative networks (DIGICOR 2016; European Commission 2015). This digitalisation enables smaller independent organisations, such as SMEs, to form teams and engage with new business opportunities, meeting the strict requirements of tender invitations in a supply chain with dynamic and complex characteristics (Mehandjiev et al. 2010). This thesis advances the body of knowledge aimed at supporting the digitalisation of inter-organisational collaboration by providing (1) innovative technologies to connect business partners through a computerised advisor, and (2) a theory concerning the factors that determine if computer-generated partner selection advice will be followed by company managers and collaborative network professionals.

In this thesis, Chapter 3 reviews the state-of-the-art of platforms and technologies supporting digital collaboration and uses a representative set of major collaborative platforms in the manufacturing industry to show that the technological implementations support simple collaboration approaches of the "one-to-one" type instead of more complex forms of inter-organisational collaboration. This initiates the conversation as to how existing research into collaboration supporting techniques should incorporate more advanced capabilities such as dynamic search, assessment, selection, and formation of coalitions (Cisneros-Cabrera et al. 2017). Chapter 3 also contributes to building an understanding of what are the characteristics of collaborative technologies that can support these digitalisation demands, and furthermore, provides a novel pair of instruments to assess i) collaborative platforms and ii) collaborative technologies supporting inter-organisational collaboration in the digitalisation context.

The review of the state-of-the-art of platforms and technologies supporting digital collaboration presented in Chapter 3 enables the understanding of the practical context of such ideas and provides a starting point to analyse the research opportunities to contribute to the digitalisation of inter-organisational collaboration. One of these opportunities appears as the development of computerised advisors suggesting teams of business partners.

Further analysis of the theoretical knowledge available to support collaborations between business partners is presented in Chapter 4. This analysis concludes that the majority of existent research solutions support a single-supplier single-team composition just like the state-of-the-art commercial solutions reviewed in Chapter 3. To address the gap towards more complex collaboration, this thesis develops TDMS, a novel computerised advisory system which proposes potential business partners through matchmaking techniques. TDMS generates advice in the form of multiple alternative compositions of teams of suppliers. This effort extends the body of knowledge by proposing a solution which meets the needs of digitalising complex inter-organisational collaboration.

Theoretical knowledge explaining the use of a TDMS-like solution is investigated in Chapter 5, establishing that knowledge about why and when users utilise computer-generated advice in such complex scenarios is limited. To address this gap, this thesis presents the theory of "Computer Advice Utilisation" (CAU) applicable when the advice is provided by a computer in support of business partner selection in manufacturing industries. CAU posits that four factors are key to influencing computer advice utilisation within the context of the research: the *transparency* of the advising process, the *quality* of the information given in the advice, the *trust* in the advice, and the expectation of potential *benefits* to be obtained through utilising the advice.

CAU presents *trust in the advice* as the element particularly unique to the scenario of computer-generated advice regarding which partners should be selected to form a collaborative team. As presented in Chapter 5, the literature indicated a tendency of trust deposited in the designer of the system, or in the system itself, however, it is to note that in the context of this research, business stakeholders concerned with partner selection tend to value trust in the partner with whom they are forming a collaboration, and this trust is carried to the digitalisation environment as well. This could be a particularity of domains with high-value decision-making, where the heavier weight of trust remains fixed to the same object of trust both in the non-digitalised and the digitalised settings.

This thesis also presents an instance of the application of ADR as a methodology to guide the results explained above. ADR is commonly utilised to develop prescriptive design knowledge of IT artefacts evaluated in an organisational setting (Sein et al. 2011) and is proposed to assist in making theoretical contributions and solving practitioner's problems (Sein et al. 2011). In this research, the activities within ADR engage with the processes of the general method of theory building (i.e. conceptual development, operationalisation, confirmation or disconfirmation, and application) (Lynham 2002) to continuously refine and develop the theoretical knowledge. Chapter 2 describes in detail this approach.

6.2 Outcomes Derived from Research Questions

To develop the research outcomes reported in this thesis, the investigation has benefited from access to the activities and partners of the DIGICOR EU project. This access provided exposure to the context of technologies, organisations, and practitioners supporting the development of Industry 4.0 collaborative platforms and its mechanisms to underpin this new industrial revolution paradigm (DIGICOR 2016). This exposure was provided to the researcher.

Three objectives have been formulated to fulfil the aim of the research: defining the problem, developing a computerised advisor supporting business partner selection, and a theorising work formalising the knowledge obtained. Linked to these objectives, three research questions have been formulated and answered.

The research question concerning the identification of *what are the factors that decision-makers consider when selecting business partners to form a collaborative network* is addressed in Chapter 3 and in the backgrounds of Chapter 4 and 5. Concretely, this thesis found that, when selecting business partners supported by a computerised advisor, decision-makers consider what they already assess in off-line contexts (such as trust in the potential partners, and an expectation of benefits by up taking the proposed collaboration). The results addressing the remainder of the research questions further reflect this consideration.

The second research question concerns *what is a suitable realisation of a computerised business advisor supporting business partner selection for collaborative networks' formation*. It is addressed in Chapter 4 which presents the details of how a computerised advisor of such kind can be developed, and what mechanisms can be designed to aid the functionalities on support of business partner selection in the manufacturing domain.

Finally, the work aiming at addressing the third research question of w*hat factors influence end-users to follow the advice made by a computer business advisor when selecting business partners to form a collaborative network* is presented in Chapter 5. The factors, as mentioned earlier, are the transparency of the advising process, the quality of the information given in the advice, the trust in the advice, and the expectation of potential benefits to be obtained through utilising the advice. The following sections present an account of how the results of this thesis contribute to theory and their implication to practice.

6.3 Theoretical Contribution and Implications to Practice

This research contributes to the body of knowledge of IS by extending the boundaries of what is known about computer advice utilisation. This contribution comprises a theory and its implications to practice regarding how to design computerised advisors to support business partner selection. Table 6.1 presents a summary of the contributions of this thesis and its implications to practice. The following subsections detail each contribution.

Table 6.1: *Summary of contributions*

Research objective	Research question	Chapter	Contribution to knowledge	Implications for practice
Not applicable	Not applicable	Chapter 2	Methodological example of the use of ADR for theorising	Method in support of applied research and development (R+D) projects
Problem formulation	RQ 1	Chapter 3	Review of collaborative platforms for Industry 4.0 Taxonomy for assessment of collaborative technologies in Industry 4.0	Tool to assess technology and support project planning/digital transformation strategy
Computerised business advisor's development	RQ 2	Chapter 4	Working computerised advisor supporting business partner selection (addition to the state-of-the-art IS artefacts for its problem class)	Tool for business partner selection Lessons learned to embed in design principles

Formalisation of knowledge	RQ 3	Chapter 5	Theory of Computer Advice Utilisation applicable when the advice is provided by a computer in support of business partner selection in manufacturing industries	Knowledge in support of improvement, control, and prediction of the use of advisory systems, to aid practical progress towards such systems Means to understand how to realise the benefits of digitalising the business partner selection process Lessons learned to embed in design principles

6.3.1 Theoretical Contribution

This thesis adds TDMS to the current state-of-the-art pool of IS artefacts supporting business partner selection for manufacturing industries. TDMS is a computerised advisor, performing matchmaking of suppliers against requirements of a call-for-tenders, and providing its users with advice regarding which partners to select for a tender (see Chapter 4). Previous work mainly focuses on developing theoretical support for partner selection (de Boer et al. 2001; Chai et al. 2013; Polyantchikov et al. 2017; Tahriri et al. 2008; Zimmer et al. 2016) neglecting the research towards knowledge to implement such advances with technological means adapted to the emerging industrial needs for scenarios beyond one-to-one supplier collaboration (Cisneros-Cabrera et al. 2017; Huang et al. 2004; Nyongesa et al. 2017; Petersen and Divitini 2002; Polyantchikov et al. 2017). TDMS contributes to advancing in this knowledge by exposing how to support such kind of partner selection with technological means (Cisneros-Cabrera et al. 2017, 2018).

Secondly, this thesis reviewed the literature and identified a knowledge gap regarding computer advice utilisation where only a few efforts seek to identify the factors driving such utilisation (MacGeorge and Van Swol 2018; Prahl and Van Swol 2017) (see (Bonsall 1992; Chow et al. 2015; Gasparic and Ricci 2015; Köhler et al. 2011; Lourenço et al. 2020; Westin et al. 2013; Ye and Johnson 1995)). This thesis adds to previous research a theory explaining the likelihood of advice utilisation based on the factors of trust, information quality, and expectation of benefits and transparency of the process. The relationships among these factors have not been identified before to the best of the author's knowledge.

The results also extend the knowledge of how the non-digitalised business partner selection is reflected in the digitalised version of the process. This thesis adds to the literature the view of the existing elements in partner selection from the organisational research, to the

IS research view. Also, areas such as Judge-Advisory-Systems (JAS) (Sniezek 1999) are extended through the addition to knowledge of a case in JAS where the advisor is a computer and what happens in such cases. The main theoretical contribution of this thesis is, thus, the addition of the theory of advice utilisation.

As mentioned in Section 6.1, this thesis includes in Chapter 3 a survey and gap analysis of collaborative platforms from the Industry 4.0 view, and a taxonomical solution to assess collaborative technologies aligned to this industrial revolution. These constitute an addition to the knowledge of collaborative platforms, technologies and the context of them within the Industry 4.0 revolution, as this analysis responds to the need of obtaining a view of the current digitalisation progress to support collaborative networks, not available before.

Finally, this thesis presents as an ancillary contribution, a methodological example of the use of ADR (Sein et al. 2011) for theorising, supporting views that ADR and Design Science (Hevner et al. 2004) approaches, should consider including theorising within its efforts (Venable 2006), where ADR is typically used for design prescriptions and IT artefact development (MacKrell and McDonald 2016). Chapter 2 presents the details of the ADR methodology and how it is utilised in this research to theorise and develop multiple outcomes beyond a single artefact (i.e. the IT artefact, in the case of this research, the computerised advisor). For theory, this represents a methodological example of the use of ADR to theorise given its compatibility with the ADR stages and the processes of the general method of theory building (Lynham 2002). Stage 1 aligns to the conceptual development process, whereas Stages 2 and 3 enable to carry on the operationalisation process. Stage 4 aligns with the confirmation or disconfirmation, and application processes (Lynham 2002).

6.3.2 Implications for Practice

The computerised advisor developed and presented in Chapter 4, has been positively accepted for its future use in practical domains. TDMS is currently in the process of being productised within the European Commission Project named “European Connected Factory Platform for Agile Manufacturing”[46] (EFPF) under the inclusion of DIGICOR outcomes that contribute to serving the digital manufacturing domain (European Factory Platform 2020a, 2020b). EFPF looks to exploit outcomes from several other EU projects towards the Industry 4.0 base of technologies and standard (European Factory Platform 2020a). TDMS is also being considered

[46] https://www.efpf.org/home

for use as one of the tools available to members in automotive and aerospace industrial clusters who took part in DIGICOR (DIGICOR 2019c).

Secondly, the proposal of the CAU theory has potential to be used in support of the improvement, control, and prediction of the use of advisory systems supporting business partner selection, which can contribute to achieving the organisational goals set for the addition of such systems in applicable industries. Practitioners can use the CAU supporting high business value decision-making to predict the behaviour of end-users when exposed to the context of computer advisors. Practitioners can consider the results of our theory within Bayesian-Network-based simulations helping them to adjust the levels of the core CAU factors within their systems to meet the desired results (Laskey 1995) in terms of the desired probability of users accepting the computer-generated advice.

Thirdly, the outcomes of the assessment of collaborative technologies and platforms have the potential to support the digital transformation strategy in practice contexts by identifying the levels of readiness for Industry 4.0 automation and digitalisation, thus, providing means to obtain a picture of what is yet required to do and prioritise the project of digital transformation.

Regarding the use of ADR as a methodological example of theorising, the value of this proposition for practice relies on ADR's possible usage to support applied research and development projects, especially when developing technological artefacts.

Finally, accompanying the CAU theory, this theorising work provides six design principles (Chandra et al. 2015) for computerised advisors supporting business partner selection. These are materiality-oriented design principles, which indicate the contents and features that a system should have (Chandra et al. 2015). They are contrasted to action-oriented design principles which indicate what a system should allow for users to do (Chandra et al. 2015). The design principles for computerised advisors supporting business partner selection represent the gained understanding and lessons learned through the CAU theorisation process and can be found in Appendix C.1.

The design principles can be considered by system designers to avoid ad-hoc searching for optimal design, resulting in saved resources. This work itself is an example of an initial ad-hoc exploration which has been eventually guided by the design principles, helping to design an impactful tool. Appendix C.2 shows a summary of the design principles aligned to its linked CAU theory concept and its theoretical source that support the findings.

6.4 Limitations and Future Research Directions

This thesis finds its limitations within the scope of its research project. First, this investigation focuses on supporting high-value decision making and business partner selection within manufacturing industries. Second, the empirical data was collected with a sample from a European market, with limited diversification beyond the European business collaboration perspective. Third, the proposed computerised advisor was developed concurrently to the theorising process included in the PhD research, thus, it is limited to the scope of the project, narrowing the window for further exploration and a stronger focus on the IT system. Fourth, the review of inter-organisational collaboration and digitalisation was impacted by the rapid pace of development of collaboration technologies because of the unfortunate events of the pandemic context in 2020, where digitalisation processes have been accelerated (Oldekop et al. 2020).

Indeed, one of the opportunities for further work is to use the taxonomy of collaborative technology readiness and the assessment of collaborative platforms; and to research how the recent events impacted the pace and nature of digitalisation of collaboration. Although collaborative technologies and platforms can be used in a variety of domains, for example personal communication, education, travel, finance, etc., the tools provided by the investigation presented in this thesis are applicable to the context in which they were developed, namely the domains of manufacturing where business collaboration is a common process.

Also, further investigations exploring the area of computer advice utilisation could address the context and scope limitations above and further extend the knowledge by designing studies testing CAU in different contexts and for different kinds of decisions. Research of this kind should potentially extend CAU.

Future directions could also involve utilising the CAU theory to guide the development of variants of computer advisory systems, for example, in different domains or for different purposes. Such new artefacts would open opportunities for research on domains ranging from computer science (e.g. to further improve the algorithms), to knowledge management (e.g. to expand the knowledge of such systems interacting with organisational contexts). This thesis points forward to the development of computerised advisors, gradually increasing their complexity and thus also their utility to a number of business domains (Bharadwaj et al. 2013; Vial 2019). This would support the ongoing digital transformation to expand to areas in which non-digitalised business processes involve advisory processes.

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Appendices

Appendix A. Supplementary data for Chapter 2

Appendix A.1: Mock-up presented in workshop

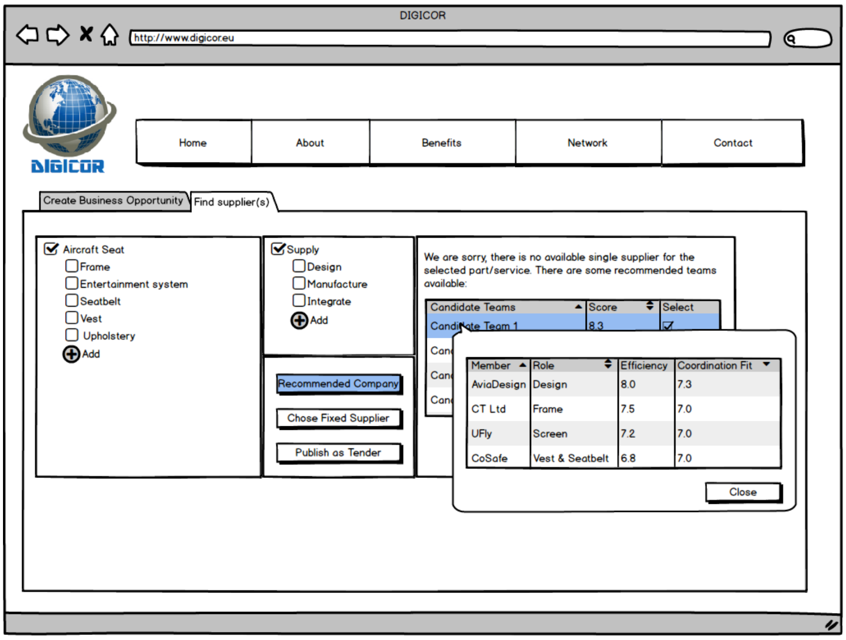


Figure A.1: In this screen, the call-for-tender can be decomposed in smaller sub-parts or sub-activities which require a company or a team of companies to fulfil them

Appendix A.2: Initial design presented as a demo version in a feedback session

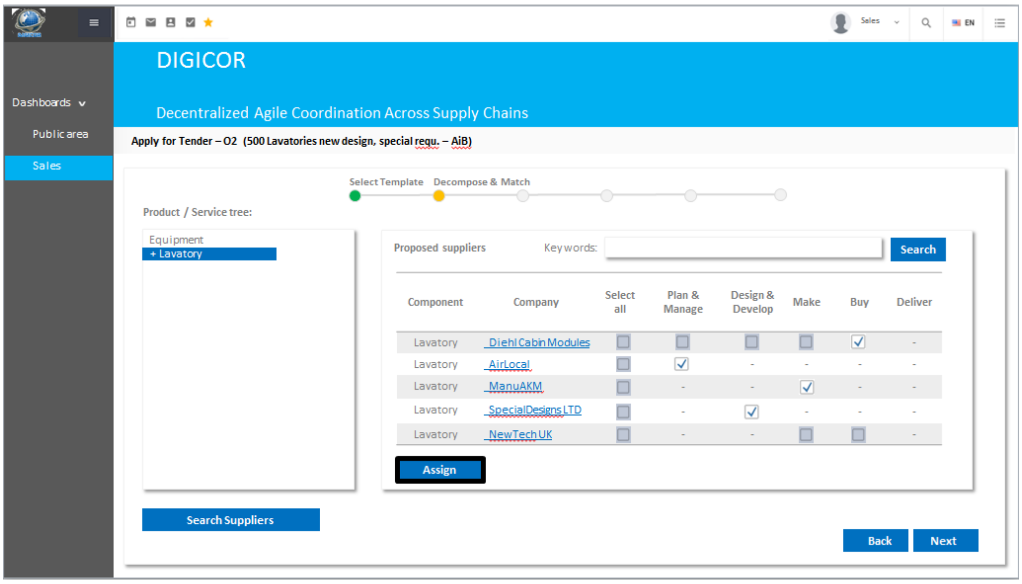
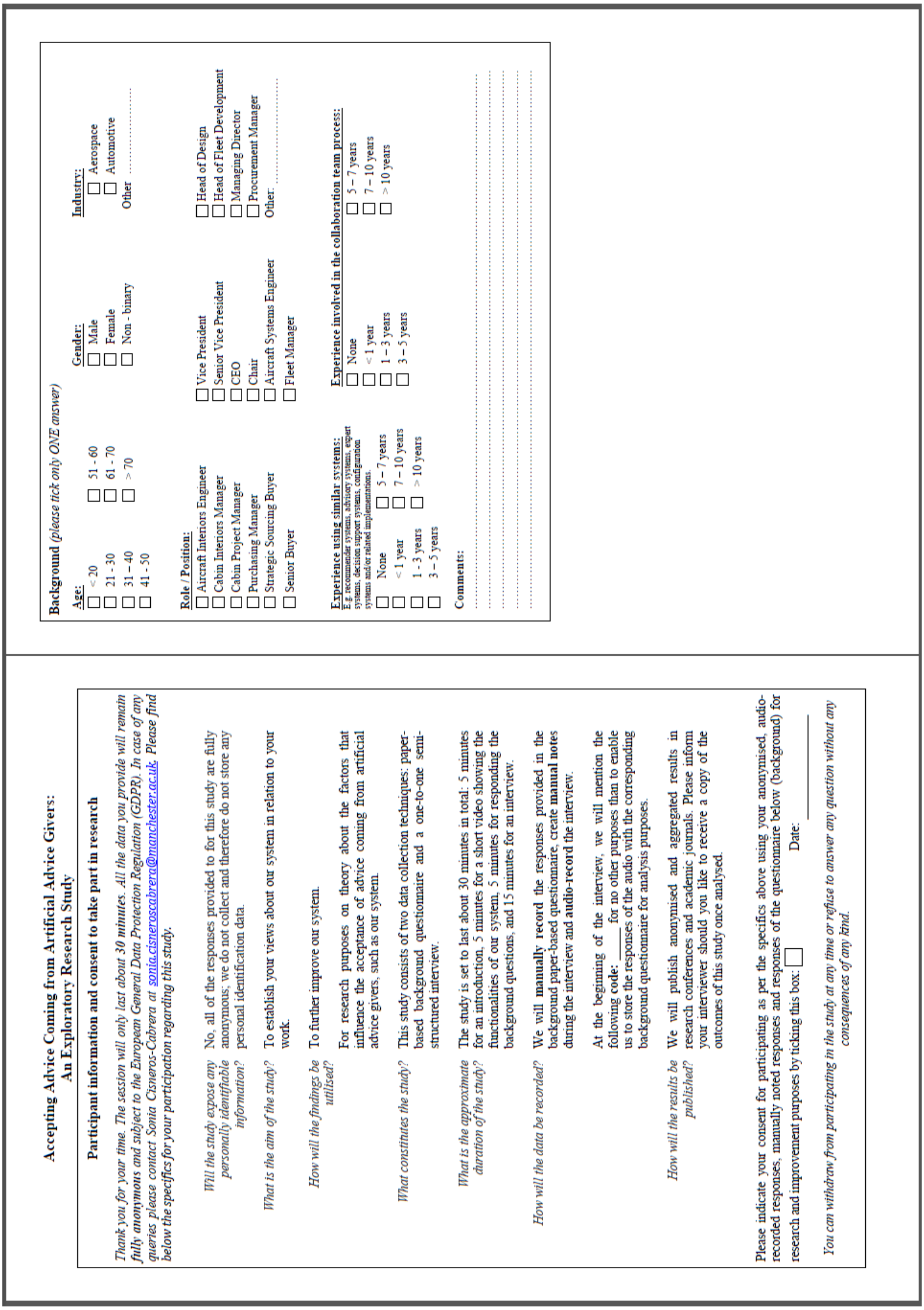


Figure A.2: In this screen, the user can view the proposed team and the decomposition of the call-for-tender. This is an updated design presented as a demo version of the computerised advisor

Appendix A.3: Sheet handled to laddering study participants



Accepting Advice Coming from Artificial Advice Givers:
An Exploratory Research Study

Participant information and consent to take part in research

*Thank you for your time. The session will only last about **30 minutes**. All the data you provide will remain **fully anonymous** and subject to the European General Data Protection Regulation (GDPR). In case of any queries please contact Sonia Cisneros-Cabrera at* sonia.cisneroscabrera@manchester.ac.uk*. Please find below the specifics for your participation regarding this study.*

Will the study expose any personally identifiable information?	No, all of the responses provided to for this study are fully anonymous; we do not collect and therefore do not store any personal identification data.
What is the aim of the study?	To establish your views about our system in relation to your work.
How will the findings be utilised?	To further improve our system. For research purposes on theory about the factors that influence the acceptance of advice coming from artificial advice givers, such as our system.
What constitutes the study?	This study consists of two data collection techniques: paper-based background questionnaire and a one-to-one semi-structured interview.
What is the approximate duration of the study?	The study is set to last about 30 minutes in total: 5 minutes for an introduction, 5 minutes for a short video showing the functionalities of our system, 5 minutes for responding the background questions, and 15 minutes for an interview.
How will the data be recorded?	We will **manually record** the responses provided in the background paper-based questionnaire, create **manual notes** during the interview and **audio-record** the interview. At the beginning of the interview, we will mention the following **code:** _____ for no other purposes than to enable us to store the responses of the audio with the corresponding background questionnaire for analysis purposes.
How will the results be published?	We will publish anonymised and aggregated results in research conferences and academic journals. Please inform your interviewer should you like to receive a copy of the outcomes of this study once analysed.

Please indicate your consent for participating as per the specifics above using your anonymised, audio-recorded responses, manually noted responses and responses of the questionnaire below (background) for research and improvement purposes by ticking this box: ☐ Date: __________

You can withdraw from participating in the study at any time or refuse to answer any question without any consequences of any kind.

Background *(please tick only ONE answer)*

Age:
- ☐ < 20
- ☐ 21 - 30
- ☐ 31 – 40
- ☐ 41 - 50
- ☐ 51 - 60
- ☐ 61 - 70
- ☐ > 70

Gender:
- ☐ Male
- ☐ Female
- ☐ Non - binary

Industry:
- ☐ Aerospace
- ☐ Automotive
- Other ....

Role / Position:
- ☐ Aircraft Interiors Engineer
- ☐ Cabin Interiors Manager
- ☐ Cabin Project Manager
- ☐ Purchasing Manager
- ☐ Strategic Sourcing Buyer
- ☐ Senior Buyer
- ☐ Vice President
- ☐ Senior Vice President
- ☐ CEO
- ☐ Chair
- ☐ Aircraft Systems Engineer
- ☐ Fleet Manager
- ☐ Head of Design
- ☐ Head of Fleet Development
- ☐ Managing Director
- ☐ Procurement Manager
- Other: ....

Experience using similar systems:
E.g. recommender systems, advisory systems, expert systems, decision support systems, configuration systems and/or related implementations.
- ☐ None
- ☐ < 1 year
- ☐ 1 - 3 years
- ☐ 3 – 5 years
- ☐ 5 – 7 years
- ☐ 7 – 10 years
- ☐ > 10 years

Experience involved in the collaboration team process:
- ☐ None
- ☐ < 1 year
- ☐ 1 – 3 years
- ☐ 3 – 5 years
- ☐ 5 – 7 years
- ☐ 7 – 10 years
- ☐ > 10 years

Comments:
....

Figure A.3: Sheet handed to the participants of the laddering interview. Includes approval sheet and demographic questions

Appendix A.4: Ladders obtained from the interviewed participants

ID	Elements conforming the ladders	ID	Elements conforming the ladders
1	Team formation functionality tools, Time saving, Fulfil other responsibilities	24	UI aids, Good communication, Successfulness, Financial benefit
2	Team formation functionality tools, Time saving, Company acquaintance, Trust	25	UI design, Time saving, Fulfil other responsibilities
3	Company information, Timeliness, Customer return, Agility	26	Explanation of results, Company acquaintance, Trust, Know-how protection, Financial benefit
4	Company information, Timeliness, Customer return, Financial benefit	27	Company acquaintance Risk saving, Know-how protection, Competitiveness, Financial benefit
5	UI design, Effort saving, Financial benefit	28	UI design, Understanding ease, Time saving, Fulfil other responsibilities
6	UI design, Time saving, Financial benefit	29	UI design, Understanding ease, Financial benefit
7	UI aids, Effort saving, Financial benefit	30	Company information, Time saving, Competitiveness, Financial benefit
8	UI aids, Time saving, Financial benefit	31	Information quality, Timeliness, Successfulness, Financial benefit
9	Explanation of results, Transparency, Trust	32	Information quality, Find the right partner, Quality
10	System technical configuration, Time saving, Timeliness, Financial benefit	33	Explanation of results, Transparency, Trust
11	Company information, Alignment of companies' strategy, Trust, Know-how protection, Financial benefit	34	Information quality, Time saving, Competitiveness
12	Company information, Alignment of companies' strategy, Resource efficiency, Financial benefit	35	Information quality, Increased tender participation, Financial benefit
13	Projects information, Transparency, Trust	36	Explanation of results, Value added, Decision making improvement
14	Team formation functionality tools, Effort saving, Financial benefit	37	UI design, Effort saving, Time saving, Fulfil other responsibilities, Competitiveness, Financial benefit
15	Explanation of results, Trust, Successfulness, Financial benefit	38	UI aids, Time saving, Financial benefit
16	Projects information, Interest attraction, Financial benefit	39	Team formation functionality tools, Find the right partner, Competitiveness
17	System technical configuration, Information quality, Good communication, Effort saving, Financial benefit	40	Explanation of results, Find the right partner, Successfulness
18	System technical configuration, Information quality, Good communication, Resource efficiency, Financial benefit	41	Company information, Company acquaintance, Trust
19	System technical configuration, Information quality, Good communication, Motivation, Successfulness, Happiness	42	Explanation of results, Company acquaintance, Trust
20	Team formation functionality tools, Time saving, Timeliness, Successfulness	43	Information quality, Trust, Quality, Successfulness
21	UI aids, Effort saving, Financial benefit	44	Information quality, Transparency, Financial benefit
22	UI aids, Time saving, Financial benefit	45	Team formation functionality tools, Time saving, Timeliness, Quality, Successfulness
23	Team formation functionality tools, Time saving, Fulfil other responsibilities, Financial benefit	46	Information quality, Time saving, Quality

Appendix A.5: Participant's sheet for usability study

Research Study on the Tender Decomposition and Matchmaking Service (TDMS)

MANCHESTER 1824 The University of Manchester — **The University of Manchester is a partner of Hanse-Aerospace in the EU-Project DIGICOR** — HANSE AEROSPACE

Participant information and consent to take part in research

Thank you for your time. The survey will only last about 15 ***minutes*** *and includes a short video showing the functionalities of our system. All the data you provide will remain* ***fully anonymous*** *and subject to the European General Data Protection Regulation (GDPR). In case of any queries please contact Prof Nikolay Mehandjiev at n.mehandjiev@manchester.ac.uk.*

The aim of this anonymous survey is to establish your views about the usability of our system in relation to your work. The findings will contribute to further improvements to our system so as to enable the system to provide a seamless user experience of its functionalities.

Please indicate your consent for using the responses provided in the survey for research purposes by ticking this box: ☐ Date: ________________

You can withdraw from participating in the study at any time or refuse to answer any question without any consequences whatsoever.

Background *(please tick only ONE answer)*

Age:
- ☐ < 20
- ☐ 21 - 30
- ☐ 31 – 40
- ☐ 41 - 50
- ☐ 51 - 60
- ☐ 61 - 70
- ☐ > 70

Gender:
- ☐ Male
- ☐ Female
- ☐ Non - binary

Industry:
- ☐ Aerospace
- ☐ Automotive
- Other ....

Role / Position:
- ☐ Aircraft Interiors Engineer
- ☐ Cabin Interiors Manager
- ☐ Cabin Project Manager
- ☐ Purchasing Manager
- ☐ Strategic Sourcing Buyer
- ☐ Senior Buyer
- ☐ Vice President
- ☐ Senior Vice President
- ☐ CEO
- ☐ Chair
- ☐ Aircraft Systems Engineer
- ☐ Fleet Manager
- ☐ Head of Design
- ☐ Head of Fleet Development
- ☐ Managing Director
- ☐ Procurement Manager
- Other: ....

Experience using similar systems:
E.g. recommender systems, advisory systems, expert systems, decision support systems, configuration systems and/or related implementations.
- ☐ None
- ☐ < 1 year
- ☐ 1 - 3 years
- ☐ 3 – 5 years
- ☐ 5 – 7 years
- ☐ 7 – 10 years
- ☐ > 10 years

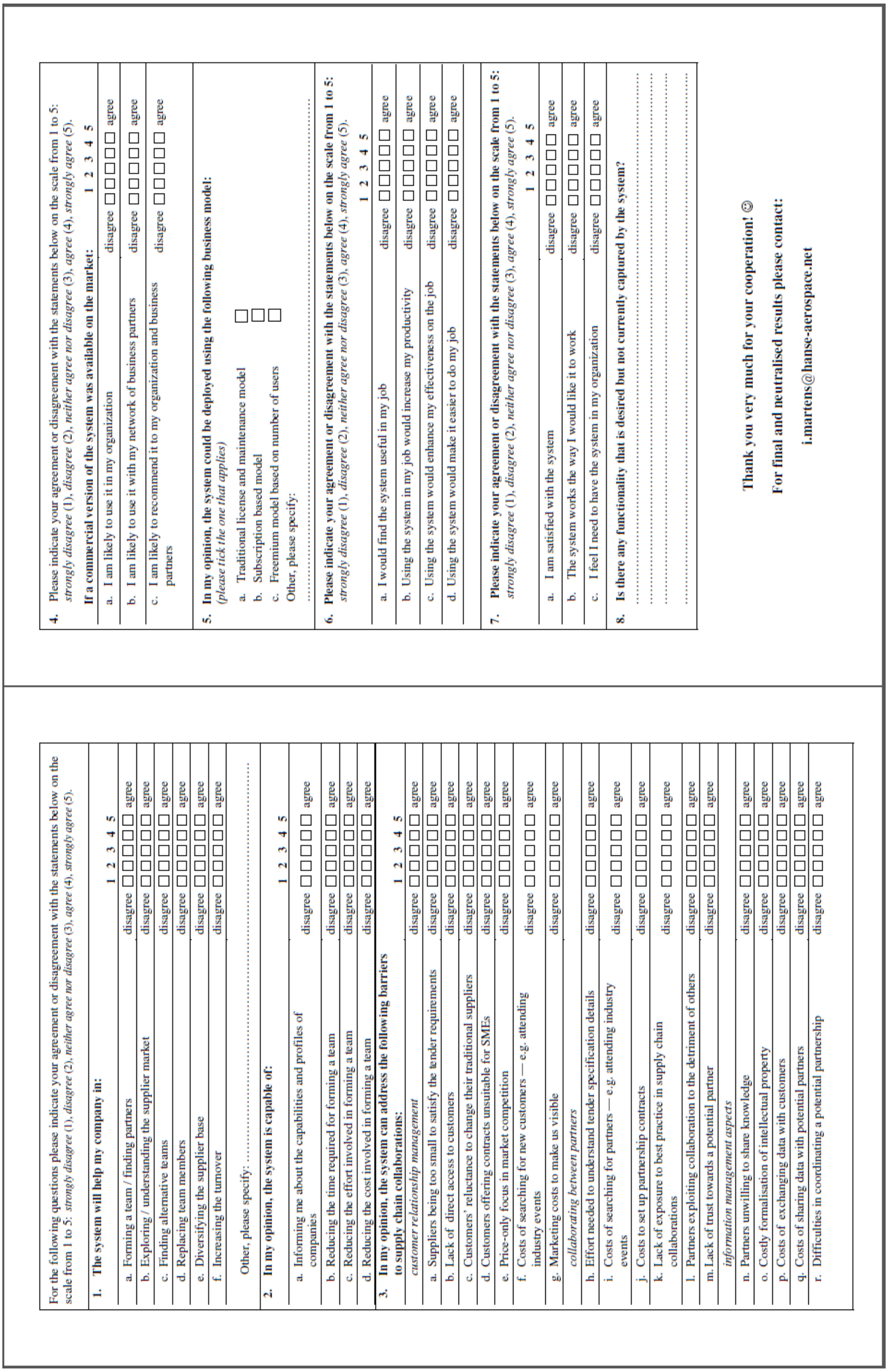
Experience of collaborating with other companies:
- ☐ None
- ☐ < 1 year
- ☐ 1 – 3 years
- ☐ 3 – 5 years
- ☐ 5 – 7 years
- ☐ 7 – 10 years
- ☐ > 10 years

Please LISTEN TO THE SHORT VIDEO showing the functionalities of our system before starting the survey. Use the QR code or the link provided below:

SCAN ME

http://bit.ly/DIGICOR

Figure A.5-1: Sheet handed to the participants of usability study. Includes approval sheet and demographic questions



For the following questions please indicate your agreement or disagreement with the statements below on the scale from 1 to 5: *strongly disagree* (1), *disagree* (2), *neither agree nor disagree* (3), *agree* (4), *strongly agree* (5).

1. The system will help my company in:

		1 2 3 4 5	
a. Forming a team / finding partners	disagree	□ □ □ □ □	agree
b. Exploring / understanding the supplier market	disagree	□ □ □ □ □	agree
c. Finding alternative teams	disagree	□ □ □ □ □	agree
d. Replacing team members	disagree	□ □ □ □ □	agree
e. Diversifying the supplier base	disagree	□ □ □ □ □	agree
f. Increasing the turnover	disagree	□ □ □ □ □	agree

Other, please specify: ....

2. In my opinion, the system is capable of:

		1 2 3 4 5	
a. Informing me about the capabilities and profiles of companies	disagree	□ □ □ □ □	agree
b. Reducing the time required for forming a team	disagree	□ □ □ □ □	agree
c. Reducing the effort involved in forming a team	disagree	□ □ □ □ □	agree
d. Reducing the cost involved in forming a team	disagree	□ □ □ □ □	agree

3. In my opinion, the system can address the following barriers to supply chain collaborations:

		1 2 3 4 5	
customer relationship management	disagree	□ □ □ □ □	agree
a. Suppliers being too small to satisfy the tender requirements	disagree	□ □ □ □ □	agree
b. Lack of direct access to customers	disagree	□ □ □ □ □	agree
c. Customers' reluctance to change their traditional suppliers	disagree	□ □ □ □ □	agree
d. Customers offering contracts unsuitable for SMEs	disagree	□ □ □ □ □	agree
e. Price-only focus in market competition	disagree	□ □ □ □ □	agree
f. Costs of searching for new customers — e.g. attending industry events	disagree	□ □ □ □ □	agree
g. Marketing costs to make us visible	disagree	□ □ □ □ □	agree
collaborating between partners			
h. Effort needed to understand tender specification details	disagree	□ □ □ □ □	agree
i. Costs of searching for partners — e.g. attending industry events	disagree	□ □ □ □ □	agree
j. Costs to set up partnership contracts	disagree	□ □ □ □ □	agree
k. Lack of exposure to best practice in supply chain collaborations	disagree	□ □ □ □ □	agree
l. Partners exploiting collaboration to the detriment of others	disagree	□ □ □ □ □	agree
m. Lack of trust towards a potential partner	disagree	□ □ □ □ □	agree
information management aspects			
n. Partners unwilling to share knowledge	disagree	□ □ □ □ □	agree
o. Costly formalisation of intellectual property	disagree	□ □ □ □ □	agree
p. Costs of exchanging data with customers	disagree	□ □ □ □ □	agree
q. Costs of sharing data with potential partners	disagree	□ □ □ □ □	agree
r. Difficulties in coordinating a potential partnership	disagree	□ □ □ □ □	agree

4. Please indicate your agreement or disagreement with the statements below on the scale from 1 to 5: *strongly disagree* (1), *disagree* (2), *neither agree nor disagree* (3), *agree* (4), *strongly agree* (5).

If a commercial version of the system was available on the market:		1 2 3 4 5	
a. I am likely to use it in my organization	disagree	□ □ □ □ □	agree
b. I am likely to use it with my network of business partners	disagree	□ □ □ □ □	agree
c. I am likely to recommend it to my organization and business partners	disagree	□ □ □ □ □	agree

5. In my opinion, the system could be deployed using the following business model:
(please tick the one that applies)

a. Traditional license and maintenance model □
b. Subscription based model □
c. Freemium model based on number of users □
Other, please specify:
....

6. Please indicate your agreement or disagreement with the statements below on the scale from 1 to 5: *strongly disagree* (1), *disagree* (2), *neither agree nor disagree* (3), *agree* (4), *strongly agree* (5).

		1 2 3 4 5	
a. I would find the system useful in my job	disagree	□ □ □ □ □	agree
b. Using the system in my job would increase my productivity	disagree	□ □ □ □ □	agree
c. Using the system would enhance my effectiveness on the job	disagree	□ □ □ □ □	agree
d. Using the system would make it easier to do my job	disagree	□ □ □ □ □	agree

7. Please indicate your agreement or disagreement with the statements below on the scale from 1 to 5: *strongly disagree* (1), *disagree* (2), *neither agree nor disagree* (3), *agree* (4), *strongly agree* (5).

		1 2 3 4 5	
a. I am satisfied with the system	disagree	□ □ □ □ □	agree
b. The system works the way I would like it to work	disagree	□ □ □ □ □	agree
c. I feel I need to have the system in my organization	disagree	□ □ □ □ □	agree

8. Is there any functionality that is desired but not currently captured by the system?
....
....
....
....

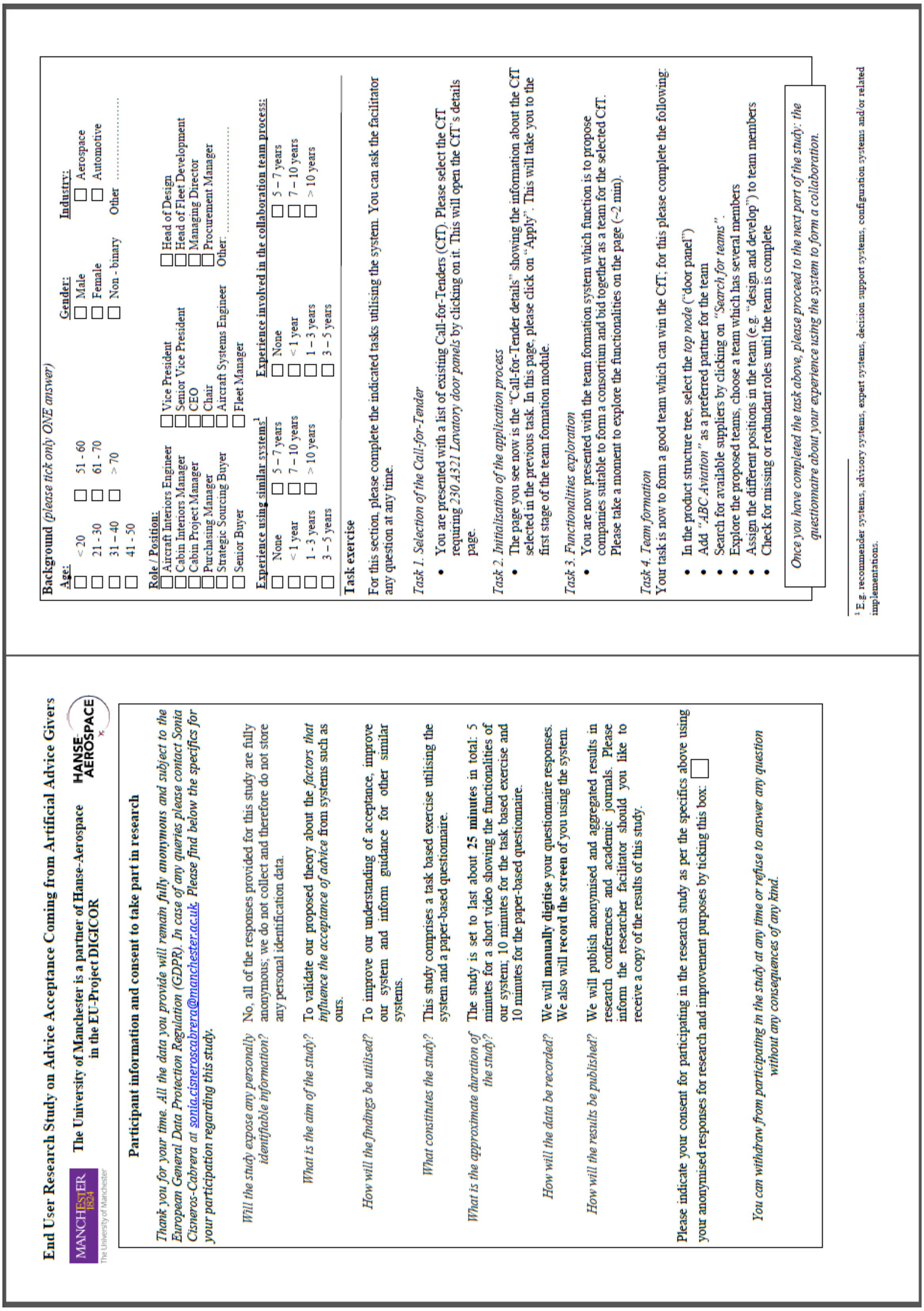
Thank you very much for your cooperation! ☺

For final and neutralised results please contact:

i.martens@hanse-aerospace.net

Figure A.5-2: Sheet handed to the participants of the usability study. Includes the questions asked.

Appendix A.6: Participant's sheet for task-based questionnaire



End User Research Study on Advice Acceptance Coming from Artificial Advice Givers

MANCHESTER 1824 The University of Manchester

The University of Manchester is a partner of Hanse-Aerospace in the EU-Project DIGICOR

HANSE-AEROSPACE

Participant information and consent to take part in research

Thank you for your time. All the data you provide will remain fully anonymous and subject to the European General Data Protection Regulation (GDPR). In case of any queries please contact Sonia Cisneros-Cabrera at sonia.cisneroscabrera@manchester.ac.uk. Please find below the specifics for your participation regarding this study.

Will the study expose any personally identifiable information?	No, all of the responses provided for this study are fully anonymous; we do not collect and therefore do not store any personal identification data.
What is the aim of the study?	To validate our proposed theory about the *factors that influence the acceptance of advice* from systems such as ours.
How will the findings be utilised?	To improve our understanding of acceptance, improve our system and inform guidance for other similar systems.
What constitutes the study?	This study comprises a task based exercise utilising the system and a paper-based questionnaire.
What is the approximate duration of the study?	The study is set to last about **25 minutes** in total: 5 minutes for a short video showing the functionalities of our system; 10 minutes for the task based exercise and 10 minutes for the paper-based questionnaire.
How will the data be recorded?	We will **manually digitise** your questionnaire responses. We also will **record the screen** of you using the system.
How will the results be published?	We will publish anonymised and aggregated results in research conferences and academic journals. Please inform the researcher facilitator should you like to receive a copy of the results of this study.

Please indicate your consent for participating in the research study as per the specifics above using your anonymised responses for research and improvement purposes by ticking this box: ☐

You can withdraw from participating in the study at any time or refuse to answer any question without any consequences of any kind.

Background *(please tick only ONE answer)*

Age:
☐ < 20 ☐ 21 - 30 ☐ 31 – 40 ☐ 41 - 50 ☐ 51 - 60 ☐ 61 - 70 ☐ > 70

Gender:
☐ Male ☐ Female ☐ Non - binary

Industry:
☐ Aerospace ☐ Automotive Other ....

Role / Position:
☐ Aircraft Interiors Engineer ☐ Cabin Interiors Manager ☐ Cabin Project Manager ☐ Purchasing Manager ☐ Strategic Sourcing Buyer ☐ Senior Buyer ☐ Vice President ☐ Senior Vice President ☐ CEO ☐ Chair ☐ Aircraft Systems Engineer ☐ Fleet Manager ☐ Head of Design ☐ Head of Fleet Development ☐ Managing Director ☐ Procurement Manager Other: ....

Experience using similar systems[1]**:**
☐ None ☐ < 1 year ☐ 1 - 3 years ☐ 3 – 5 years ☐ 5 – 7 years ☐ 7 – 10 years ☐ > 10 years

Experience involved in the collaboration team process:
☐ None ☐ < 1 year ☐ 1 – 3 years ☐ 3 – 5 years ☐ 5 – 7 years ☐ 7 – 10 years ☐ > 10 years

Task exercise

For this section, please complete the indicated tasks utilising the system. You can ask the facilitator any question at any time.

Task 1. Selection of the Call-for-Tender

- You are presented with a list of existing Call-for-Tenders (CfT). Please select the CfT requiring *230 A321 Lavatory door panels* by clicking on it. This will open the CfT's details page.

Task 2. Initialisation of the application process

- The page you see now is the "Call-for-Tender details" showing the information about the CfT selected in the previous task. In this page, please click on "Apply". This will take you to the first stage of the team formation module.

Task 3. Functionalities exploration

- You are now presented with the team formation system which function is to propose companies suitable to form a consortium and bid together as a team for the selected CfT. Please take a moment to explore the functionalities on the page (~2 min).

Task 4. Team formation

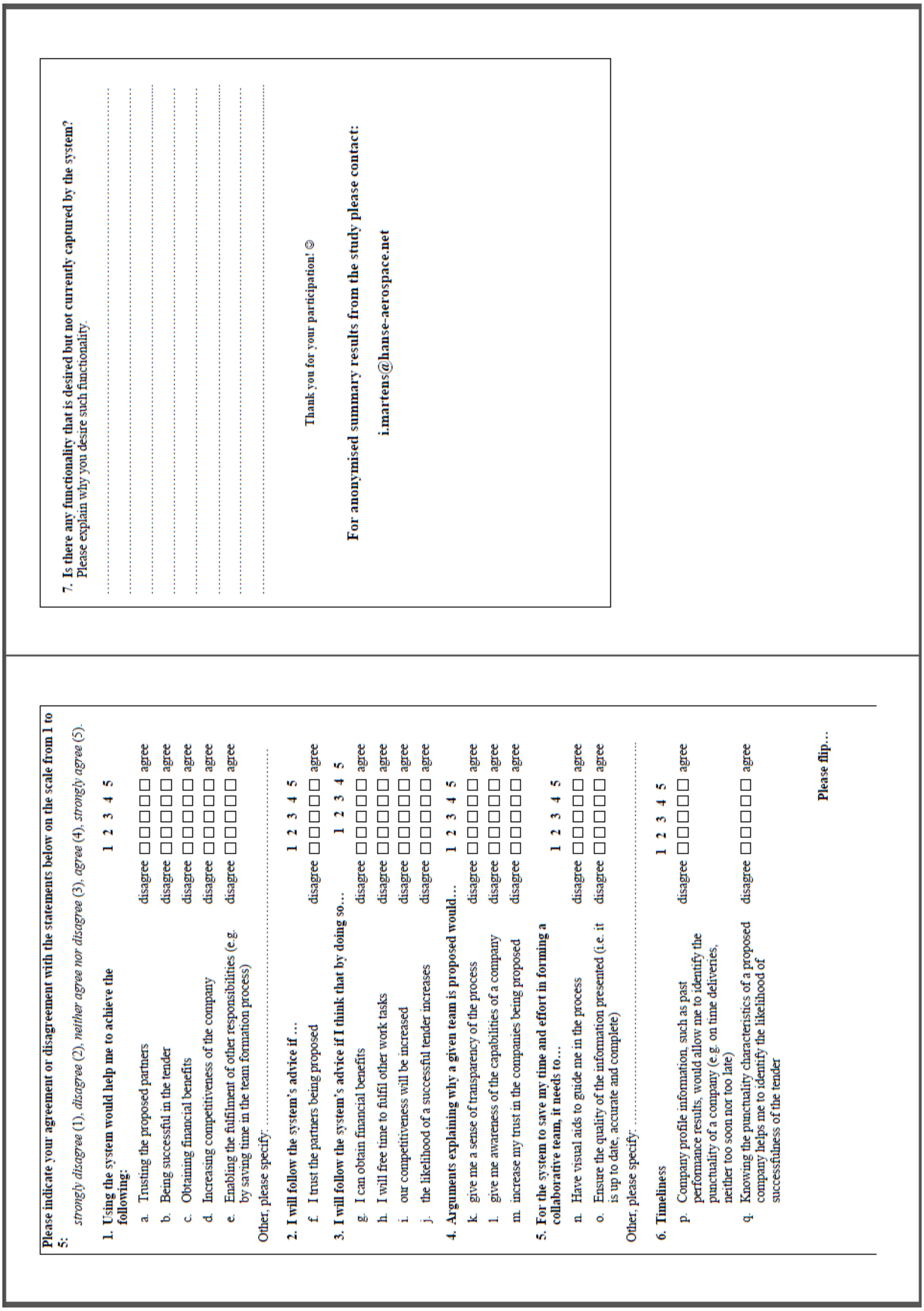
Your task is now to form a good team which can win the CfT; for this please complete the following:

- In the product structure tree, select the *top node* ("door panel")
- Add *"ABC Aviation"* as a preferred partner for the team
- Search for available suppliers by clicking on *"Search for teams"*.
- Explore the proposed teams, choose a team which has several members
- Assign the different positions in the team (e.g. "design and develop") to team members
- Check for missing or redundant roles until the team is complete

Once you have completed the task above, please proceed to the next part of the study: the questionnaire about your experience using the system to form a collaboration.

[1] E.g. recommender systems, advisory systems, expert systems, decision support systems, configuration systems and/or related implementations.

Figure A.6-1: Sheet handed to the participants of the task-based questionnaire. Includes approval sheet, demographic questions and task exercise



Please indicate your agreement or disagreement with the statements below on the scale from 1 to 5:

strongly disagree (1), *disagree* (2), *neither agree nor disagree* (3), *agree* (4), *strongly agree* (5).

1. Using the system would help me to achieve the following: **1 2 3 4 5**

a. Trusting the proposed partners disagree ☐☐☐☐☐ agree

b. Being successful in the tender disagree ☐☐☐☐☐ agree

c. Obtaining financial benefits disagree ☐☐☐☐☐ agree

d. Increasing competitiveness of the company disagree ☐☐☐☐☐ agree

e. Enabling the fulfilment of other responsibilities (e.g. by saving time in the team formation process) disagree ☐☐☐☐☐ agree

Other, please specify: ……………………………………………………………

2. I will follow the system's advice if … **1 2 3 4 5**

f. I trust the partners being proposed disagree ☐☐☐☐☐ agree

3. I will follow the system's advice if I think that by doing so… **1 2 3 4 5**

g. I can obtain financial benefits disagree ☐☐☐☐☐ agree

h. I will free time to fulfil other work tasks disagree ☐☐☐☐☐ agree

i. our competitiveness will be increased disagree ☐☐☐☐☐ agree

j. the likelihood of a successful tender increases disagree ☐☐☐☐☐ agree

4. Arguments explaining why a given team is proposed would… **1 2 3 4 5**

k. give me a sense of transparency of the process disagree ☐☐☐☐☐ agree

l. give me awareness of the capabilities of a company disagree ☐☐☐☐☐ agree

m. increase my trust in the companies being proposed disagree ☐☐☐☐☐ agree

5. For the system to save my time and effort in forming a collaborative team, it needs to… **1 2 3 4 5**

n. Have visual aids to guide me in the process disagree ☐☐☐☐☐ agree

o. Ensure the quality of the information presented (i.e. it is up to date, accurate and complete) disagree ☐☐☐☐☐ agree

Other, please specify: ……………………………………………………………

6. Timeliness **1 2 3 4 5**

p. Company profile information, such as past performance results, would allow me to identify the punctuality of a company (e.g. on time deliveries, neither too soon nor too late) disagree ☐☐☐☐☐ agree

q. Knowing the punctuality characteristics of a proposed company helps me to identify the likelihood of successfulness of the tender disagree ☐☐☐☐☐ agree

Please flip…

7. Is there any functionality that is desired but not currently captured by the system?
Please explain why you desire such functionality.

……………………………………………………………

……………………………………………………………

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Thank you for your participation! ☺

For anonymised summary results from the study please contact:

i.martens@hanse-aerospace.net

Figure A.6-2: Sheet handed to the participants of the task-based questionnaire. Includes questions after the tasks were completed

Appendix A.7: Online vignette questionnaire

MANCHESTER 1824
The University of Manchester

UoM Research Participant Information Sheet

Research Study on Advice Acceptance Coming from Artificial Advice Givers: Digitising the Formation of Manufacturing Collaborative Networks

Participant Information Sheet (PIS)

You are invited to take part in a research study which aims to establish if you would accept software-given advice. The results will help to complete a PhD project. Before you decide whether to take part, it is important for you to understand why the research is being conducted and what it will involve. Please take time to read the following information carefully before deciding whether to take part and discuss it with others if you wish. Please ask if there is anything that is not clear or if you would like more information. Thank you for taking the time to read this.

About the research

➢ **Who will conduct the research?**

Prof Nikolay Mehandjiev and Dr Pedro Sampaio, MPhil Sonia Cisneros-Cabrera, *Alliance Business School, The University of Manchester*.

Distribution support is given by Dipl. Ing. Ingo Martens, Project Manager from *Hansa-Aerospace*; Gash Bhullar, Managing Director of *Control2K*; and Dr Maria Papadaki from *The British University in Dubai* and Managing Director of the *Dubai Centre for Risk & Innovation*.

➢ **What is the purpose of the research?**

The present study has been designed to further explore the validity of our understanding about what makes end-users follow software advice in the manufacturing domains. For this, experts involved in such domains are invited to participate.

➢ **Will the outcomes of the research be published?**

Yes, the outcomes may be published in academic, conference papers and student theses.

➢ **Who has reviewed the research project?**

The project has been reviewed by the Alliance Manchester Business School Ethics Committee.

➢ **Who is funding the research project?**

The project is co-funded by Mexico's National Council for Science and Technology (abbreviated CONACYT), the European Commission (H2020) Research Programme, the Engineering and Physical Sciences Research Council (EPSRC), and the University of Manchester.

Version 1; Date 05/Dec/2019

What would my involvement be?

➢ **What would I be asked to do if I took part?**

You will be asked to watch a video which lasts 1 minute and fill a questionnaire which will take you about 8 minutes. The expected total time to complete the study is about 10 minutes.

➢ **Will I be compensated for taking part?**

No, there are no payment arrangements for compensation for your participation in the study.

➢ **What happens if I do not want to take part or if I change my mind?**

It is up to you to decide whether or not to take part. If you decide to take part you are still free to withdraw at any time without giving a reason and without detriment to yourself. Once your response is submitted, it will not be possible to remove it from the system as we will not be able to identify your specific data since it is anonymous. This does not affect your data protection rights. If you decide not to take part you do not need to do anything further.

Data Protection and Confidentiality

➢ **What information will you collect about me?**

In order to participate in this research project we will collect information about your opinion on the use of software advice systems under different system characteristics. Additionally, we will need to collect:

- Your age range (within a 10 year age range)
- Your gender (however, no sexual orientation is collected nor required)
- Your main industry domain / expertise
- Your main job description title
- Your experience in using computer systems expressed in number of years (within a 2 year range)
- Your experience in collaborative business settings expressed in number of years (within a 2 year range)

➢ **Under what legal basis are you collecting this information?**

We are collecting and storing this information in accordance with data protection law which protects your rights. These state that we must have a legal basis (specific reason) for collecting your data. For this study, the specific reason is that it is "a public interest task" and "a process necessary for research purposes".

➢ **What are my rights in relation to the information you will collect about me?**

You have a number of rights under data protection law regarding your personal information. If you would like to know more about your different rights or the way we use your personal information to ensure we follow the law, please consult our Privacy Notice for Research.

Version 1; Date 05/Dec/2019

Figure A.7-1: Content of the participant information sheet, part 1

➢ **Will my participation in the study be confidential and my information be protected?**

In accordance with data protection law, The University of Manchester is the Data Controller for this project. This means that we are responsible for making sure the information is kept secure, confidential and used only in the way you have been told it will be used. All researchers are trained with this in mind, and your data will be looked after in the following way:

Only the study team at The University of Manchester will have access to the collected information. Your name and any other identifying information will not be collected and the details of your use of the survey will be replaced with a random ID number. No IP or any system's identification is recorded. Your consent form and provided data will be retained for 10 years at a University of Manchester secure server.

When you agree to take part in a research study, anonymised information about you may be provided to researchers running other research studies in this organisation. The future research will be of a similar nature to this research project and will concern technological acceptance. Your information will only be used by researchers to conduct research in accordance with The University of Manchester's Research Privacy Notice and EPSRC policy framework on research data. This information will not identify you and will not be combined with other information in a way that could identify you.

Data restrictions will be applied according to data sharing agreements defined by the University of Manchester. Where access to the data is restricted, the published metadata should give the reason and summarise the conditions which must be satisfied for access to be granted.

This information will not identify you and will not be combined with other information in a way that could identify you. The information will only be used for the purpose of analysis and validation of automated advice acceptance knowledge and cannot be used to contact you regarding any other matter.

Please also note that individuals from The University of Manchester or regulatory authorities may need to look at the data collected for this study to make sure the project is being carried out as planned. All individuals involved in auditing and monitoring the study will have a strict duty of confidentiality to you as a research participant.

What if I have a complaint?

If you have a complaint that you wish to direct to members of the research team, please contact:

Professor Nikolay Mehandjiev **<*n.mehandjiev@manchester.ac.uk*>**

If you wish to make a formal complaint to someone independent of the research team or if you are not satisfied with the response you have gained from the researchers in the first instance then please contact:

The Research Governance and Integrity Officer, Research Office, Christie Building, The University of Manchester, Oxford Road, Manchester, M13 9PL, by emailing: research.complaints@manchester.ac.uk or by telephoning +44 0161 275 2674.

Version 1; Date 05/Dec/2019

If you wish to contact us about your data protection rights, please email dataprotection@manchester.ac.uk or write to The Information Governance Office, Christie Building, The University of Manchester, Oxford Road, M13 9PL at the University and we will guide you through the process of exercising your rights.

You also have a right to complain to the Information Commissioner's Office about complaints relating to your personal identifiable information Tel +44 0303 123 1113

Contact Details

If you have any queries about the study or if you are interested in taking part then please contact the researcher(s):

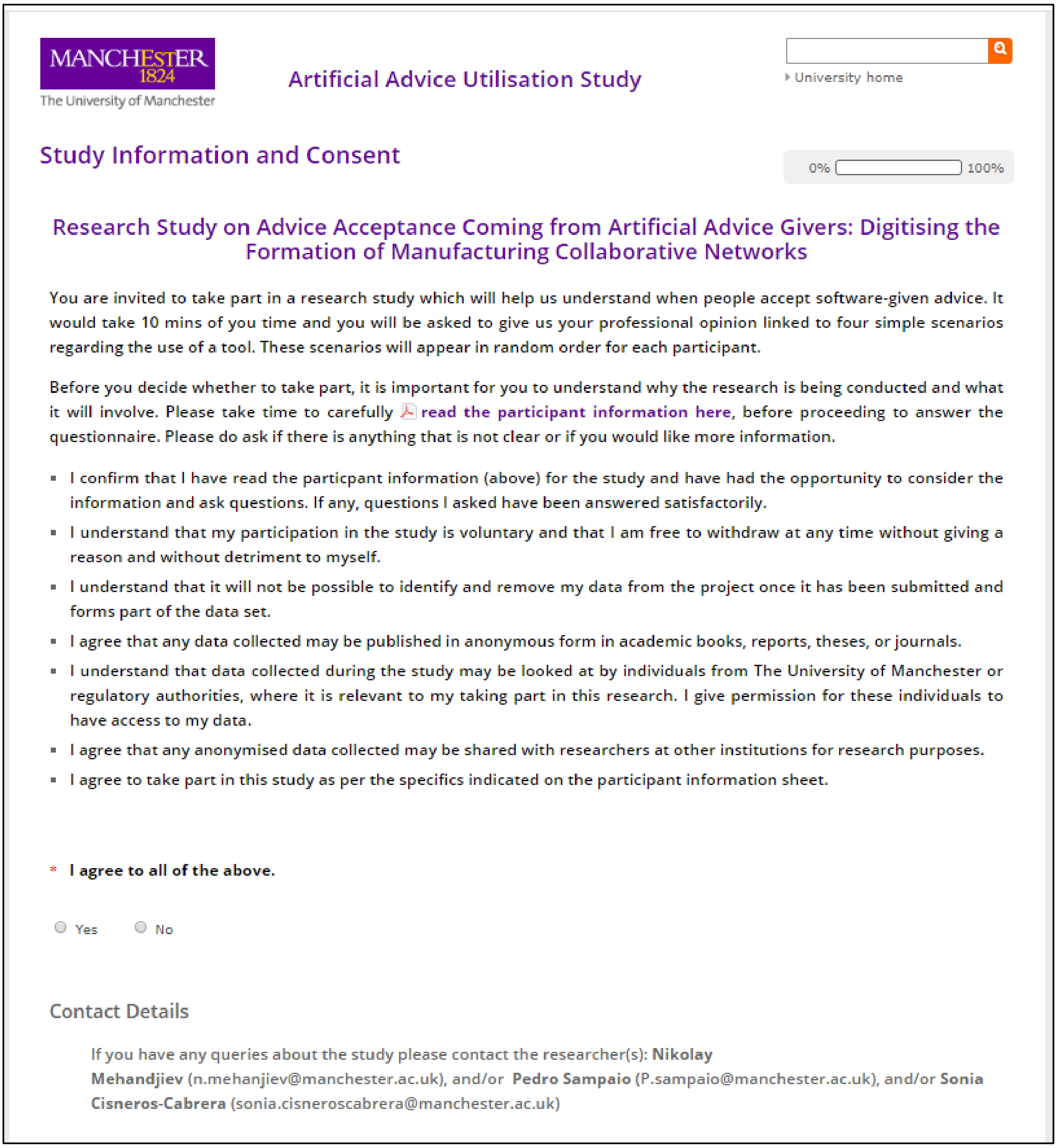
Prof Nikolay Mehandjiev (n.mehanjiev@manchester.ac.uk) and/or

Dr Pedro Sampaio (P.sampaio@manchester.ac.uk)

MPhil Sonia Cisneros-Cabrera (sonia.cisneroscabrera@manchester.ac.uk)

Version 1; Date 05/Dec/2019

Figure A.7-2: Content of the participant information sheet, part 2



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The University of Manchester

Artificial Advice Utilisation Study

University home

Study Information and Consent

0% 100%

Research Study on Advice Acceptance Coming from Artificial Advice Givers: Digitising the Formation of Manufacturing Collaborative Networks

You are invited to take part in a research study which will help us understand when people accept software-given advice. It would take 10 mins of you time and you will be asked to give us your professional opinion linked to four simple scenarios regarding the use of a tool. These scenarios will appear in random order for each participant.

Before you decide whether to take part, it is important for you to understand why the research is being conducted and what it will involve. Please take time to carefully **read the participant information here**, before proceeding to answer the questionnaire. Please do ask if there is anything that is not clear or if you would like more information.

- I confirm that I have read the particpant information (above) for the study and have had the opportunity to consider the information and ask questions. If any, questions I asked have been answered satisfactorily.
- I understand that my participation in the study is voluntary and that I am free to withdraw at any time without giving a reason and without detriment to myself.
- I understand that it will not be possible to identify and remove my data from the project once it has been submitted and forms part of the data set.
- I agree that any data collected may be published in anonymous form in academic books, reports, theses, or journals.
- I understand that data collected during the study may be looked at by individuals from The University of Manchester or regulatory authorities, where it is relevant to my taking part in this research. I give permission for these individuals to have access to my data.
- I agree that any anonymised data collected may be shared with researchers at other institutions for research purposes.
- I agree to take part in this study as per the specifics indicated on the participant information sheet.

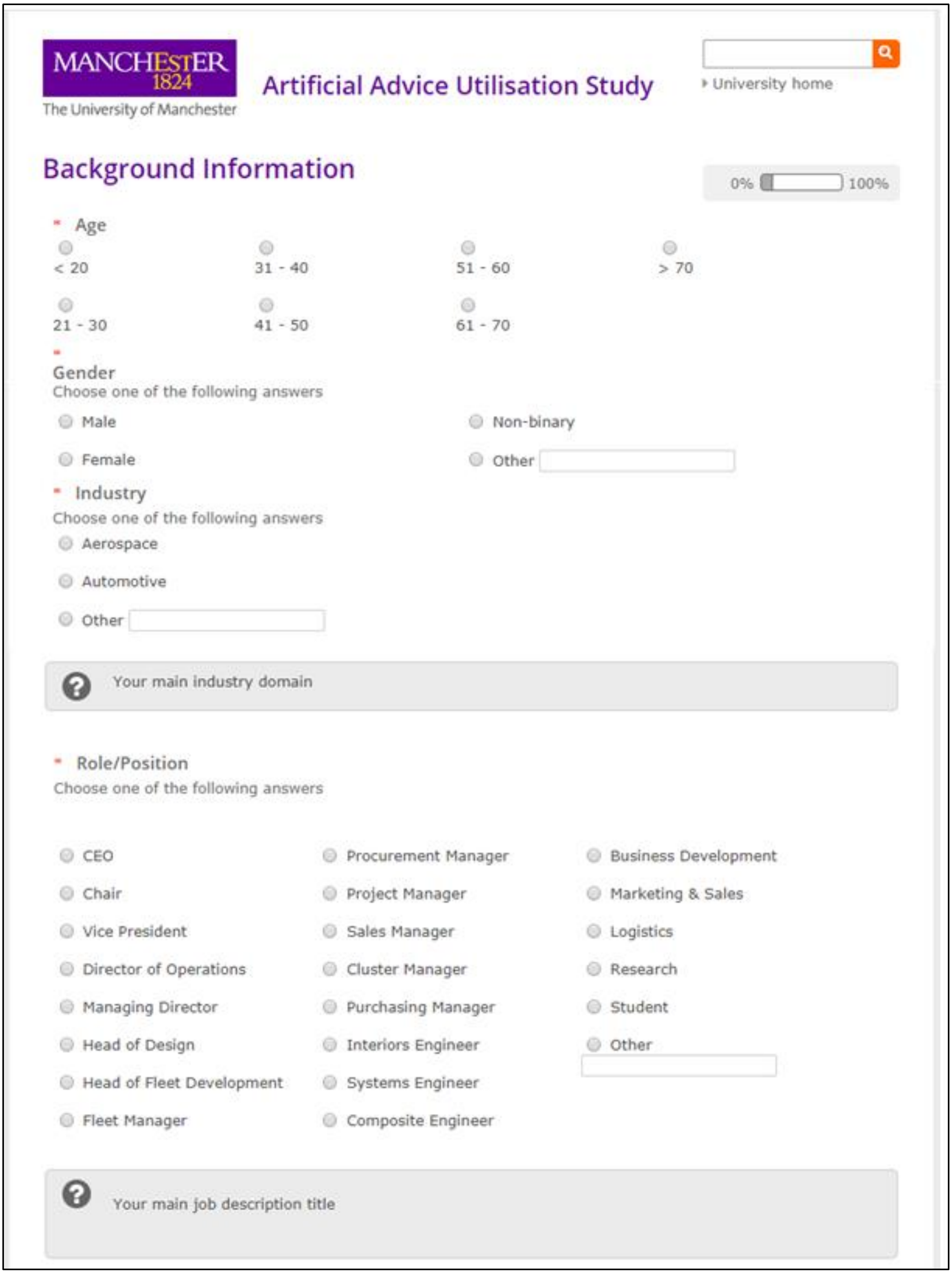
* **I agree to all of the above.**

Yes No

Contact Details

If you have any queries about the study please contact the researcher(s): **Nikolay Mehandjiev** (n.mehanjiev@manchester.ac.uk), and/or **Pedro Sampaio** (P.sampaio@manchester.ac.uk), and/or **Sonia Cisneros-Cabrera** (sonia.cisneroscabrera@manchester.ac.uk)

Figure A.7-3: Online vignette study information and consent



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Artificial Advice Utilisation Study

University home

Background Information

0% 100%

* Age

- < 20
- 21 - 30
- 31 - 40
- 41 - 50
- 51 - 60
- 61 - 70
- > 70

* Gender

Choose one of the following answers

- Male
- Female
- Non-binary
- Other

* Industry

Choose one of the following answers

- Aerospace
- Automotive
- Other

Your main industry domain

* Role/Position

Choose one of the following answers

- CEO
- Chair
- Vice President
- Director of Operations
- Managing Director
- Head of Design
- Head of Fleet Development
- Fleet Manager
- Procurement Manager
- Project Manager
- Sales Manager
- Cluster Manager
- Purchasing Manager
- Interiors Engineer
- Systems Engineer
- Composite Engineer
- Business Development
- Marketing & Sales
- Logistics
- Research
- Student
- Other

Your main job description title

Figure A.7-4: Online vignette study demographic questions, part 1

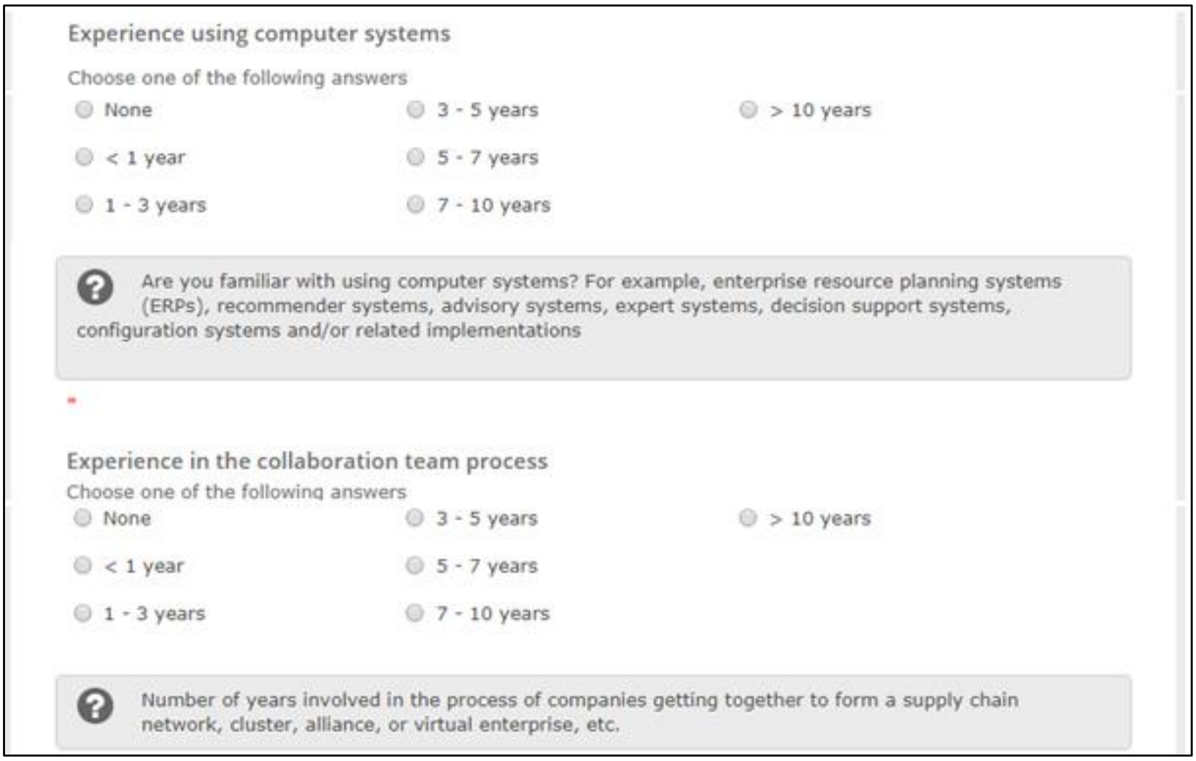

Figure A.7-5: Online vignette study demographic questions, part 2

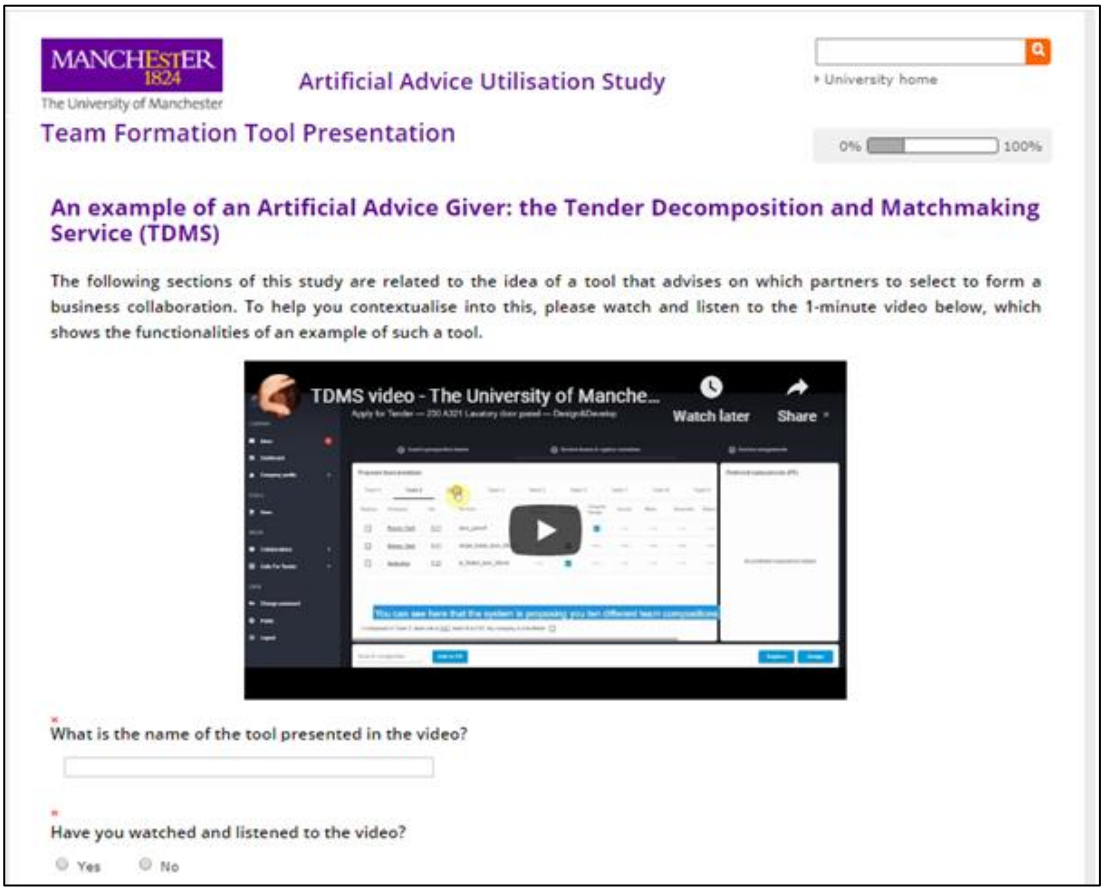

Figure A.7-6: Online vignette study tool presentation section


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Selecting Business Partners with the Help of an Artificial Advisor

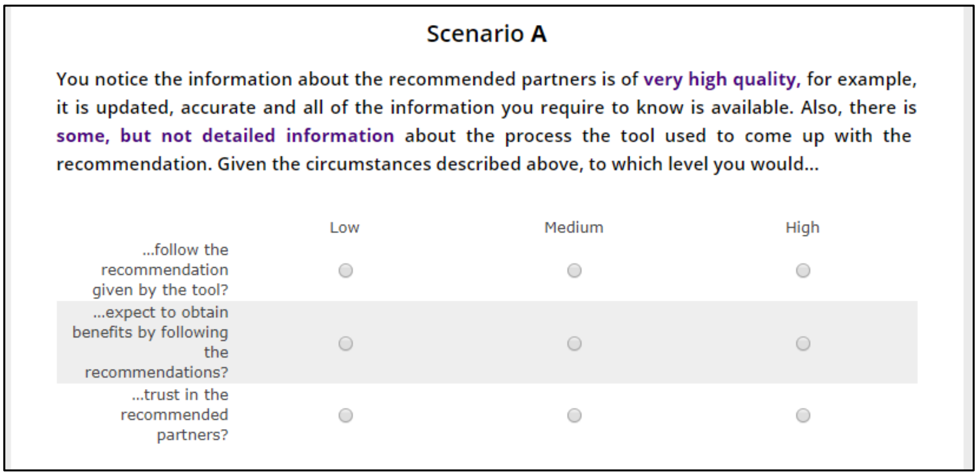
0% 100%

*

Please read the scenario below and in the questions select the option that reflects more closely your opinion given the scenario.

You find a tender opportunity suitable for your organisation; however, on a closer inspection, it appears that the requirements cannot be met by your organisation alone. To participate, you will need to find partners to team-up with. You then remember about this new tool which can recommend potential partners for the team. Now, you are logged into the tool and...

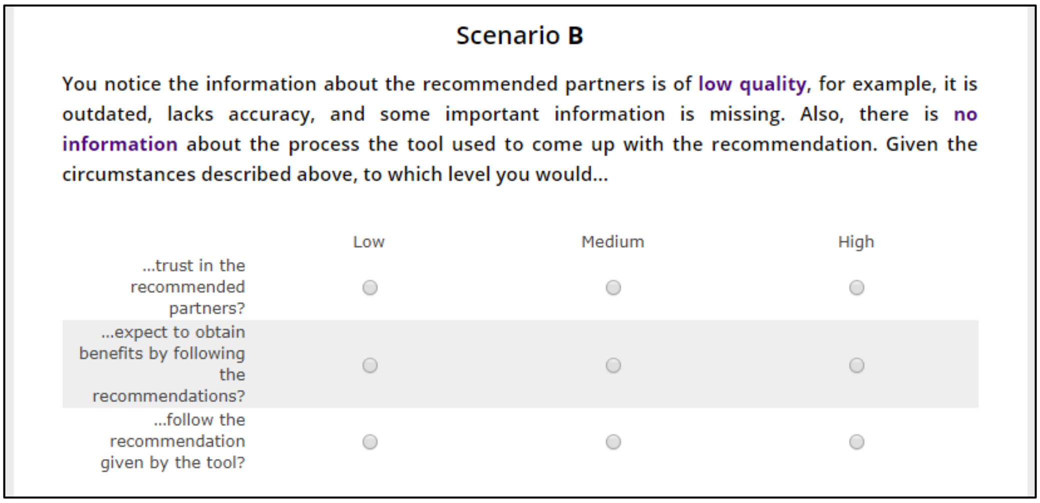
Figure A.7-7: Online vignette study base scenario


Scenario A

You notice the information about the recommended partners is of **very high quality**, for example, it is updated, accurate and all of the information you require to know is available. Also, there is **some, but not detailed information** about the process the tool used to come up with the recommendation. Given the circumstances described above, to which level you would...

	Low	Medium	High
...follow the recommendation given by the tool?			
...expect to obtain benefits by following the recommendations?			
...trust in the recommended partners?			

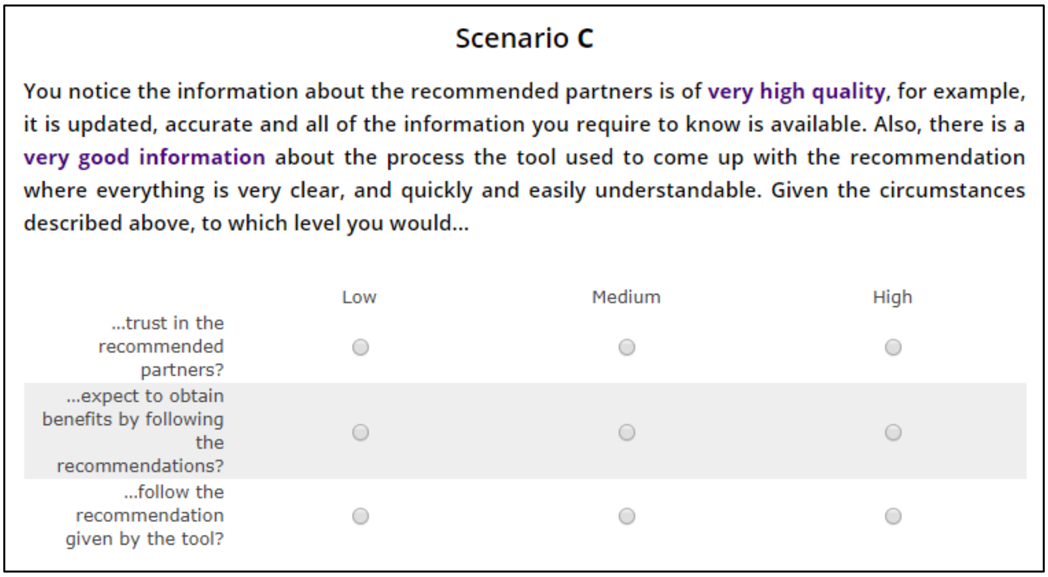
Figure A.7-8: Online vignette study, scenario A (high information quality, medium transparency)


Scenario B

You notice the information about the recommended partners is of **low quality**, for example, it is outdated, lacks accuracy, and some important information is missing. Also, there is **no information** about the process the tool used to come up with the recommendation. Given the circumstances described above, to which level you would...

	Low	Medium	High
...trust in the recommended partners?			
...expect to obtain benefits by following the recommendations?			
...follow the recommendation given by the tool?			

Figure A.7-9: Online vignette study, scenario B (low information quality, low transparency)

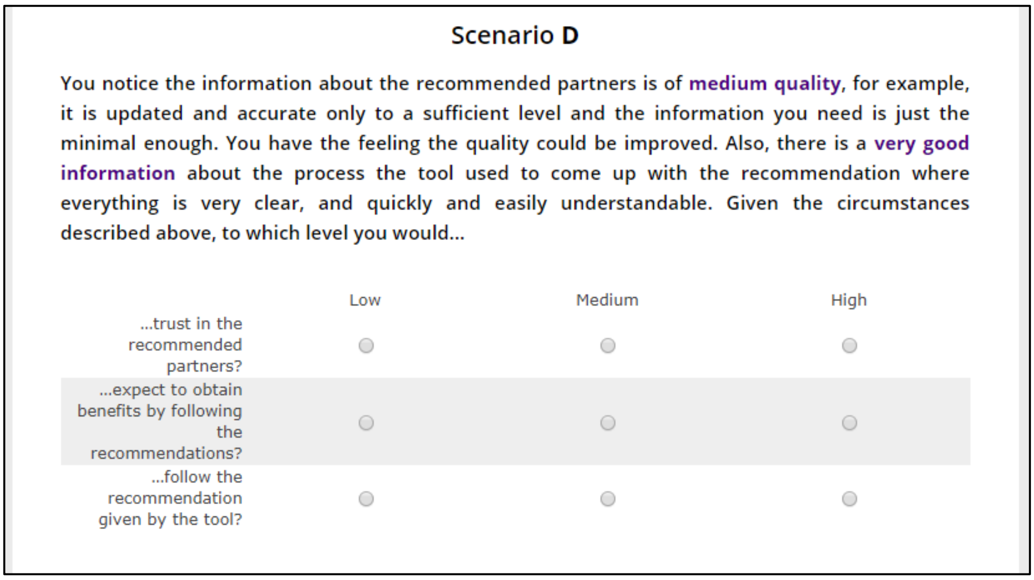


Scenario C

You notice the information about the recommended partners is of **very high quality**, for example, it is updated, accurate and all of the information you require to know is available. Also, there is a **very good information** about the process the tool used to come up with the recommendation where everything is very clear, and quickly and easily understandable. Given the circumstances described above, to which level you would...

	Low	Medium	High
...trust in the recommended partners?	○	○	○
...expect to obtain benefits by following the recommendations?	○	○	○
...follow the recommendation given by the tool?	○	○	○

Figure A.7-10: Online vignette study, scenario C (high information quality, high transparency)



Scenario D

You notice the information about the recommended partners is of **medium quality**, for example, it is updated and accurate only to a sufficient level and the information you need is just the minimal enough. You have the feeling the quality could be improved. Also, there is a **very good information** about the process the tool used to come up with the recommendation where everything is very clear, and quickly and easily understandable. Given the circumstances described above, to which level you would...

	Low	Medium	High
...trust in the recommended partners?	○	○	○
...expect to obtain benefits by following the recommendations?	○	○	○
...follow the recommendation given by the tool?	○	○	○

Figure A.7-11: Online vignette study, scenario D (medium information quality, high transparency)

Appendix A.8: Studies' demographic data

Laddering Interviews

From the 20 valid respondents, there were 2 females (10%) and 18 male respondents (90%) which is a sample consistent with the known female minority of the aerospace industry (Halleran 2019). 40% of the respondents were 31-40 years old, followed by 30% in the 51–60 group, and 20% in the 41 – 50 group. There was one respondent younger than 30 and one older than 60 years. The respondent's domain of expertise was indicated as Aerospace for 75% of the answers and one each in “Industrial”, “Research & Consulting”, and “Logistics”. From those, 20% of the participants are CEOs, 15% Logistics Professionals, 10% Managing Directors, 10% Sales Managers, and the rest were an Aviation Journalist, a Cabin Project Manager, a Chair, a Corporate Manager, a Head of Design, an Operations Director, a Product Manager, a Project Manager and a Research professional. 35% have more than 10 years of experience in the forming collaborative teams. 45% declared to have no experience using computerised systems, and 20% declared having more than 10 years of experience using them.

Usability Study

From the 36 participants, 12 were in the 41-50 age group, 11 in the 21-30, 8 in the 31-40 and 5 in the 51-60, where 75% were males, 22% females and 3% unspecified. As in the laddering interviews study, there was a variety of roles from participants coming from the aerospace and other manufacturing domains (e.g. metallurgy). The roles of the participants include aircraft interiors engineers (2 respondents), purchasing managers (3), aircraft systems engineers (3), vice president (1), CEO (3), managing director (1), sales (8), and a diversified participation from research, cluster managers, business development, composite engineers and business managers. Only 1 person indicated null experience in the partner selection process, and 10 people had null experience in the use of computer systems in support of their role responsibilities.

Task-based Questionnaire

German Aviation Cluster

The participants in this study were distributed in the age groups of 21-30 (1 respondent), 31-40 (1) and 41-50 (3), where 1 participant was female. The roles of the participants included 4 business managers and 1 vice president in the aerospace domain where only 1 had more than 10 years of experience in the partner selection process, and 2 declared to have no experience.

Welsh Automotive Cluster

The participants in this study were distributed in the age groups of 21-30 (5 respondents), 31-40 (2), 41-50 (4), 51-60 (6), and 61-70 (1), where 1 participant was female and 1 was not specified (left in blank). The roles of the participants included 5 director levels included 2 CEO, 2 IT graduates, 1 technical director, 5 project managers, and one each in research, sales, systems engineer, control, and advisor roles where 8 had more than 10 years of experience in the partner selection process, and only 1 declared to have no experience.

Vignettes Study

We obtained 14 responses where 36% of the participants are in the 51-60 age group, 29% in the 31-40, 21% in the 41-50, and 7% each in the 21-30 and 61-70 age groups. From these, 29% are females. The main industries where the participants work vary, with 50% from the aerospace domain, 7% from the automotive domain, and 43% from "other". Among the category of "other", we find: "Service, Systems, Industrial Electronics, Information technologies, Food, and Construction". Among the roles of the respondents, 21% are Project Managers, 14% are CEOs, 14% Directors of Operations, and 7% each are diversified in the positions of managing director, cluster manager, purchasing manager, systems engineer, business developer, safety advisor, and researcher.

Our respondents also indicated their experience in years using computer systems for their jobs, where 71% indicated more than 10 years, 21% between 7 to 10 years, and 7% between 5 and 7 years. The experience in partner selection ranged from 29% with experience of more than 10 years, 1 CEO and 2 Directors of Operations indicating no experience (21%), 21% with experience between 3-5 years, 14% with experience of less than a year, and 7% each with experience between 5-7 years, and 7-10 years.

References

Halleran, M. S. 2019. "Gender Balance in Aviation," The Collegiate Aviation Review International (37:1). (https://ojs.library.okstate.edu/osu/index.php/CARI/article/view/7821).

Appendix B. Supplementary data for Chapter 4

Appendix B.1: Technical evaluation data

CfT data

cftID	cftTitle	contractType	targetItem
1	600 Lavatory wash table module	Contract Build to Print	Lavatory_wash_table_module1
2	150 Lavatory door module	Contract Service contract	Lavatory door module
3	35000 Mirror inside lavatory	Contract for work & labour	Mirror inside lavatory
4	780 Lavatory door handle	Contract Build to Print	Lavatory door handle
5	230 Lavatory door panel	Contract Design & Build	Door panel
cftID	**capabilitiesRequiredTechnology**	**capabilitiesRequired ATA**	**goal**
1	Technology measurement, technology forming	ATA_25	Design & Develop, Make

2	Technology chip removing processes, technology cutting, technology machining, Technology grinding	ATA_52	Deliver
3	Technology surface treatment	ATA_25	Make, Deliver
4	Technology machining, technology heat treatment	ATA_52	Make, Source
5	Technology chip removing processes, technology grinding	ATA_52	Design & Develop, Source
cftID	**targetRegionsRequired**	**minNumberOfEmployeesRequired**	**minAnnualTurnoverRequired**
1	North America, South America, Middle East	1000	10000000.0
2	Asia, Africa	200	10000000.0
3	Australia, Europe, Africa, Asia	500	0.0
4	Australia, Africa, Germany, North America	500	1000000.0
5	North America, Africa, Asia	200	1000000.0

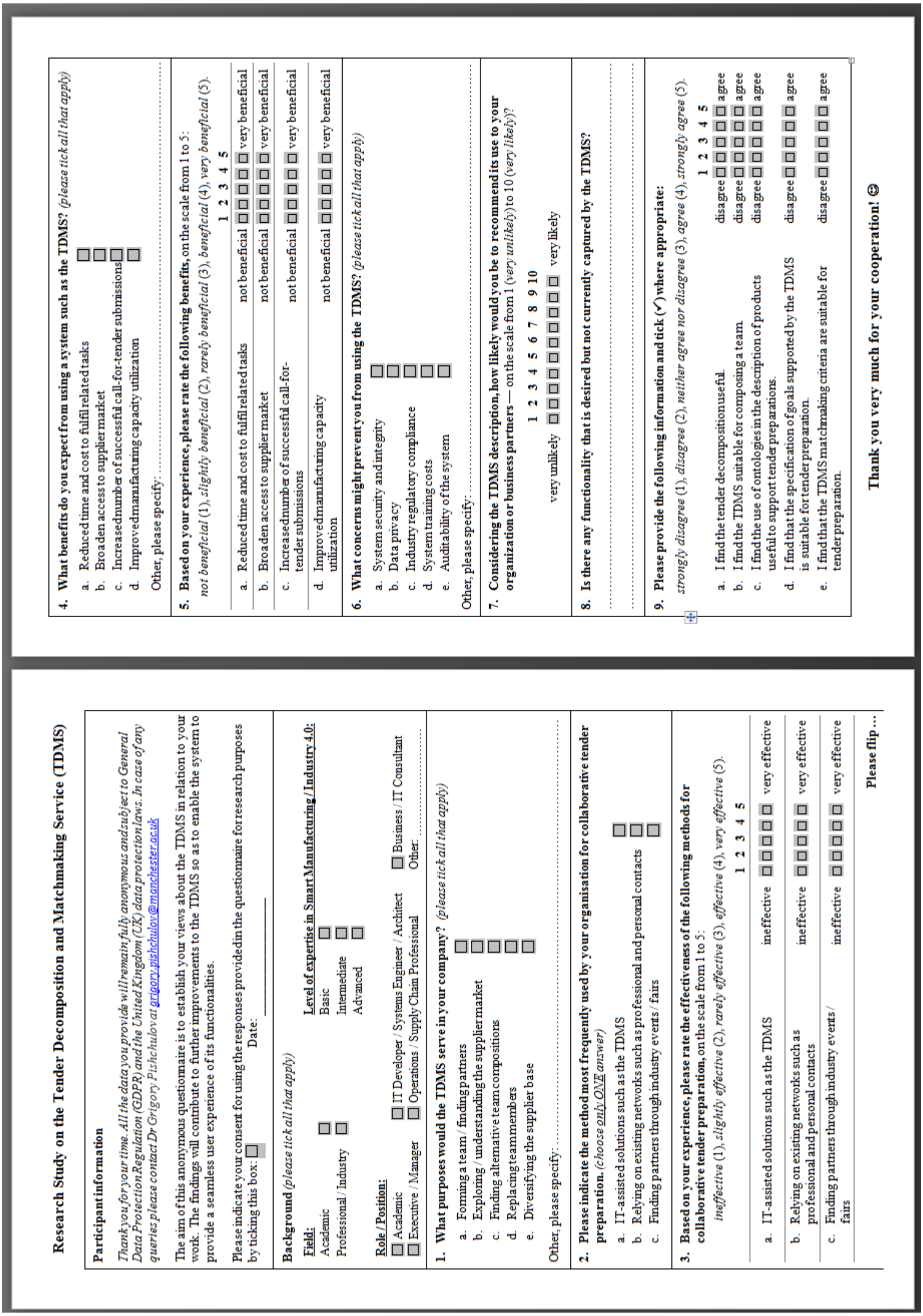
Company data

companyID	companyName	numberOfEmployees	annualTurnover	contractTypes
1	AviaDesign	1001-5000	10000000-100000000	Contract Build to Print
2	CT Ltd.	1001-5000	10000000-100000000	Contract Buy
3	Ufly Control	201-500	10000000-100000000	Contract Service contract
4	Lavino Ltd.	501-1000	0-1000000	Contract for work & labour
5	AirFrames Ltd.	501-1000	0-1000000	Contract for work & labour
6	Diehl Ltd	501-1000	0-1000000	Contract for work & labour
7	CoUK coop	501-1000	10000000-100000000	Contract Build to Print, Contract Service Contract
8	Design Vital Ltd	501-1000	10000000-100000000	Contract Build to Print
9	ABC Aviation	501-1000	10000000-100000000	Contract Build to Print, Contract Design & Build
10	Openlane Plc	501-1000	10000000-100000000	Contract Build to Print, Contract Design & Build
11	Newex Tech	201-500	10000000-100000000	Contract Design & Build
12	Iselectrics	201-500	10000000-100000000	Contract Design & Build
13	Ontoair	201-500	0-1000000	Contract Design & Build

14	Bluetronics	51-200	10000000-100000000	Contract Design & Build

companyID	capabilitiesSpecialty	targetRegions	capabilitiesTechnology
1	Lavatory_wash_table_module1: Make, Source	North America, Middle East	Technology measurement, technology forming
2	Lavatory_wash_table_module1: Design & Develop, Plan & Manage	South America, Middle East	Technology forming
3	Lavatory door module: Deliver, Make, Source	Asia, Africa	Technology chip removing processes, technology cutting, technology machining, technology grinding
4	Mirror inside lavatory: Make, Deliver	Australia, Europe, Africa, Asia	Technology surface treatment
5	Mirror inside lavatory: Deliver	Australia, Europe	Technology surface treatment
6	Mirror inside lavatory: Make, Plan & Manage	Europe, Africa, Asia	Technology surface treatment
7	Lavatory lever type handle for single blade door: Make, Deliver	Australia, Africa, Germany	Technology machining
8	Lavatory lever alternate materials: Make, Deliver	Australia, North America	Technology heat treatment
9	Lavatory standard handle for single blade door: Deliver, lavatory lever type handle for single blade door: Deliver	Africa, Germany, North America	Technology machining, technology heat treatment
10	Lavatory door handle: Source, Assemble, Plan & Manage	Africa, Germany, North America	Technology machining, technology heat treatment
11	Single blade door 20inch: Design & Develop, door panel: Plan & Manage, Source, Integrate Design, Design & Develop	North America	Technology chip removing processes
12	Bi folded door 20inch: Design & Develop, Plan & Manage, Source	North America, Asia	Technology grinding
13	Bi folded door 20inch: Design & Develop, Plan & Manage, Source	North America, Asia	Technology chip removing processes
14	Single blade door 20inch: Design & Develop, Plan & Manage, Source	Africa	Technology grinding

Appendix B.2: Survey instrument


Research Study on the Tender Decomposition and Matchmaking Service (TDMS)

Participant information

Thank you for your time. All the data you provide will remain fully anonymous and subject to General Data Protection Regulation (GDPR) and the United Kingdom (UK) data protection laws. In case of any queries please contact Dr Grigory Pishchulov at grigory.pishchulov@manchester.ac.uk

The aim of this anonymous questionnaire is to establish your views about the TDMS in relation to your work. The findings will contribute to further improvements to the TDMS so as to enable the system to provide a seamless user experience of its functionalities.

Please indicate your consent for using the responses provided in the questionnaire for research purposes by ticking this box: ☐ Date: ____________

Background *(please tick all that apply)*

Field:
Academic ☐
Professional / Industry ☐

Level of expertise in Smart Manufacturing / Industry 4.0:
Basic ☐
Intermediate ☐
Advanced ☐

Role / Position:
☐ Academic ☐ IT Developer / Systems Engineer / Architect ☐ Business / IT Consultant
☐ Executive / Manager ☐ Operations / Supply Chain Professional Other: ....

1. What purposes would the TDMS serve in your company? *(please tick all that apply)*

a. Forming a team / finding partners ☐
b. Exploring / understanding the supplier market ☐
c. Finding alternative team compositions ☐
d. Replacing team members ☐
e. Diversifying the supplier base ☐

Other, please specify: ....

2. Please indicate the method most frequently used by your organisation for collaborative tender preparation. *(choose only ONE answer)*

a. IT-assisted solutions such as the TDMS ☐
b. Relying on existing networks such as professional and personal contacts ☐
c. Finding partners through industry events / fairs ☐

3. Based on your experience, please rate the effectiveness of the following methods for collaborative tender preparation, on the scale from 1 to 5:
ineffective (1), *slightly effective* (2), *rarely effective* (3), *effective* (4), *very effective* (5).

		1 2 3 4 5	
a. IT-assisted solutions such as the TDMS	ineffective	☐ ☐ ☐ ☐ ☐	very effective
b. Relying on existing networks such as professional and personal contacts	ineffective	☐ ☐ ☐ ☐ ☐	very effective
c. Finding partners through industry events / fairs	ineffective	☐ ☐ ☐ ☐ ☐	very effective

Please flip …

4. What benefits do you expect from using a system such as the TDMS? *(please tick all that apply)*

a. Reduced time and cost to fulfil related tasks ☐
b. Broaden access to supplier market ☐
c. Increased number of successful call-for-tender submissions ☐
d. Improved manufacturing capacity utilization ☐

Other, please specify: ....

5. Based on your experience, please rate the following benefits, on the scale from 1 to 5:
not beneficial (1), *slightly beneficial* (2), *rarely beneficial* (3), *beneficial* (4), *very beneficial* (5).

		1 2 3 4 5	
a. Reduced time and cost to fulfil related tasks	not beneficial	☐ ☐ ☐ ☐ ☐	very beneficial
b. Broaden access to supplier market	not beneficial	☐ ☐ ☐ ☐ ☐	very beneficial
c. Increased number of successful call-for-tender submissions	not beneficial	☐ ☐ ☐ ☐ ☐	very beneficial
d. Improved manufacturing capacity utilization	not beneficial	☐ ☐ ☐ ☐ ☐	very beneficial

6. What concerns might prevent you from using the TDMS? *(please tick all that apply)*

a. System security and integrity ☐
b. Data privacy ☐
c. Industry regulatory compliance ☐
d. System training costs ☐
e. Auditability of the system ☐

Other, please specify: ....

7. Considering the TDMS description, how likely would you be to recommend its use to your organization or business partners — on the scale from 1 (*very unlikely*) to 10 (*very likely*)?

1 2 3 4 5 6 7 8 9 10
very unlikely ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ very likely

8. Is there any functionality that is desired but not currently captured by the TDMS?

....
....

9. Please provide the following information and tick (✓) where appropriate:
strongly disagree (1), *disagree* (2), *neither agree nor disagree* (3), *agree* (4), *strongly agree* (5).

		1 2 3 4 5	
a. I find the tender decomposition useful.	disagree	☐ ☐ ☐ ☐ ☐	agree
b. I find the TDMS suitable for composing a team.	disagree	☐ ☐ ☐ ☐ ☐	agree
c. I find the use of ontologies in the description of products useful to support tender preparations.	disagree	☐ ☐ ☐ ☐ ☐	agree
d. I find that the specification of goals supported by the TDMS is suitable for tender preparation.	disagree	☐ ☐ ☐ ☐ ☐	agree
e. I find that the TDMS matchmaking criteria are suitable for tender preparation.	disagree	☐ ☐ ☐ ☐ ☐	agree

Thank you very much for your cooperation! ☺

Figure B.1: Participant's sheet for the Expert feedback survey

Appendix B.3: Data model

Company data

Attribute	Type	Description	Notes
companyID	Identifier	Unique company identification	-
companyName	Identifier	Legal company name	
shortDescription	Identifier	A brief description of the company	-
acceptCurrencyNegotiation	Characteristic	Y = Yes, N = No, null if unknown	E.g. one company operates in Euro and another one in Pound Sterling
numberOfEmployees	Characteristic	To select from a range of employees, e.g. 501–200	One company has only one
annualTurnover	Characteristic	To select from a range of turnover size in EUR, e.g. 0M–1M	One company has only one
contractTypes	Characteristic	To select from a list of contract types, e.g. Build-to-Print	One company can have many
certifications	Characteristic	To select from a list of certificates, e.g. ISO 9110	One company can have many
targetRegions	Characteristic	Regions, for which the company can make its products. To select from a list of regions, e.g. Africa	One company can have many
departments	Characteristic	To select from Service, Sales and Manufacturing	One company can have many
departmentLocations	Characteristic	To select the location of the declared department. E.g. Sales in the UK, Manufacturing in Italy	One department can have many locations e.g. if the department is spread in separated places
capabilities	Characteristic	Company capabilities expressed in terms of ATA Classification, Materials, Technology and Specialty (see Appendix A3 for illustration)	Speciality is the most important characteristic and is mandatory. It is associated with the product ontology and further requires specification of a goal that the company can fulfil for the respective item (e.g. Lavatory – make), as well as capacityPerWeek

Call-for-tenders (CfT) data

Attribute	Type	Description	Notes
cftID	Identifier	Unique identifier of the CfT	-
cftTitle	Identifier	Title of this CfT	For displaying purposes
issuingCompany	Identifier	The company that issues and owns the CfT	Company ID
estimatedCostEUR	Characteristic	Estimation for information purposes	Can have decimals
estimatedEffortPersonMonths	Characteristic	Estimation for information purposes	Cannot have decimals
contractType	Characteristic	To select from a range of contract types, e.g. Build-to-Print	One CfT can have several contract types
offersDeadline	Characteristic	Date until all offers must be submitted	-
dueDateFixed	Characteristic	Due date if there is no recursive date	Used if the final delivery date is a unique fixed date, otherwise null
dueDateRecursive	Characteristic	First date if the due dates are recursive	Used if the delivery dates are part of a recursive date arrangement, otherwise null
totalDeliveriesRecursive	Characteristic	Number of repetitions of the recursive date. E.g. if recursivePeriod is 'year' and recursivePeriodNumber is 2 then the value of 3 here means that 3 deliveries will be expected every 2 years	-
recursivePeriod	Characteristic	Time unit {day, week, month, year} for specifying the time span separating recursive due dates	If dueDateFixed is null and dueDateRecursive is not
recursivePeriodNumber	Characteristic	The value specifies how many recursivePeriod's comprise the time span that separates recursive due dates	If dueDateFixed is null and dueDateRecursive is not
targetItem	Requirement	Item, i.e. product/service requested by the CfT	Defined in terms of the product ontology. One CfT has exactly one target item
goal	Requirement	To select from 'Plan & Manage', 'Design & Develop', 'Integrate Design', 'Source', 'Make', 'Assemble', and 'Deliver'	One CfT can have many goals. A targetItem with a goal represents a Specialty (see also the table 'Company data' above)
targetItemQuantity	Requirement	The quantity of a specified item to be delivered	-

targetItemQuantityUnit	Requirement	Unit of measurement for the targetItemQuantity	E.g. piece, meter, kg, litre, cubic_meter
capabilitiesRequired	Requirement	Capabilities required by the CfT in terms of ATA, Materials and Technology characteristics	Specialities are not considered here because they are specified by the targetItem and goal requirements. One CfT can have many capabilities required
minAnnualTurnoverRequired	Requirement	To select from 0, 1M, 10M, 100M, 500M, 1B, 10B, 100B, 500B	One CfT has only one
minNumberOfEmployeesRequired	Requirement	To select from 1, 2, 10, 50, 200, 500, 1000, 5000, 10000, 100000, 500000	One CfT has only one
targetRegionsRequired	Requirement	Regions which the targetItem needs to accommodate to. To select from the list of regions, e.g. Africa	One CfT can have many
certificationsRequired	Requirement	To select from the list of certificates, e.g. ISO 9110	One CfT can have many

Team data

Attribute	Type	Description	Notes
teamID	Identifier	Team's unique identification	Assigned by TDMS
collaborationID	Identifier	Collaboration's unique identification	Assigned by the service that handles the VE operation and evolution phases. Initially null until receiving the assigned ID from the external service
cftID	Characteristic	CfT, in response to which this team has been formed	CfT ID. One team has one CfT. One CfT can have many different teams (e.g. created by different TDMS users)
assignments	Characteristic	Assignments expressed as 'which company is doing what to this CfT'. Allocated in a separate entity to allow having several assignments in a single team	TDMS assigns the ID to this. Details of the content can be found in the table 'Assignments data' below

Assignments data

Attribute	Type	Description	Note
assignmentID	Identifier	Unique identifier of a task assignment within a team	TDMS assigns this ID
company	Characteristic	The company assigned to perform the respective task	Company ID
item	Characteristic	The item associated with the respective task	Defined in terms of the product ontology

parentItem	Characteristic	Item immediately containing the given item, if any	As defined by the product ontology
goal	Characteristic	To select from 'Plan & Manage', 'Design & Develop', 'Integrate Design', 'Source', 'Make', 'Assemble', and 'Deliver'. Applicable to the item above	One assignment has one item with one goal associated with it. An item combined with a goal represents a Specialty (see also the table 'Company data' above)
collaboration Decision	Characteristic	To select from: open (no company was assigned), invited (the company was assigned and invited but no decision has been received — the default), rejected (invitation rejected), accepted (invitation accepted), quit (can only be if collaboration decision was 'accepted' previously)	The service which handles the team operation and evolution will communicate this decision to TDMS
riskScore	Characteristic	The estimated risk of this company for this given CfT	Results of risk calculation will be communicated to TDMS by an external service (see also Section 'REST Calls' in Appendix A2).

Appendix B.4: TDMS events and REST calls

TDMS Events			
Group Identifier	*Name*	*Produced when*	*Usage for the TDMS*
Produced by TDMS			
TeamFormed	TeamFormed	A new team has been selected using the TDMS	To publish the new/updated team resulting from the use of TDMS (company + item-goal)
	TeamUpdated	Given a team already formed, repeated use of the TDMS creates an addition to the team or a replacement	
Consumed by TDMS			
Call-for-tenderData	CfTcreated	A new CfT has been created	To find the target item (i.e., product/service) of the CfT and decompose it later. To find the CfT information required for the matchmaking algorithm (e.g. contract types).
	CfTupdated	A CfT has been modified	
	CfTdeleted	A CfT has been deleted	
CompanyData	CompanyCreated	A new company profile has been created	To save company details and display them when the user wants to know details about the proposed companies. To search in the details
	CompanyUpdated	A company profile has been modified	

	CompanyDeleted	A company profile has been deleted	and include/discard the company in the matchmaking algorithm.
CollaborationCreated	CollaborationCreated	After the teamFormed event is consumed, a collaboration area is created for the team, and a collaboration identifier is assigned	To keep track of the team that was created using the TDMS and to allow the user come back to TDMS in case they need it, without making the user do everything 'from scratch' for teams that have been previously created. TDMS will receive collaborationID and associate it with the corresponding teamID. E.g., on consuming CollaborationCreated(103, 520), TDMS will associate collaborationID 520 with teamID 103.
CollaborationDecision	CollaborationDecision	When a company accepts or rejects an invitation to join a team. When a company quits a team	To keep track of the dynamism of the team, and allow the users to look for open positions avoiding recommendations of companies which already rejected or quit. Manual addition can be done, however, for such cases in which a company quit by mistake, for example.

TDMS REST calls			
Group Identifier	*Name*	*Description*	*REST call syntax*
CompanyData	addCompany	Creates a company in the ontology	
	readCompany	Reads all companies' data from the ontology	
	updateCompany	Updates a company's data in the ontology	updatecompany/companyID
	deleteCompany	Deletes a company from the ontology	deletecompany/companyID
CfTData	addCfT	Creates a call-for-tenders in the ontology	
	readCfT	Reads all call-for-tenders data from the ontology	
	readCftById	Reads a specified call-for-tenders from the ontology	cftbyid/cftID

	updateCfT	Updates a call-for-tenders data in the ontology	updateCfT/cftID
	deleteCfT	Deletes a call-for-tenders data in the ontology	deleteCfT/cftID
Matchmaking	Matchmaking	Executes the matchmaking algorithm	matchmaking/targetItemID/cftID matchmaking/subItemID/cftID
Product & Enums	rootItems	Reads the list of root items from the ontology	
	treeStructure	Reads the structure of a specified item	treeStructure/Item where item represents an ID which can be either a root item or any of its parts
	itemClassSearch	Reads the hierarchy of product categories	
	enums	Reads the ranges of enum attributes from the ontology	
TeamsData	replaceTeam	Replaces team members	replaceTeam/targetItemID/cftID
	checkTeam	Checks for possible gaps in the team compositions	checkteam/tagetItem/cftID
	addTeam	Adds a team to the ontology	Addteam/targetItem/cftID
	updateTeam	Updates a team in the ontology	Updateteam/targetItem/cftID/teamID

Appendix B.5: Ontology extract

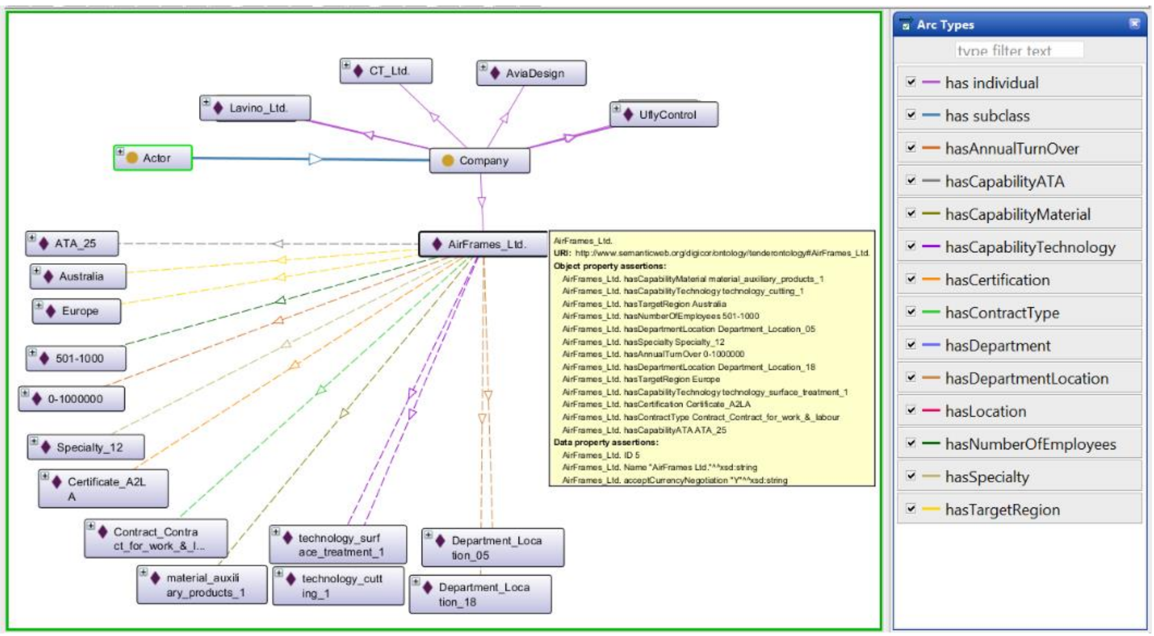


Figure B.2: Ontology extract representing a company

Appendix C. Supplementary data for Chapter 6

Appendix C.1: Design principles for computerised advisors supporting business partner selection

Design principle 1: The type of information provided should aid trust and facilitate decision making (type of information). Designers of computerised business advisors should ensure they include a certain type of information, such as risk indicators, and company details, which would contribute to building trust in the computer-generated advice; this, recalling trust in the automated advice is one of the most influential factors for user computer-advice utilisation (see CAU theory propositions, Chapter 5). This principle recommends including the following information:

- **Risk indicators.** The specific type of risk indicators should be elicited with the eventual end-users, e.g. whether it is preferred a numerical indicator (e.g. a numerical scale system) or a conceptual indicator (e.g. "low", "medium", "high"); however, an objective indicator should be presented in such a way that it allows decision-makers to compare and contrast the potential risk of the possible options presented (i.e. the advice). Risk indicators are valuable trust builders because they provide uncertainty reduction to the users (Bansal et al. 2010; Kim et al. 2008; Yang et al. 2015).
- **Company profile.** This principle recommends including a company profile which will support the process of getting to know the potential business partner, such as how it happens outside the digital world. There are certain pieces of information that should be included in such company profile to aid the trust-building of the decision-makers in the advice of which business partners to select, these include:
    - *Basic profile information.* The information presented should be quick to read and accurately answer the question "Who is this company, and what can it provide?".
    - *Past performance.* Independent, objective and measurable indicators of how the given business partner performed in past collaborations. This information has the potential to influence the three dimensions of trust: competence, integrity and reliability (Wang and Benbasat 2005); therefore, care should be taken to include past performance information reporting on these three dimensions. The specifics of what are the key past performance indicators for a given system and how these should look is required to be elicited with the targeted end-users, e.g.

to find out whether it is preferred a numerical indicator (e.g. a numerical scale system) or a conceptual indicator (e.g. "low", "medium", "high"), on only environmental, social, or economic past performance indicators (Amrina and Yusof 2011; Ishaq Bhatti et al. 2014) or in all of them, as well as which specific ones within each category.

- *Products catalogue.* A standardised approach of a capabilities presentation to aid the understanding of what a company is capable of providing. The particular characteristics of the capabilities presentation (i.e. the catalogue) should be adjusted to support the specific goals of the recommendation and the purpose of the system. For example, is the purpose to assign suppliers to one task, or is it to find the best supplier based on strategy alignment?
- *Certifications.* To build trust in the competence dimension people rely on external assurances (Tan and Thoen 2002). To aid this dimension of trust, designers of automated business advisors should include domain-reputable certifications as part of the company profile of the potential business partners.
- *Explanation of results.* Explaining the logic behind the advice given offers transparency to end-users and builds their trust in the system as advisor and trust in the piece of information given (Ye and Johnson 1995). Explanations should be easy to understand, quick to read and preferably of the type of "why" explanations (i.e. why a result is the way it is), and "why no results" (i.e. why there are no results) in cases where a requested result was not found. For example, if the reason is that the requirements were too strict; then perhaps relaxing them could be recommended).

Design principle 2: The information within the system should possess data quality characteristics (information quality), favouring timeliness, correctness, and completeness. In addition to the type of information included, such information and the particular information required for the specific community of end-users should possess the following data quality elements to effectively aid trust-building in the recommendation advice (Bonsall 1992; Gasparic and Ricci 2015; Jin et al. 2017). Even with the correct type of data included, the fit for its purpose will decrease as the quality of the information decreases (Gao et al. 2012; Raghunathan 1999). Secondly, good quality data reduces the time required to resolve issues arising from outdated, incorrect, incomplete data. Particular attention should be given to act on the following data quality dimensions:

- **Timeliness.** The computer advisory system should have up to date and valid information at any point it is presented; this is especially relevant for the quality of the business partners proposed considering that the potential successfulness of business collaboration is likely to be low if it is based on grounds no longer holding true.
- **Correctness.** One of the most representative dimensions of quality, following the "wrong in, wrong out" approach (Kilkenny and Robinson 2018; Oliveira et al. 2005). Automated business advisors should be designed with mechanisms to ensure compliance with data correctness both from the point how the database is formed, how the information is processed and how it is presented to the end-user.
- **Completeness.** The information gathered, and the information presented to the end-users should be comprehensive enough to effectively enable informed decision making, preferably in such a way that the end-user would not require looking for information outside the computer advisory system.

Design principle 3: Users should be involved as early as possible in the development of the system (user participation). To influence trust in the system, facilitate a quick deployment and promote adoption of the system, we recommend taking into consideration the following aspects of user participation (Barki and Hartwick 1989) which should happen as early as possible during the system development:

- **Demo iterations.** Potential end-users should be involved since the early stages of the system's development. This principle recommends implementing an approach of iterations of demo versions where end-user feedback is collected and re-adapted for future iterations. Such an approach offers a guide to shape the computerised advisor to the particular needs of the particular end-users pool and offers them the involvement in the design of the system required to influence trust.
- **Previous trials.** A set of trials should be placed to enable users "test" the system and assess the benefits such system would offer them aiding the barrier of resistance to change or adopt new methods of carrying out an activity. A trial phase is also an opportunity to collect feedback and keep the user in the loop of the development.
- **Training.** Users want to be able to perform their tasks as quick and easy as possible (Davis 1989). Especially with less experienced users in systems usage, training offers an approach to increase the speed in which tasks can be done and the time required for users to understand by themselves how to utilise and benefit from the system.

- **Ease of use.** This principle recommends involving the user's opinions and feedback as to what makes for them an easy to use the computerised advisor, considering cultural differences, domain context, age, and experience in the industry and using information systems, particularly relevant for ad-hoc systems.

Design principle 4: User Interface (UI) design should favour effort and time saving (user interface). There are many aspects of UI that can be considered; however, there are some aspects that users of computerised advisors would appreciate and which would likely have a higher impact on the ease of use and satisfaction with the system — and therefore in the advice utilisation. The UI should be designed to reduce the time and effort required to benefit from its usage successfully. Despite a specific shape and form of each UI aspect, general principles are offered as follows:

- **Font size.** Adaptive font size relative to the accessing device should be offered where, in all times, the font size scales adequately with the entire UI. This adaptability allows the user to be able to read and consume the information as quick and easy as possible regardless of the device used (e.g. mobile, tablet, PC, a large monitor).
- **Familiar design.** Users tend to perform tasks quickly and effortlessly in such processes that are already familiar to them (Lim et al. 1996), to benefit from this, designers should encourage the utilisation of known approaches in the overall UI interaction, e.g. use of "Windows-like" appearance or functionalities.
- **Centralised information** (i.e. in one page). The user should be able to visualise and read the key information of the advice given in one single area. Multiple clicks required should be avoided. This approach facilitates effort and time saving, which are influential in users assessing the quality of the recommendations presented and its utilisation.
- **Standardised presentation.** To influence trust in the advice proposed, comparisons present a practical approach for users to identify by themselves what suits best their purposes; comparisons can only be possible if the presentation and data are standardised. Also, it is recommended that between screens or stages of the system, no significant changes are done to the UI to facilitate users recalling what to do in each stage.

- **UI aids.** Besides training, help should be available within the system to reduce the effort and time required by the user to utilise computerised advisor successfully. We recommend the following UI aids to serve this purpose:
  - *Hover hints.* Users should be able to receive concise information about meanings of concepts used in the system as well as indicators for the user to know what would happen if an action from them is done in the system, such as "clicking" on a given button. The use of hover hints presents a useful solution to this without adding extra mental load and visual alterations to the UI composition.
  - *Process guidance.* Users should be able to successfully utilise the system without the need of another person's help, for this, the system should offer guidance in the form of process indicators for the user to know what is required from her/him as next steps in the use of the system.
  - *Comparisons functionality.* Being able to compare and contrast the advice received recreates how decision making is usually done, and it is a functionality that supports users in saving effort to process the information required. Designers should include aids to enable users to carry on a comparison to support their decision.

Design principle 5: End-user's key security aspects for off-line settings should be implemented in digital form in the computerised advisor (digitalised security). Despite technical security aspects not being the main focus of the design principles for computerised advisors design, two aspects concern security. These appeared from the BIE interventions in this investigation, where it was identified that end-users highly consider them as elements that should be present in the system. This design principle, however, can be considered for practitioners to consider eliciting what are the key security aspects their users value when not using a system (off-line settings). In the context of inter-organisational business partner selection, we found the following:

- **Knowledge protection.** Knowledge transfer and knowledge protection play a significant role, particularly towards collaborations. "Know-how" is one of the most critical assets of the business to remain competitive and therefore, it is of high interest to protect it. Designers of computerised advisors should aid know-how protection to considerably augment the likelihood of users utilising the advice given by the system;

this is also related to mechanisms of informing the risk of loses, potentially caused by partnering with a proposed potential business partner.

- **Governance rules.** Policies and monitoring of results of the inter-organisational collaborations formed through following the computer-generated advice would reinforce the trust in the system in the competence dimension of the system as an advisor, by proving the advice given is controlled and mediated in the same or closely similar way that is done in processes carried out of the system; this also relates to the CAU factor of transparency and trust, as presented in the CAU theory.

Design principle 6: The benefits of following the advice given by the system should be clear and existent. Finally, the design of the system should present a clear value added to the user, in comparison to not utilising the advice given by the system. This value is one of the main motivators for the users to follow the computer-generated advice to form inter-organisational collaborations. This principle recommends focusing on the following benefits:

- **Time-saving.** The user should be able to save time by benefiting from an automated business advisor compared to consulting and following advice offered by a person. The importance of the time saving resides in an indirect financial benefit, a sense of a possibility of competitiveness (e.g. by being quicker or keep up with the quick pace required) and the opportunity to fulfil other obligations and responsibilities with the saved time.
- **Effort saving.** The user should have a reduced effort required to fulfil the goal of forming a business collaboration by using the system, compared to other approaches used for the same purpose.
- **Profit enabler.** Clear and measurable benefits which fall in a profit benefit should be exposed; for example, showing an accurate record of how competitors utilising the computer-generated advice saved costs by reducing the expenses of visiting companies in another neighbouring country to expand the market base.
- **Competitiveness supporter.** Businesses are after remaining competitive, for this, it is relevant to design a computer advisory system that supports this goal in such a way that the system could be considered a collaborator towards maintaining the business running.

- **Increased efficiency.** The system should be able to present an increase in the number of successful collaborations (i.e. maximised profits and minimised loses) by using an algorithm to propose a better-suited business partner.

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Appendix C.2: Design principles and its associated theory proposition

The first column of the table below describes the general design principle, and the second column refers to the specific design aspect as expanded in Appendix C.1.

Design principle	Elements included to support the design principle	CAU theory concept	CAU proposition	Theoretical support
The type of information provided by the system should aid trust and facilitate decision making (type of information)	Risk values Company profile	Trust	If the judge trusts the advice, then the likelihood of utilising the advice will increase	(Andersen and Kumar 2006; Bansal et al. 2010; Campbell et al. 2010; Hoff and Bashir 2015; Kim et al. 2008; Lambert et al. 1996; Li and Rowley 2002; Parasuraman and Riley 1997; van Swol 2011; Wilkinson et al. 2005; Yang et al. 2015; Ye and Johnson 1995)
The information within the system should possess data quality characteristics (timeliness, correctness, completeness)	Timeliness Correctness Completeness	Information quality Trust	If the quality of the information contained in the advice is high, then the judge will more likely trust the advice	(Bonsall 1992; Gasparic and Ricci 2015; Jin et al. 2017; Zo et al. 2019)
Users should be involved as early as possible in the development of the system (user participation)	Demo iterations Trials Training Ease of use	Transparency of the process Trust	If the advising process is transparent and the quality of the information contained in the advice is high, then the judge will more likely trust the advice	(Andersen and Kumar 2006; Barki and Hartwick 1989; Campbell et al. 2010; Lambert et al. 1996; Li and Rowley 2002; Wilkinson et al. 2005)
User Interface (UI) design should favour effort and time saving (user interface)	Font size Familiar design Centralised information Standardised presentation User Interface (UI) aids	Potential benefits expectation Transparency of the process	If the judge has high expectations of obtaining benefits from utilising the advice, then the likelihood of utilising the advice will increase.	(Bonner and Cadman 2014; Calcagno and Monticone 2015; Garfagnini et al. 2014; Gregor and Benbasat 1999; Lim et al. 1996; MacGeorge and Van Swol 2018)
End-user's key security aspects for off-line settings should be implemented in digital form in the computerised advisor (digitalised security)	Knowledge protection Governance rules	Trust	If the judge trusts the advice, then the likelihood of utilising the advice will increase	(Andersen and Kumar 2006; Campbell et al. 2010; Lambert et al. 1996; Li and Rowley 2002; Wilkinson et al. 2005)
The benefit of following the advice given by the system should be clear and existent	Time-saving Effort-saving Profit enabler Competitiveness supporter Increased efficiency	Potential benefits expectation	If the judge has high expectations of obtaining benefits from utilising the advice, then the likelihood of utilising the advice will increase	(Bonner and Cadman 2014; Calcagno and Monticone 2015; Garfagnini et al. 2014; MacGeorge and Van Swol 2018)

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