Thuan, N., Antunes , P., & Johnstone, D. (2018). A Decision Tool for Business Process Crowdsourcing: Ontology, Design, and Evaluation. Group Decision and Negotiation, 27(2), 285-312. doi:10.1007/s10726-018-9557-y

A Decision Tool for Business Process Crowdsourcing: Ontology, Design, and Evaluation

Nguyen Hoang Thuan (corresponding author)
Can Tho University of Technology
Faculty of Information Technology
256 Nguyen Van Cu street, Can Tho city, Vietnam
Phone +84 02923897574
nhthuan@ctuet.edu.vn

Pedro Antunes
Victoria University of Wellington,
School of Information Management,
PO Box 600, Wellington, 6140, New Zealand
Pedro.Antunes@vuw.ac.nz

David Johnstone
Victoria University of Wellington,
School of Information Management,
PO Box 600, Wellington, 6140, New Zealand
David.Johnstone@vuw.ac.nz

Abstract

As the crowdsourcing strategy becomes better known, the managerial decisions necessary to establish it as a viable business process are becoming increasingly important. However, a divide and conquer approach, currently dominant in the field, leads to scattered decision support for the crowdsourcing processes. We propose an ontology-based decision tool that supports the whole business process crowdsourcing. The advantage of the ontology approach is that it collects and consolidates knowledge from the existing literature to provide a solid knowledge base for the tool construction. Operationalising the ontology, the tool helps make the decision to crowdsource or not, and choose appropriate design alternatives for the crowdsourcing process. We evaluated the tool through a controlled experiment with 190 participants. The obtained results show that the tool is useful by significantly increasing: 1) the performance in making the decision to crowdsource or not, and 2) the design of crowdsourcing processes.

Keywords: Business Process Crowdsourcing, Crowdsourcing, Decision Support System, Experiment, Ontology

Conflict of Interest: The authors declare that they have no conflict of interest.

1 INTRODUCTION

Over the last decade, crowdsourcing has become a viable organisational practice (Howe 2006). Many organisations have been applying this strategy for different purposes, such as group decision, idea generation, problem solving, and software development (Kucherbaev et al. 2016; Rowe et al. 2015;

Seeber et al. 2017). By adopting crowdsourcing, organisations can tap into external expertise and creativity for operationalising their business activities. More importantly, organisations can access a large elastic workforce in terms of availability, strength and cost.

Business Process Crowdsourcing (BPC) has emerged as a new practice that emphasises the use of crowdsourcing as repeatable business processes. We stress here the key characteristics of BPC: 'repeatable' and 'process'. The repeatable characteristic is important for organisations to derive more predictable outputs from crowdsourcing. The process-oriented characteristic leverages crowdsourcing as a template for creating multiple, real life instances of business activities (Thuan et al. 2017). By embodying these two characteristics firms may substitute many traditional business processes, and even some non-traditional ones such as outsourcing and virtual organisations, with a new way of doing business that involves the crowd.

Given the potential impact of BPC on firms, several developments supporting BPC have already started to emerge. By and large, existing research can be categorised into two major camps: technical support and decision support. The former addresses the development of dedicated systems that bring together businesses and crowd workers by integrating mechanisms such as task distribution, activity synchronisation, recruitment, and incentives (Tranquillini et al. 2015). In the decision support camp, researchers regard BPC as a set of decisions that determine the overall structure and quality of a business process that absorbs crowdsourcing. Considering the two camps together, we could say that the decision view can only maximise its value with effective infrastructure, while the technical view can only maximise its contribution if firms can make proper decisions.

In this research we will focus on decision support. Prior research has developed decision support systems (DSSs) for some specific tasks of the crowdsourcing process, in particular task assignment (Mo et al. 2015; Yuen et al. 2015) and results aggregation (Prokesch and Wohlenberg 2014). However, we note that just addressing parts of the process may increase the risks of making *ad-hoc* decisions that are task-oriented and uncoordinated. From the process viewpoint, we emphasise the need for DSSs capable of supporting the coordinated crowdsourcing process in a coherent way.

Both research and practice currently lack a decision tool supporting the coordinated process of BPC. That is, a tool assists decision makers from the beginning when they make a decision to crowdsource or not, to several design decisions that coordinate the crowdsourcing process. Consider for instance the following two challenges:

- In the decision to crowdsource or not, the literature has widely agreed that this decision is driven by several factors, including task characteristics, the availability of the crowd, cost, and infrastructure (Afuah and Tucci 2012; Thuan et al. 2016; Zhao and Zhu 2014). However, how to operationalise these factors in a decision support system has not been investigated.

- In the crowdsourcing process design, recent literature suggests that crowdsourcing is a complex workflow as it involves various concerns (Amrollahi 2015; Tranquillini et al. 2015). One challenge to decision makers is to understand what are these concerns (e.g. task design, quality control, etc.), what alternatives they can choose in a particular concern, and what guide they can follow to make their choice.

In line with these challenges, we fundamentally agree with Amrollahi (2015) that there is a current lack of "a comprehensive guideline through which practitioners can initiate and manage their crowdsourcing projects" (Amrollahi 2015). Translating into DSS language, the domain still lacks a solid knowledge base defining the semantics and actionable guidelines supporting the whole crowdsourcing process. Furthermore, it also lacks empirical evidence regarding the impact of DSSs for crowdsourcing, something also suggested by other researchers (Geiger 2016; Yuen et al. 2015).

To address these problems, we have developed a managerial tool supporting the whole BPC process. Adopting the design science research paradigm (Gregor and Hevner 2013; Hevner et al. 2004), we devised a comprehensive approach that starts with a BPC ontology, develops a decision tool based on the ontology, and evaluates the tool using a set of experiments. More precisely, we extended the scope of the BPC ontology reported in (Thuan et al. 2015), which enables us to formalise and represent a set of essential BPC concepts and decision-making elements, with the purpose to develop a tool that utilises the ontology to provide decision support. The tool assists managers in two ways: making decisions about whether to crowdsource or not, and if so, making decisions regarding how to design crowdsourcing processes. The tool thus helps different decision makers, e.g. project leaders and process managers, reach coordinated BPC decisions. The tool is empirically evaluated in a controlled experiment with 190 participants. The results provide evidence that the tool contributes to making better decisions regarding both the decision to crowdsource and the design of a crowdsourcing process.

This research provides the following contributions. First, we extend the scope of the BPC ontology (Thuan et al. 2015). The BPC ontology provides an actionable way to represent the BPC domain knowledge. Second, we propose a tool supporting the BPC process, based on the BPC ontology. We also provide empirical evidence on the usefulness of the developed tool and thus extend previous theoretical efforts in conceptualising the BPC phenomenon (e.g. Geiger and Schader 2014). Finally, we contribute to practice with a decision tool that can be used by business managers to decide whether to crowdsource or not, and to design crowdsourcing processes.

The remaining sections of this paper are organised as follows. Section 2 reviews the related work, providing an overview of BPC and crowdsourcing processes. Section 3 formulates the ontological model backing the developed tool. The tool development is described in Section 4. The controlled experiment and corresponding results are provided in Section 5. Section 6 discusses the impact of this research. We conclude the paper with a summary of the results and outline future work directions.

2 RELATED WORK

The literature identifies three main research streams related to crowdsourcing and BPC. These streams address: 1) generic crowdsourcing frameworks that provide a conceptual foundation of crowdsourcing; 2) the BPC view perceiving crowdsourcing as a system of interrelated activities; and 3) the decision support necessary to establish BPC as a repeatable process. These streams are arranged symmetrically from overview to more focus on the research phenomenon. We discuss each stream below.

2.1 Crowdsourcing Frameworks

A crowdsourcing framework identifies a set of activities, actors, and operations that are conceptually needed to realise a crowdsourcing strategy. Such generic frameworks reveal the basic structure of the crowdsourcing strategy and thus it is an important topic in the research literature. Early literature provided simple frameworks to describe the crowdsourcing phenomenon. For instance, the framework proposed by Vukovic (2009) described crowdsourcing as the interaction between a requestor, a crowdsourcing platform, and a crowd. In this framework, each actor performed specific activities: organisations submitted a task request, validated competition, and paid compensation; the crowd undertook the tasks and charged the requestor; the platform issued credentials for requestors and the crowd. Aligning with Vukovic (2009), other researchers also described crowdsourcing as a collection of distinctive activities with different levels of detail (Geiger et al. 2011; Rouse 2010; Schenk and Guittard 2009).

More recent literature suggests that crowdsourcing is indeed a complicated workflow involving the coordination of activities. Pedersen et al. (2013) developed an input-process-output model involving problems, technology, processes, governance, people, and outcomes. In this vein, Kittur et al. (2013) defined a list of twelve abstract activities, including workflow design, task assignment, hierarchy, real-time response, collaboration, quality control, crowds guiding artificial intelligence, artificial intelligence guiding crowds, platforms, task design, reputation, and motivation. Thuan et al. (2015) aggregated even more activities and configurations. Overall, this research trend suggests that crowdsourcing is a complex collection of activities, which have multiple dependencies and relationships between them according to different configurations.

In this study, we support the workflow viewpoint and further contribute to the discussion by consolidating the common activities of crowdsourcing. The need to consolidate knowledge is common in emerging fields like crowdsourcing where fragmented knowledge sources exist (Amrollahi 2015; Kucherbaev et al. 2016). This fragmentation is because the crowdsourcing phenomenon starts being explored in different specific cases and applications. Only recently has a greater concern for consolidation arisen, requiring us to structure latent aspects of crowdsourcing, including common activities, components, information flows and data entities (Amrollahi 2015; Thuan et al. 2017). This leads us to the viewpoint of business process crowdsourcing described in this paper.

2.2 Business Process Crowdsourcing

This research investigates crowdsourcing using a business process lens. We refer to this lens as business process crowdsourcing (BPC). This concept was first alluded by La Vecchia and Cisternino (2010), referring to a model allowing firms to transfer some of their internal business processes to the crowd. In this research, BPC regards crowdsourcing as an integrated process of the firm that leverages the work done by the crowd (Thuan et al. 2017). Our thesis is that BPC proposes an integrated approach for organisations to efficiently establish business process based on crowdsourcing. More precisely, the business process lens allows for the analysis of both individual aspects of crowdsourcing and consolidating them into an organisational workflow (La Vecchia and Cisternino 2010; Lüttgens et al. 2014). Furthermore, BPC also enables the standardisation of crowdsourcing processes, which can be achieved through the repeatable workflows emphasised by BPC.

Recent literature started discussing several challenges related to the crowdsourcing process, especially how to support organisations to successfully design crowdsourcing processes. Vukovic et al. (2010) asked “how does crowdsourcing become an extension of the existing business process” (p. 7). Similar concerns were echoed by Khazankin et al. (2012), Djelassi and Decoopman (2013) and Tranquillini et al. (2015). For instance, Tranquillini et al. (2015) raised and highlighted the issue of how to model and enact crowdsourcing processes.

In spite of these concerns, there has been little investigation into BPC. Some prior studies touched on specific BPC components. For instance, Satzger et al. (2011) sought to support “fully automate[d] deployment of their tasks to a crowd, just as in common business process models” (p. 67), but focused only on choosing suitable workers to perform tasks. Similarly, Khazankin et al. (2012) were concerned with how to optimise task properties for supporting business process execution. Recently, Tranquillini et al. (2015) modelled crowdsourcing processes using the Business Process Model and Notation (BPMN), and designed a run-time environment to enact such models. Their research offered a visual editor that allowed firms to graphically create and manage BPC processes. We note, however, that even though the tool can model and enact crowdsourcing processes, it does not offer support for making decisions regarding BPC. Our research addresses this aspect of the problem.

2.3 DSS for Crowdsourcing

Since crowdsourcing processes encompass several complex activities involving unstructured decisions, DSSs can be particularly helpful to assist the related decisions. However, given the fragmented nature of the domain, we could not find DSSs that address the whole decision process. Rather, we find a few DSSs supporting specific implementations of the crowdsourcing process. For instance, Yuen et al.

(2015) and Geiger et al. (2014) constructed a recommendation system matching individuals in the crowd with types of crowdsourcing tasks. Prokesch and Wohlenberg (2014) proposed decision support for processing outcomes from the crowd. Overall, despite an increasing range of decision support for very specific BPC elements, there is still no DSS that addresses the coordinated BPC.

This lack of a comprehensive DSS can be viewed from an ontological perspective, where the knowledge base necessary to support the whole decision process has not yet been consolidated. It is widely agreed that ontologies can effectively be used to develop DSSs (Delir Haghighi et al. 2013; Liu and Zaraté 2014). Although two prior ontologies were proposed in the crowdsourcing domain (Hetmank 2014; Luz et al. 2015), they mainly attempted to classify and define crowdsourcing concepts. Thus, the domain still needs an ontology that not only consolidates the semantics of the domain, but also represents them in a way that can be translated into instantiated DSSs.

There is also a shortage of empirical evidence examining how decision support can impact crowdsourcing. Again, we can only find empirical evidence assessing decision support on particular aspects of crowdsourcing. For instance, Schnitzer et al. (2016) conducted a survey with 500 participants regarding perceived task similarities, which served as a key parameter for building a task recommender. In a similar vein, Geiger (2016) collected survey responses from 490 participants regarding the usability of a recommendation system for task design in crowdsourcing.

In the study reported in this paper, we address decision support covering the whole crowdsourcing process. This decision support tool will be developed from an integrated ontological view. The ontological approach helps to explicitly define concepts and semantics (Corcho et al. 2003), and provides a solid knowledge base for decision support. The decision support tool instantiates and validates the ontology (application-based validation). Further, we also provide empirical evaluation on how well the tool helps decision makers.

3 ONTOLOGY OF BUSINESS PROCESS CROWDSOURCING

This section introduces the BPC ontology that will serve as a foundation for the decision support tool. Ontologies have a proven record for improving knowledge structures within the domain by specifying the concepts and their relationships explicitly (Amailef and Lu 2013; Miah et al. 2014). This strength of ontologies is further highlighted in the current paper from both BPC and DSS views.

From the BPC viewpoint, ontologies can help resolve conflicts in the emerging domain by identifying whether several ‘things’ are represented by the same constructs (Shanks et al. 2003). Thus, they provide a basis to deal with fragmentation of knowledge sources and coordination issues in the domain, noted previously in Section 2. From the DSS viewpoint, ontologies serve as knowledge bases of an application domain for enhancing and representing semantics and reasoning knowledge (Delir Haghighi et al. 2013). Together, we suggest that a BPC ontology can coordinate key concepts and semantic relationships of the domain, from which knowledge can be inferred. With this knowledge base, instantiated decision tools can be further constructed to support BPC.

3.1 Overall Approach

In line with design science (Hevner et al. 2004), ontology development requires a rigorous method consisting of solid construction and evaluation. For this purpose, we reviewed the ontology engineering literature to identify and justify the activities of ontology development methods. This led us to adopt the four steps commonly used in ontology engineering: definition of scope and objectives, ontology capture, knowledge organisation, and ontology evaluation through operationalisation (Delir Haghighi et al. 2013; Uschold and King 1995).

Step one defined the scope and justified the objectives of the BPC ontology, which allowed us to understand the purposes and challenges that the BPC ontology aims to address. Step two identified the ontological elements, e.g. concepts and semantic relationships. Here, we faced the challenge of fragmentation where existing literature has mainly studied individual aspects of the crowdsourcing process. Addressing the challenge, we adopted a scoping review that enabled us to analyse the existing knowledge for the common repeatable elements of the crowdsourcing process (Paré et al. 2015).

Step three organised the identified ontological elements to represent the domain knowledge. We tried to represent the ontology in different structures and ultimately adopted the hierarchical structure represented by UML notations. This enabled us to move from conceptualised knowledge to an instantiated decision tool. The fourth and final step evaluated the ontology. In this paper we adopted an application-based evaluation that applied the ontology to develop the decision tool.

Figure 1 presents the four steps of the BPC ontology construction. Each of which will be discussed and exemplified in the next sections. We note that step two has been described in detail elsewhere (Thuan et al. 2015) and will only be summarised here. The other steps extend the scope of the ontology capture by operationalising and evaluating the ontology through an instantiated application.

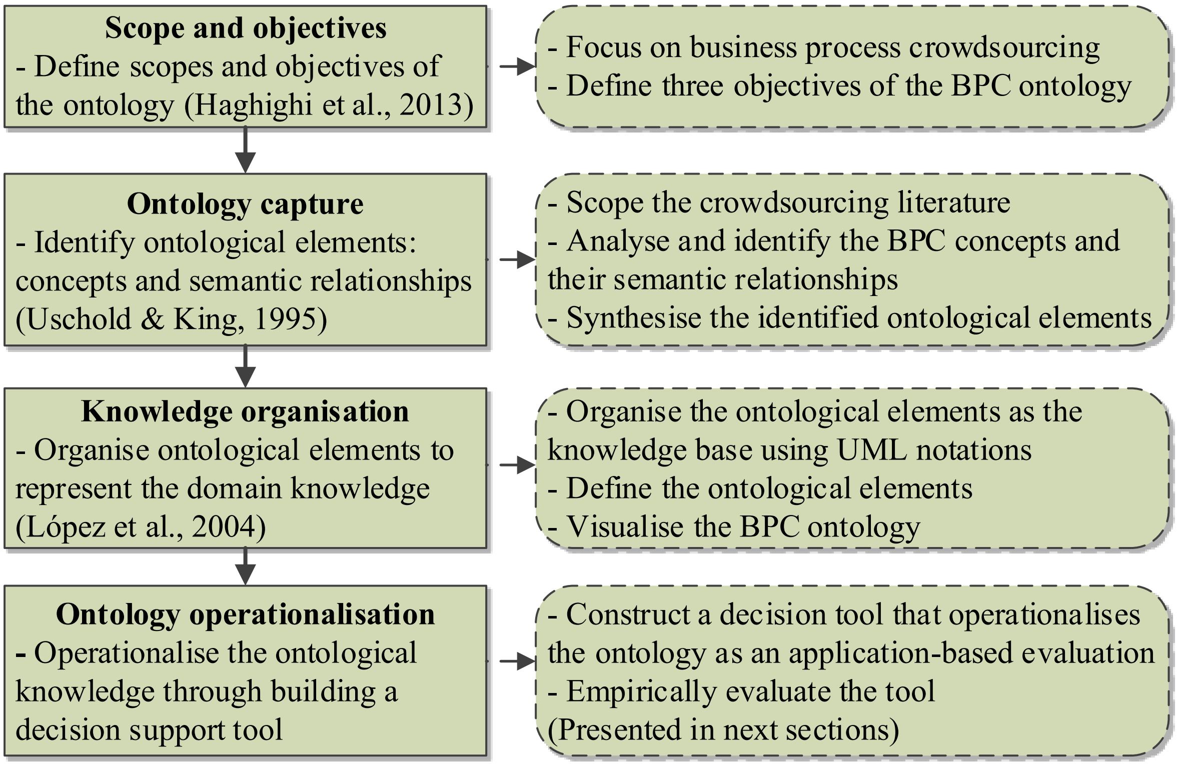

Figure 1. The four steps of BPC ontology construction

3.2 The Four Steps of BPC Ontology Construction

Scope and Objectives

As stated earlier, the ontology focuses on BPC for supporting crowdsourcing as a repeatable business process. In that context, we considered three objectives of the ontology development. The first objective was to identify the repeatable activities of existing crowdsourcing processes, of which common decisions, their alternatives and decision factors should be recognised. This objective addressed fragmentation of existing knowledge sources in the domain. The second objective was to provide a descriptive conceptualisation of crowdsourcing as a repeatable business process, which explicated and consolidated the main BPC concepts and their relationships. The third objective was to represent knowledge in a way that can be operationalised for the development of the decision tool.

Knowledge Capture

This step identifies the ontological elements related to BPC, consisting of concepts and semantic relationships. As fragmented knowledge sources exist in the domain, we rely on a scoping review to identify common activities, repeatedly found in multiple knowledge sources. The detailed steps of the scoping review are described in (Thuan et al. 2015) and summarised below.

We searched crowdsourcing conference and journal papers from eight online bibliographic databases: ACM, EcoHost, IEEE, Emerald, Sage, Science Direct, Springer Link, and Wiley. Using a screening technique (Okoli 2015), we filtered out the irrelevant papers by reading the sources' titles, keywords, and abstracts. Consequently, we selected 238 sources as raw data for extracting the ontological elements. We analysed these sources for concepts, activities, decision factors, design alternatives and their sematic relationships. We extracted the elements using a deductive analysis that used themes and codes pre-selected from well-known frameworks (e.g. Pedersen et al. (2013) and Kittur et al. (2013) discussed in Section 2). We also employed an inductive analysis where we captured additional ontological elements that have emerged more recently.

We then synthesised the extracted elements through a four-phase procedure. First, we reviewed, compared and aggregated the extracted elements. Second, we merged the 'conceptually similar' elements. For instance, probability of crowdsourcing (Afuah and Tucci 2012) and decision to adopt crowdsourcing (Lüttgens et al. 2014) were merged. Third, we rationalised the semantic relationships among them by mapping some sub-elements into more generic ones. As a result the ontological elements were grouped, at an abstract level, into two main BPC processes: decision to crowdsource and process design, which concern two main types of decision-makers in the BPC process (i.e. project managers and process designers). Finally, we synthesised the sources' recommendations, rules, and best practices that were related to particular elements.

The synthesis results revealed a diversity of elements. However, the number of sources supporting each of them was highly different, ranging from 69 sources supporting 'quality control' to only a few supporting 'crowdsourcing with artificial intelligent'. We refined the ontological elements by focusing on thematic elements that were supported by at least 10 review sources. Table 1 represents the thematic elements, the number of supporting sources (in parentheses), and key references. Besides these core elements, we also included other concepts that have strong sematic relationships to the core elements, given the important roles of relationships in ontologies (Guarino et al. 2009; Sánchez and Moreno 2008). As a result, 109 thematic elements were identified from the dataset, serving as the basic for the BPC ontology.

Table 1. Thematic BPC concepts from the literature (Thuan et al. 2015)

Main concepts and Categories	**Concepts and sub-concepts** (number of supporting sources)	**Reference source**
Decision to crowdsource		
Decision factor (19)	Task characteristics (30) + Ease of task delineation (13) + Partitioned task (11) Availability of the crowd (19) Risk & challenge (16) Availability of crowdsourcing platform (10)	(Lüttgens et al. 2014; Muhdi et al. 2011)
Process design		
Quality control (69)	Design-time quality control (11) + Worker selection (16) Run-time quality control (13) + Identifying malicious behaviour (19) + Gold standard (16)	(Allahbakhsh et al. 2013)

	+ Output agreement (12)	
Incentive mechanism (46)	Monetary reward (29) Fun (11)	(Kaufmann et al. 2011)
Crowdsourcing output (38)	Output quality (36)	(Pedersen et al. 2013)
Task design (37)	Task description (10)	(Tokarchuk et al. 2012)
Crowd management (34)	Task assignment (20) Profiling the crowd (10) + Worker profile (10) + Worker reputation (10)	(Kittur et al. 2013)
Crowdsourcing task (34)	Simple task (13) Complex task (12)	(Schenk and Guittard 2011)
Characteristics of the crowd (23)	Type of worker (12) Motivation of the crowd (10)	(Kittur et al. 2013)
Workflow design (21)	Result aggregation (29) Task decomposition (10)	(Afuah and Tucci 2012)
Technical configuration (14)	Control and feedback (17) Platform (or intermediary) (13)	(Hetmank 2013; Hossfeld et al. 2014)

Note: the presentation of sub-concepts starts with the '+' symbol.

Knowledge Organisation

In this step, we organised, interpreted and represented the ontological elements into the BPC ontology. To start, we had to make a key decision about what modelling language to use. In this paper, we decided to use UML notations, which was driven by three reasons. First, UML is a standardised modelling language widely used by both academia and industry, which allows us to share the BPC ontology with wide audiences. Second, the BPC ontology is built to provide a foundation for the decision tool, and UML is a modelling language that enables us to move from conception to development. Finally, UML is considered appropriate for visualising ontological models, as suggested by Moral et al. (2017).

Using UML, we then organised the ontological elements into the BPC ontology. This was a highly iterative process, where we tried different structures to represent the ontology, including a network structure and a hierarchical structure. Yet, the network structure did not appear to be suitable to our goals because it made the ontology representation too complex, with many links and crosscuts. Thus, we adopted the hierarchical structure, which diminishes complexity by arranging concepts and relationships into several branches with division concerns. This structure was further suitable with the chosen UML modelling language because UML includes several notations to represent hierarchical relationships (e.g. generalisation, as-is, and association).

As a result, we arranged the BPC ontology as two hierarchical structures regarding the two core BPC processes: decision to crowdsource and process design. In general, BPC begins with the decision to crowdsource that evaluates whether crowdsourcing is appropriate to accomplish the organisational tasks. Figure 2 presents the BPC ontology regarding this decision. The decision to crowdsource is driven by four decision factors: task characteristics, people, management, and infrastructures. Each of them is broken down in the second level, which includes 17 sub-factors. These sub-factors enable us to derive decision rules on whether to crowdsource or not. For instance, the decision to crowdsource should be made only if tasks can be performed through the Internet (Thuan et al. 2016).

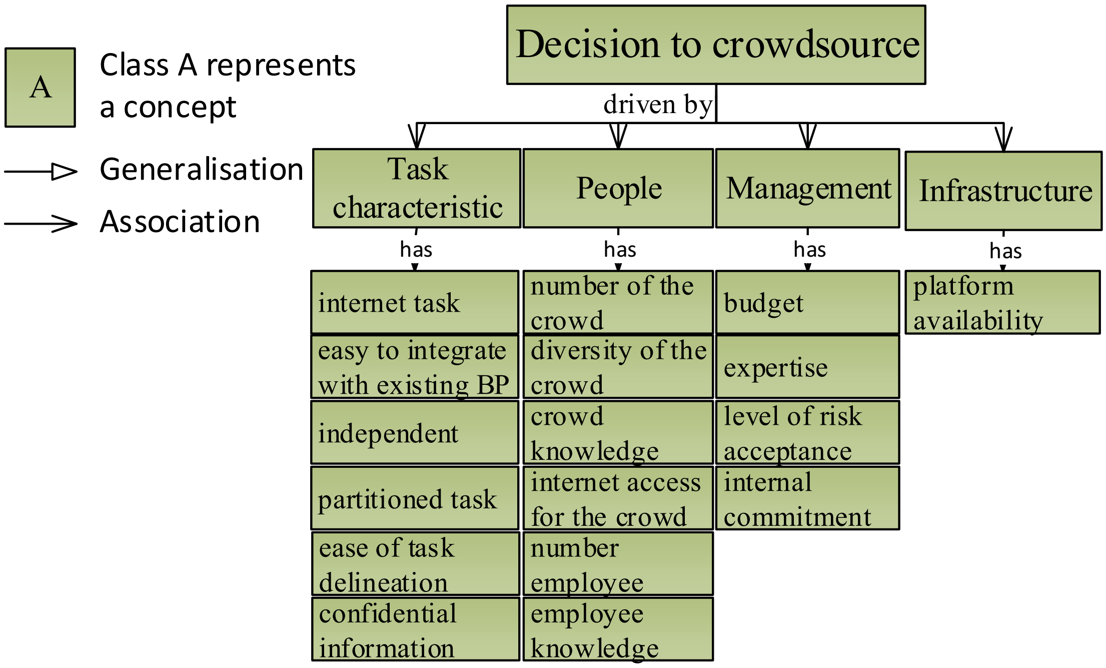

Figure 2. BPC Ontology: Decision to crowdsource

If organisations decide to crowdsource, then a process is needed to transfer the abstract decision into concrete crowdsourcing processes. Figure 3 presents the BPC ontology regarding the process design. The concept of 'process design' involves seven key components: task design, workflow design, crowd management, incentive mechanism, quality control, technical configuration, and outputs. We further identify 18 activities that support the implementation of the key components. These activities are detailed with data types and attributes. Together, the total number of key components, activities, data types and attributes in the ontology is 78, each of which is further defined in an ontology dictionary (the ontology dictionary can be viewed and downloaded from this link).

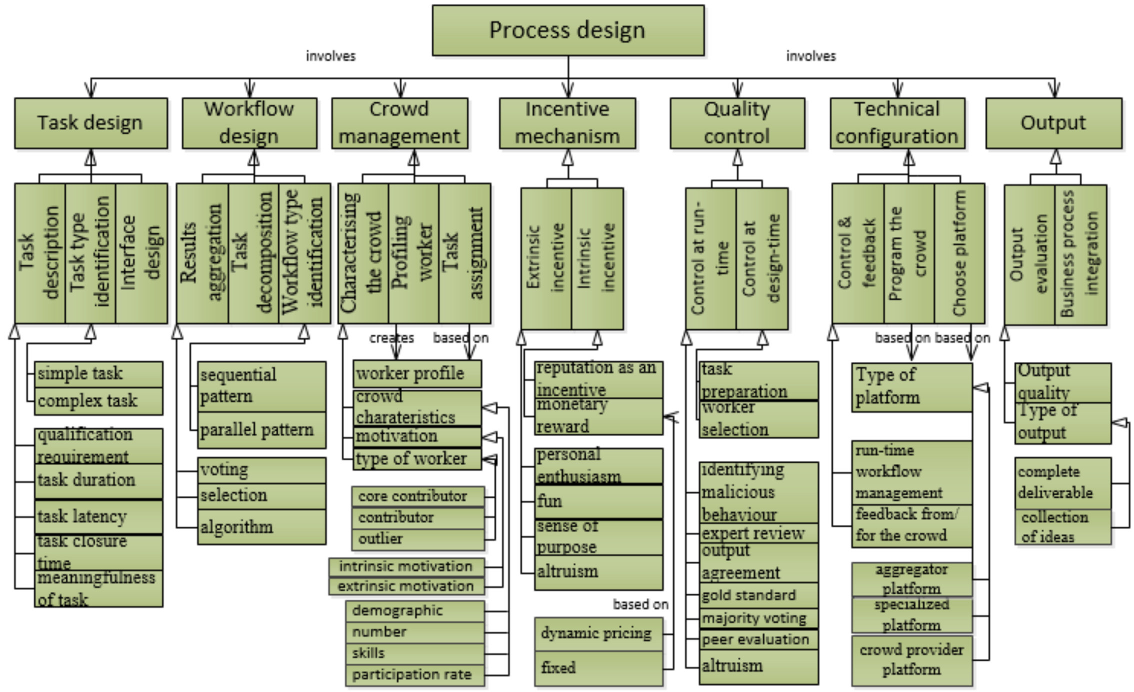

Figure 3. BPC Ontology: Process Design

Ontology Evaluation

Different approaches can be used to evaluate ontologies, which can be grouped into four categories: 1) gold standard evaluation compares the ontology with golden standards existing in the domain; 2) evaluation by humans uses experts to assess the ontology; 3) data driven evaluation compares the ontology with the source of data; and 4) application-based evaluation uses the ontology in a domain application and then assesses the results (Brank et al. 2005; Delir Haghighi et al. 2013). Having reviewed each approach for its strengths and limitations, we chose the application-based evaluation.

We evaluated the BPC ontology using the application-based evaluation, for four reasons. First, this approach is strongly aligned with the purpose of our research: constructing the BPC ontology and then applying the ontology to develop the decision tool. Second, the application-based evaluation allows us to show the usability of the ontology, one of the key evaluation criteria of design science (Hevner and Chatterjee 2010). Third, the application-based evaluation has complemented our previous data-driven evaluation, where we compared the BPC ontology with an ontology version automatically generated by software using the same data sources (Thuan et al. 2015). Finally, we could perhaps have evaluated the BPC ontology using other approaches, yet the lack of a widely accepted BPC ontology and the subjectivity of human evaluation supports the adoption of application-based evaluation.

By choosing the application-based evaluation, we assessed the applicability of BPC ontology for DSS implementation. This criterion was popularly used in the application-based approach to evaluate domain ontologies (Delir Haghighi et al. 2013; Morente-Molinera et al. 2016). Using this criterion, we explored whether the ontology can be applied to a DSS instantiation to deal with the complexity of BPC. Indeed, as shown in the next sections, the BPC ontology was operationalised and instantiated as a decision tool.

In particular, the ontology served as the knowledge base that standardises terminological differences and semantic conflicts, which enable us to resolve fragmented problems existing in the domain. Further, the ontology suggested what activities should be performed, which alternatives and decision factors should be considered in the crowdsourcing processes. With this knowledge base, the decision tool was successfully developed. The developed decision tool demonstrates applicability of the BPC ontology to DSS instantiation supporting crowdsourcing processes, and thus satisfies the application-based targets of the BPC ontology.

4 A DECISION TOOL FOR BUSINESS PROCESS CROWDSOURCING

This section presents a decision tool that managers and process designers can use to make informed decisions in BPC establishment. Based on the BPC ontology, the tool supports decision making by providing a set of thematic activities necessary to instantiate the crowdsourcing process, storing decisions, decision factors, and alternatives related to these activities, and retrieving knowledge, including decision rules and what-if scenarios. Reflecting the BPC ontology, the tool has two main functions: tool 1 supporting the decision to crowdsource and, tool 2 supporting the design of crowdsourcing process. The tool architecture is depicted in Figure 4.

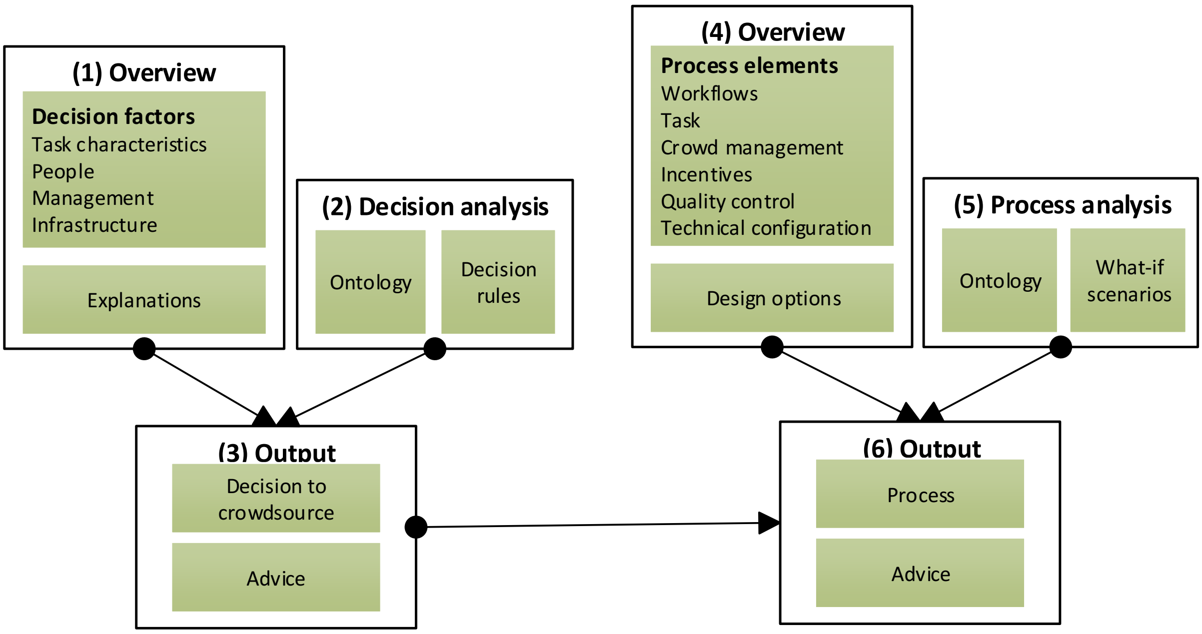

Figure 4. Tool architecture

Tool 1 supports project managers making the decision to crowdsource or not. Tool 1 has three components. Component 1 identifies a set of 17 factors and sub-factors defined by the ontology that the user has to contextualise to the crowdsourcing task in hand. Component 2 then analyses the factors using the set of derived decision rules. In component 3, tool 1 suggests whether crowdsourcing is an appropriate choice for the task or not. It also identifies possible actions that may lean the decision towards crowdsourcing.

Tool 2 shows the user the main activities involved in a crowdsourcing process, which also has three components (designated as component 4, 5 and 6). Component 4 provides an overview about the main workflows of crowdsourcing processes, which include task, workflow, crowd management, incentive mechanism, quality control, and technical configuration. For each workflow, the tool suggests a set of activities and design options that can be used to instantiate these activities. The workflows, activities, and design options are aligned with the hierarchical structure of the BPC ontology (Figure 3). Based on the inputs provided by the user, component 5 defines the crowdsourcing process, and then component 6 gives more detailed advice to operationalise the crowdsourcing activity. Together, these components offer what-if scenarios that allow users to change one or more design options, and observe the effected change of the process design. We note that both tool 1 and tool 2 use the BPC ontology (Figure 2 and Figure 3) as a knowledge base for suggesting options and scenarios.

4.1 Graphical User Interface

The tool, including tool 1 and tool 2, was developed using PHP and MySQL. The graphical user interface (GUI) of the tool is shown in Figure 5 (tool 1) and Figure 6 (tool 2). Even though tool 1 and tool 2 serve different purposes and may target different types of users, we intentionally designed them with a consistent user-interface that consists of three main modules: overview, configuration, and advice. The overview module is located on the left-hand side. It displays all decisional elements involved in crowdsourcing a business task, including the decision to crowdsource and the crowdsourcing process. The overview module is presented as a tree structure, reflecting the hierarchical structure of the BPC ontology. Users have two ways of navigation: 1) they may choose sequential navigation using the 'Next question' button and access each and every element; or 2) they may use the navigation tree to select and interact with specific elements of interest. With this module, the tool guides the users through the essential activities/decisions of the crowdsourcing process.

When the user selects an element, the configuration module is displayed on the right-hand side. This module presents a set of pre-defined questions that the user should answer. It also shows optional parameters that the user may select (presented as radio buttons or checkboxes), along with explanations about the questions and the parameters. The questions, parameters, and explanation reflect the semantics defined by the ontology. With this module, the tool offers understanding about the detailed elements of the crowdsourcing process. Further, the tool retrieves data to contextualise the crowdsourcing project, which will be used in the advice module.

The final module provides advice to the user. This module combines the data input by the user with business rules and what-if scenarios defined by the BPC ontology, so that the advice provided is contextualised to the business task. Two kinds of advice are provided. First, the tool provides *ad-hoc* advice, in relation with a specific input data. For instance, in Figure 5 when the user declares that the task of a crowdsourcing project is easy to define, the tool suggests the task is 'suitable with crowdsourcing' (The advice-box of Figure 5). Second, the tool further assesses interdependency among the inputs and provides advice for the whole crowdsourcing project. The user accesses this function through the button 'Project Summary & Project Advice', after she provides inputs for all elements of the crowdsourcing project (an example is provided below).

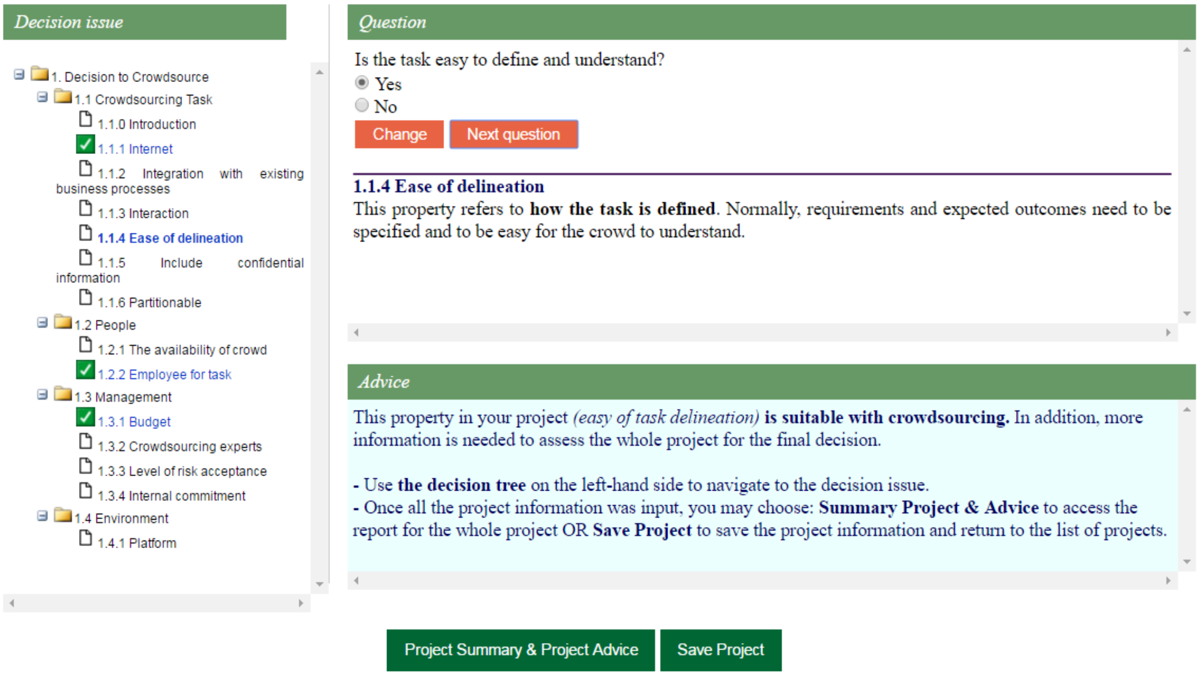

Figure 5. GUI of the tool 1: decision to crowdsource

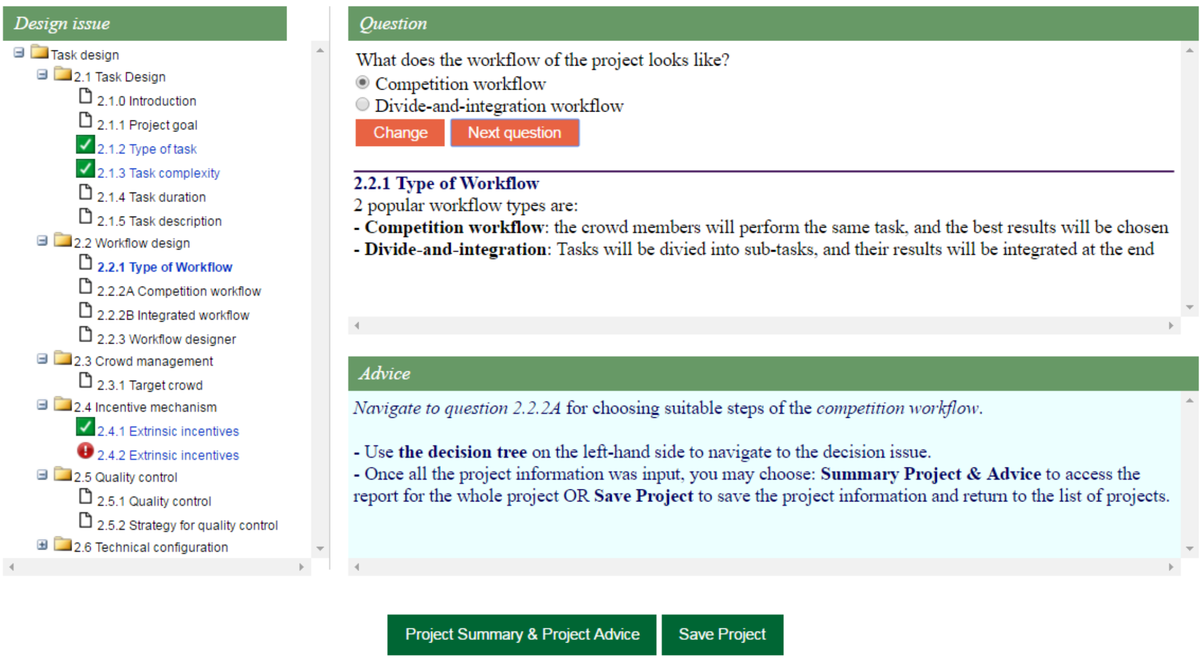

Figure 6. GUI of the tool 2: crowdsourcing process design

For better understanding of how the decision tool works, an example using tool 1 is presented. Company X has 10,000 pictures about wild animals that were captured by motion-triggered cameras in 40 wild locations in New Zealand. In this project, the main tasks are to identify the animals and their names in the pictures. These pictures are independent and thus the tasks can be performed individually. Company X wants help with finding whether crowdsourcing is appropriate for the project.

Accessing tool 1, the manager of company X sees a set of decision factors (left-hand side of Figure 5). Reflecting the project, she chooses to interact with four factors and fulfils the answers for them: 1) Internet: the task can be done through the Internet; 2) easy of delineation: the task can be easy to define; 3) employee for task: the number of employees for the task is small; and 4) budget: the company is dedicated a large budget for the task. We note that the tool reminds the manager the two factors of employee for task and budget that she could forget if not using the tool. After filling in all information, the manager chooses 'Project Summary & Project Advice' to assess the whole project. The tool compares the provided answers with the rules captured by the BPC ontology. Given that the inputs of factor one, two, and three all influence positively on the decision to crowdsource (Afuah and Tucci 2012; Thuan et al. 2016), the tool suggests this project is *suitable with crowdsource.* Further, as the project has large budget (factor four), the tool also suggests *using this budget for hiring crowdsourcing experts to ensure the success of crowdsourcing*. Now, the manager can further explore different what-if scenarios by fulfilling answers for other factors and re-assessing the project until she reaches the most appropriate decision.

5 EMPIRICAL EVALUATION

The evaluation was based on a controlled laboratory experiment, which followed the guidelines of Montgomery (2012). In this section we overview the experiment and describe the experimental design, selection of participants, and procedure. Subsequently, we analyse and discuss the results.

5.1 Overview of Laboratory Experiment

To collect empirical evidence about the tool, we conducted six laboratory experiments. The aim of the experiments was to study the utility of the tool in supporting the BPC decisions. For this purpose, we defined utility as 'having the ability to make difference on the performance between participants using the tool and others who do not use the tool'. To assess the difference, we compared the tool's performance against a null condition, which consisted in measuring the participants' performance without tool support. The groups of participants that used the tool were designated *treatment groups*, while the groups that did not use the tool were designated *control groups*.

According to the evaluation goals, the tool is considered useful if the treatment groups outperform the control groups. Given that, the independent variable used in the experiments was the levels of decision support, which had two values considering the tool support or not. The dependent variable considered the performance of the participants making BPC decisions, a variable that is measured using the participants' answers to two pre-defined exercises, designed according to the decision to crowdsource and the process design. Consequently, we postulated the following hypotheses:

H1a: Use of tool 1 will result in better performance when making the decision to crowdsource.
H1b: Use of tool 2 will result in better performance when designing crowdsourcing processes.

We expected the two hypotheses would hold. That is, we expected that the developed decision support tool would increase the users' performance in both activities.

5.2 Experimental Design and Participants

As typical in comparative experiments, we could design the experiments so that the treatment groups would use tool 1 and tool 2, while the control groups would not use any tool. However, such an experimental design may not allow us to measure the performance of the two tools separately, because of the learning effect. That is, if the participants gain experience using tool 1, then they will perform better when they come to use tool 2. Considering this issue, the experimental design twisted the group role regarding the two tools, using the configuration presented in Table 2.

Table 2. Experimental design

	Exercise 1: decision to crowdsource	**Exercise 2: process design**
Group A	Control group (without Tool 1)	Treatment group (using Tool 2)
Group B	Treatment group (using Tool 1)	Control group (without Tool 2)

Participants were students at Can Tho University of Technology (CTUT). The participants received a 10 NZD gift card for mobile phone re-charge. To keep the participants homogeneous, the recruitment was based on class units, which were a combination of major and study year in CTUT. In particular, we recruited second and third year students with a background in Information Technology (IT) and Industrial Management (IM). As a result, six experimental sessions were assembled. In each session, the participants were randomly assigned to group A and group B. The number of participants per session is presented in Table 3.

Table 3. Number of participants per session (chronological order)

Session	Major	Study Year	Number of participants	**Group A** (Exercise 1 without tool; exercise 2 using tool)	**Group B** (Exercise 1 using tool; exercise 2 without tool)
1	IM	Second	19	10	9
2	IT	Second	40	22	19
3	IM	Third	38	18	20
4	IT	Third	25	12	13
5	IT	Second	24	15	9
6	IM	Second	44	21	22

5.3 Procedure

The experiments were carried out in six sessions. At the beginning of each session, the participants were tutored to become familiar with the crowdsourcing concepts and were instructed on how to use the tool. They were then randomly placed into two computer labs according to groups A and B. The participants then had to complete exercises 1 and 2, each of which requiring about 30 minutes to complete. The same exercises were delivered to both group A and group B. The only difference between the two groups was the treatment, where each group was instructed to use either tool 1 or tool 2 with either exercise 1 or 2. At the end of each exercise, the participants handed their answers to the researchers.

The two exercises required the participants to make decisions regarding to crowdsource or not and defining a crowdsourcing process. Exercise 1 focussed on the decision to crowdsource and considered four different scenarios where crowdsourcing was a possibility. Each scenario had a short description and a question asking 'should the task [in the scenario] be crowdsourced?' To make the scenarios diverse and close to practice, their descriptions highlighted different decision factors, which were adapted from Afuah and Tucci (2012).

Exercise 2 addressed issues related to the process. It identified two scenarios that were based on two actual crowdsourcing projects. Each scenario had a short description and two questions asking about different aspects of the crowdsourcing process: task division, task description, incentive mechanism, and quality control. These aspects were adopted from Kittur et al. (2013) and Pedersen et al. (2013).

Regarding the questions presented in the exercises, each of the two exercises contained four yes/no and multiple-choice questions. Furthermore, we asked the participants to explain their reason(s) for making the choice. To increase the neutrality of the experimental evaluation, the participants had the option to choose 'No Idea', if they thought that the exercise did not provide enough information to answer a particular question. The details of the two exercises are presented in Appendix A.

Pilot experiment

A pilot experiment was conducted with 46 students. It served as a test to refine the experiment materials (Dennis and Valacich 2001). Learning from the pilot experiment, two changes were made to the main experiments. First, the pilot experiment recruited only students with IT background, which could lead to limited results in the decision to crowdsource since IT students could neglect a managerial focus. The main experiments extended the recruitment to include both IT and management students. Second, the pilot results showed high scores of participants both using and not using the tool in both exercises. This suggested that the pilot exercises were not complex enough to discriminate the results (Dennis and Valacich 2001). Addressing this issue, the main experiments increased the complexity of the exercises and asked the participants to provide reasons for their answers.

Measurement

Solution scores were used to measure the participant's performance. Because of the complexity of the exercises, scoring the participants' answers was not a straightforward task. Given that, a marking team was formed with four lecturers from CTUT (excluding the researchers). The team started by developing standard answers and formulating the scores, using well-known frameworks in the domain (Afuah and Tucci 2012; Kittur et al. 2013; Pedersen et al. 2013). They formulated the scores as: a wrong answer was scored 0; a correct answer was 0.5, plus meaningful explanation was an additional 0.5; 'No idea' was either 0 or 0.5 depending on the explanation. This meant that each answer scored either 0 (zero), 0.5, or 1. Given that each exercise had four questions, the scale ranged from 0 to 4.

Using this procedure, the team started by marking together ten answers and discussed the differences. After building consensus, they then did their marking individually. The marking was arranged in a way that each session (i.e. both control and treatment groups) was marked by a single marker, which could reduce marking bias when comparing scores across the two groups. At the end of the marking process, the researcher compared the means of the scores among the sessions. One session had quite a high mean compared to others. A moderation meeting was organised to review the marks of that specific session, which lead to a few corrections.

5.4 Experimental Results

Overall, 190 students participated in the six experimental sessions. All answers were scored and recorded in the sample. Starting the analysis, we tested the normality assumption of the sample. As the solution scores were treated as discontinuous measures (the minimum difference between two scores is 0.5), we expected that the normality assumption might not hold, which was confirmed by the Shapiro-Wilk tests, i.e. *p-values < 0.001 for both exercises*. These results strongly guided our choice of statistical tests in the following analysis. Table 4 shows descriptive statistics of the sample regarding each session.

Table 4. Descriptive results of six experimental sessions

Exercise	Session	N	Mean	Std.	Mean rank
Exercise 1	1	19	2.55	.74	95.47
	2	40	2.40	.95	89.10
	3	38	2.46	.92	91.84
	4	25	2.46	.83	90.78
	5	24	2.75	.78	106.88
	6	44	2.61	.92	100.97
	Total	**190**	**2.53**	**.88**	
Exercise 2	1	19	2.71	.89	98.74
	2	40	2.40	.70	75.98

	3	38	2.71	.84	98.84
	4	25	2.68	.79	96.18
	5	24	2.96	.72	113.29
	6	44	2.74	.82	98.88
	Total	**190**	**2.68**	**.80**	

We then looked at the directions of measures within each session. Table 5 presents the descriptive statistics, comparing the means between groups using the tool and not using the tool in the two exercises. Overall, the directions of measures were in line with our expectation in the two hypotheses. Almost all treatment groups had higher means than the control groups. One exception occurred in session 4, regarding exercise 1, where the treatment group had a lower mean than the other group. For all sessions (the last row of Table 5), the results are consistent with the hypothesis directions.

Table 5. Comparison between groups using the tool and without the tool

	Exercise 1		**Exercise 2** (Swapped the group role)	
	Group A - Without tool Mean (Std.)	**Group B - Using tool** Mean (Std.)	**Group A - Using tool** Mean (Std.)	**Group B - Without tool** Mean (Std.)
Session 1	2.35 (0.85)	2.78 (0.57)	2.85 (0.88)	2.56 (0.92)
Session 2	2.34 (1.07)	2.47 (0.79)	2.71 (0.55)	2.03 (0.70)
Session 3	2.16 (0.84)	2.73 (0.92)	2.89 (0.78)	2.55 (0.89)
Session 4	2.54 (0.78)	2.39 (0.89)	3.00 (0.60)	2.39 (0.85)
Session 5	2.57 (0.75)	3.06 (0.77)	3.23 (0.68)	2.50 (0.56)
Session 6	2.48 (0.88)	2.75 (0.97)	3.25 (0.67)	2.22 (0.63)
All sessions	**2.40 (0.87)**	**2.67 (0.86)**	**2.99 (0.70)**	**2.34 (0.77)**

To use integrated data from these sessions, we first checked the potential differences of the scores among sessions. As our sample datasets were not normally distributed, we used the non-parametric Kruskal–Wallis tests, which are an accepted alternative to ANOVA in case the datasets come from non-normally distributed population (Soh et al. 2006). The results of the Kruskal-Wallis tests showed that there were no significant differences among the six sessions for both exercise 1 (*p-value = 0.788*) and exercise 2 (*p-value =0.145*) at the 0.05 level. These results allowed us to analyse the datasets in an integrated way.

Using the integrated dataset, we then tested hypotheses H1a and H1b. We chose Mann-Whitney tests to compare the performance between the treatment and control groups because, first, the tests were appropriate given the non-normally distributed population of the performance scores (Anderson et al. 2011). Second, the discontinuous measures used in the study called for the use of non-parametric tests, which might lead to having higher power compared to parametric tests (Soh et al. 2006). Finally, the distribution-free nature of the Mann-Whitney tests placed few restrictions on the dataset, and thus allowed us to analyse the integrated dataset from the six sessions. A similar use of the Mann-Whitney tests for analysing integrated datasets was reported by others, such as Mendling et al. (2012).

For each exercise, the Mann-Whitney tests were applied to the integrated dataset. We ran the tests using SPSS version 23.0. Regarding exercise 1, the results of the Mann-Whitney tests are presented in Table 6. The distributions of the two groups are graphically shown in Figure 7.

Table 6. Results of Mann-Whitney tests on exercise 1

Exercise 1	p-value	Group A -Without tool				Group B - Using the tool			
		N	Mean	Std.	Mean Rank	N	Mean	Std.	Mean Rank
Solution score	0.03 (0.03)	99	2.40	0.87	87.44	91	2.67	0.86	104.27

Note: the p-value of t-test is shown in parentheses for comparison purposes.

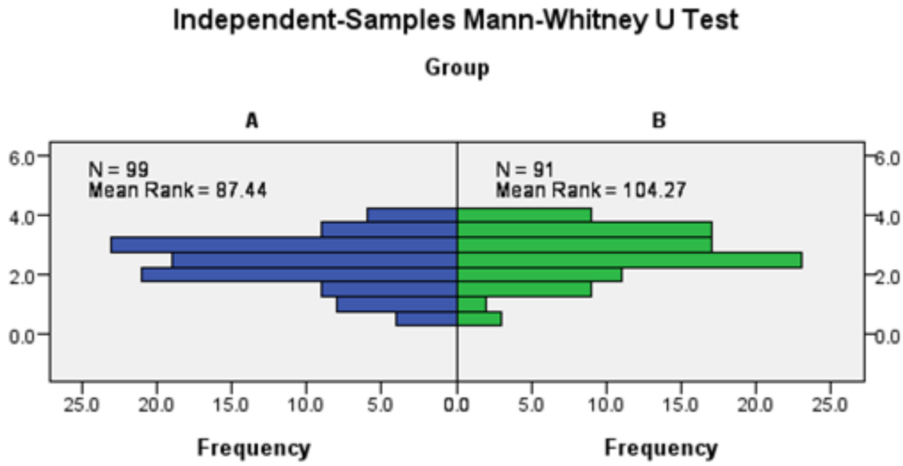

Figure 7. Distributions of Group A and Group B: Exercise 1

Regarding exercise 2, the results of the Mann-Whitney tests are presented in Table 7. The distributions of the two groups are graphically shown in Figure 8. We note the swapping roles of the two groups, group A using the tool and group B without the tool.

Table 7. Results of Mann-Whitney tests on exercise 2

Exercise 2	p-value	Group A - Using the tool				Group B -Without tool			
		N	Mean	Std.	Mean Rank	N	Mean	Std.	Mean Rank
Solution score	<0.001 (<0.001)	99	2.99	0.70	116.62	91	2.34	0.07	72.53

Note: the p-value of t-test is shown in parentheses for comparison.

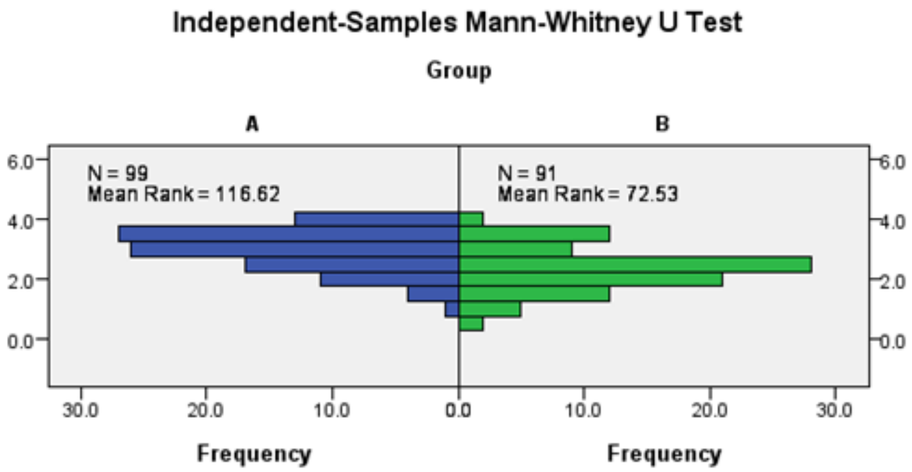

Figure 8. Distributions of Group A and Group B: Exercise 2

The experimental results shown in Figure 7 and Figure 8 support the hypotheses H1a and H1b. More precisely, the results show that the performance of the treatment groups were indeed higher than the control groups (mean rank = 104.27 vs. 87.44 regarding exercise 1, and 116.62 vs. 72.53 regarding exercise 2). Furthermore, the results confirm that the differences are significant at a 0.05 level in both exercise 1 (p-value = 0.03 and U = 5,302.5) and exercise 2 (p-value < 0.001 and U = 2,414.0). From these results, we suggest both hypotheses are accepted. In other words, *both tool 1 and tool 2 improve the BPC decision-making performance*.

6 DISCUSSION AND CONCLUSION

In our research, we investigate an important aspect of crowdsourcing: how to support the crowdsourcing process from a business perspective. While researchers are well aware that a business perspective should be adopted with respect to crowdsourcing, there have been few attempts to research business process crowdsourcing, and even fewer attempts to actually support the decisions involved with a dedicated tool. Existing tools in the crowdsourcing field have focussed on specific aspects of the problem, such as task assignment (Geiger 2016) and results aggregation (Prokesch and Wohlenberg 2014), rather than the whole problem.

The current research adopts a more integrated view over the BPC phenomenon. Our research efforts include the development of an ontology-based decision-making tool, and empirical evidence from the tool usage. Consequently, our research provides the following theoretical and empirical contributions. From a theoretical perspective, we extend prior ontologies (Hetmank 2014; Luz et al. 2015; Thuan et al. 2015) by structuring crowdsourcing concepts and semantics. The BPC ontology enables us to move from understanding to application. We demonstrate the usability of the ontology through the application-based evaluation, where the ontology was actually integrated into the decision tool as a reasoning module.

We further highlight the systematic approach to develop the ontology (Section 3). This approach allows us to integrate existing knowledge sources in the domain to develop the ontology, which in turn backs the DSS development. As a result, the ontology provides a common basis to deal with fragmented issues existing in the crowdsourcing domain. To some extent, this systematic ontology-based approach can be seen as a part of knowledge management for decision support systems (Delir Haghighi et al. 2013). While focusing on the BPC domain in this paper, we believe that this systematic approach can be generalised and applied to other GDN domains.

From a more practical perspective, we developed a tool supporting managers making more informed decisions about crowdsourcing processes. Such decisions may be done by different decision makers using the same tool, e.g. project leaders and process managers. The successful construction of such a tool means five things. First, the tool proves that BPC can be operationalised. Second, the tool demonstrates the applicability of the BPC ontology. That is, the ontology can be implemented in a working system. Third, our research delivers an instantiation artefact (Hevner et al. 2004; March and Smith 1995): a decision tool supporting decision makers to define a crowdsourcing process. Further, the tool complements and extends other research works addressing the support to crowdsourcing tasks (Geiger 2016; Prokesch and Wohlenberg 2014), addressing the whole crowdsourcing process. Finally, the tool enables concrete assessments of its utility.

We assessed the tool using laboratory experimentation. The findings show that the tool increases decision makers' performance for two functions: decision to crowdsource or not, and process design. We note that both functions are useful and both are statistically supported, i.e. process design (p-value < 0.001) and decision to crowdsource (p-value $= 0.03$). When positioning the empirical results within the current literature, we note that the crowdsourcing domain has a shortage of empirical evidence on the use of decision support, e.g. in the case of crowdsourcing recommendation systems that "one of the most fundamental issues for future research [...] is the empirical evaluation of its general utility to the crowdsourcing process" (Geiger and Schader 2014). This research addresses the above shortage and shows the empirical impact of decision support on BPC.

Through a critical lens, this research inevitably has certain limitations. First, we understand the risk of building decision support from ontologies that put together knowledge from diverse knowledge sources, and which may exhibit their own biases and limitations (Kitchenham 2007). We however note that building on diverse knowledge sources is also a strong point, which ensures the comprehensiveness and integrated-ness of the ontology. Regarding the tool, it was primarily developed for research purposes and therefore targeted only at the level of evaluation and demonstration. Although the tool can be redesigned to serve business managers, future developments could use more attractive user interfaces and more recent technology. Finally, we recognise that using students as proxies for business decision makers could be a limitation. Yet, we note that using students to validate software tools has been an acceptable practice. Sjøberg et al. (2005) surveyed 113 software controlled experiments and showed that "87 percent of the subjects were students" (p. 751).

Our work also presents large research opportunities for further work in both academia and industry. In particular, as a solid knowledge base in the domain, the BPC ontology can be used to develop other tools. Some that we can think of at this point in time are knowledge-based and collaborative-based systems. Others may emerge from the combination of interoperability, reasoning and knowledge organisation provided by the ontology. From a technical perspective, our work mainly focuses on the business process aspects of crowdsourcing, which could be extended to other domains. In particular, it could be interesting to integrate our work with existing crowdsourcing platforms. We note that several toolkits that configure and manage crowdsourcing processes have already been developed (Little et al. 2010; Tranquillini et al. 2015). Given that, future research may investigate how to link the decision-support focus with application interfaces. Such connections would assist organisations, from the time they analyse, model, and design crowdsourcing processes, until the time they instantiate them on a particular platform.

REFERENCES

Afuah A, Tucci CL (2012) Crowdsourcing as a solution to distant search. Academy of Management Review 37:355-375

Allahbakhsh M, Benatallah B, Ignjatovic A, Motahari-Nezhad HR, Bertino E, Dustdar S (2013) Quality control in crowdsourcing systems: Issues and directions. IEEE Internet Computing 17:76-81

Amailef K, Lu J (2013) Ontology-supported case-based reasoning approach for intelligent m-Government emergency response services. Decision Support Systems 55:79-97

Amrollahi A (2015) A Process Model for Crowdsourcing: Insights from the Literature on Implementation. Proceedings of the Australasian Conference on Information Systems 2015 Paper 18

Anderson DR, Sweeney DJ, Williams TA (2011) Statistics for business and economics. South-Westerb, Cengage Learning,

Brank J, Grobelnik M, Mladenić D (2005) A survey of ontology evaluation techniques. In: Proceedings of the Conference on Data Mining and Data Warehouses (SiKDD), Ljubljana, Slovenia.

Corcho O, López MF, Gómez-Pérez A (2003) Methodologies, tools and languages for building ontologies. Where is their meeting point? Data & Knowledge Engineering 46:41-64

Delir Haghighi P, Burstein F, Zaslavsky A, Arbon P (2013) Development and evaluation of ontology for intelligent decision support in medical emergency management for mass gatherings. Decision Support Systems 54:1192-1204

Dennis AR, Valacich JS (2001) Conducting experimental research in information systems. Communications of the Association for Information Systems 7

Djelassi S, Decoopman I (2013) Customers' participation in product development through crowdsourcing: Issues and implications. Industrial Marketing Management 42:683-692

Geiger D (2016) Personalized Task Recommendation in Crowdsourcing Systems. Progress in IS. Springer International Publishing,

Geiger D, Schader M (2014) Personalized task recommendation in crowdsourcing information systems—Current state of the art. Decision Support Systems 65:3–16

Geiger D, Seedorf S, Schulze T, Nickerson RC, Schader M (2011) Managing the crowd: towards a taxonomy of crowdsourcing processes. Proceedings of the Seventeenth Americas Conference on Information Systems:Paper 430

Gregor S, Hevner AR (2013) Positioning and presenting design science research for maximum impact. MIS Quarterly 37:337-355

Guarino N, Oberle D, Staab S (2009) What is an Ontology? In: Staab S, Studer R (eds) Handbook on ontologies. Springer, pp 1-17

Hetmank L (2013) Components and Functions of Crowdsourcing Systems–A Systematic Literature Review. Paper presented at the 11th International Conference on Wirtschaftsinformatik, Leipzig, Germany

Hetmank L (2014) Developing an Ontology for Enterprise Crowdsourcing. Paper presented at the Multikonferenz Wirtschaftsinformatik, Paderborn

Hevner A, Chatterjee S (2010) Design Research in Information Systems: Theory and Practice. Integrated Series in Information Systems. vol 22. Springer Berlin Heidelberg,

Hevner A, March ST, Park J, Ram S (2004) Design science in information systems research. MIS Quarterly 28:75-105

Hossfeld T, Keimel C, Hirth M, Gardlo B, Habigt J, Diepold K, Tran-Gia P (2014) Best Practices for QoE Crowdtesting: QoE Assessment With Crowdsourcing. IEEE Transactions on Multimedia 16:541-558

Howe J (2006) The rise of crowdsourcing. vol 14. Dorsey Press,

Kaufmann N, Schulze T, Veit D (2011) More than fun and money. Worker motivation in crowdsourcing–a study on mechanical turk. Proceedings of the Seventeenth Americas Conference on Information Systems, Detroit, MI:Paper 340

Khazankin R, Satzger B, Dustdar S (2012) Optimized execution of business processes on crowdsourcing platforms. IEEE 8th International Conference on Collaborative Computing: Networking, Applications and Worksharing:443 - 451

Kitchenham B (2007) Guidelines for performing systematic literature reviews in software engineering. Ver 23 EBSE Technical Report

Kittur A, Nickerson J, Bernstein M, Gerber E, Shaw A, Zimmerman J, Lease M, Horton J (2013) The Future of Crowd Work. Proceedings of the 2013 Conference on Computer Supported Cooperative Work

Kucherbaev P, Daniel F, Tranquillini S, Marchese M (2016) Crowdsourcing processes: a survey of approaches and opportunities. IEEE Internet Computing 2:50 - 56

La Vecchia G, Cisternino A (2010) Collaborative Workforce, Business Process Crowdsourcing as an Alternative of BPO. In: Daniel F, Facca FM (eds) ICWE2010. LNCS, vol 6385. LNCS. Springer, pp 425-430

Little G, Chilton LB, Goldman M, Miller RC (2010) Turkit: human computation algorithms on mechanical turk. Proceedings of the 23nd annual ACM symposium on User interface software and technology:57-66

Liu S, Zaraté P (2014) Knowledge based decision support systems: A survey on technologies and application domains. In: Joint International Conference on Group Decision and Negotiation. Springer, pp 62-72

Lüttgens D, Pollok P, Antons D, Piller F (2014) Wisdom of the crowd and capabilities of a few: internal success factors of crowdsourcing for innovation. Journal of Business Economics 84:339-374

Luz N, Silva N, Novais P (2015) A survey of task-oriented crowdsourcing. Artificial Intelligence Review 44:187-213

March ST, Smith GF (1995) Design and natural science research on information technology. Decision Support Systems 15:251-266

Mendling J, Strembeck M, Recker J (2012) Factors of process model comprehension—findings from a series of experiments. Decision Support Systems 53:195-206

Miah SJ, Kerr D, von Hellens L (2014) A collective artefact design of decision support systems: design science research perspective. Information Technology & People 27:259-279

Mo J, Sarkar S, Menon S (2015) Making Task Recommendations in Crowdsourcing Contests. PACIS 2015 Proceedings AISeL Paper 132

Montgomery CD (2012) Design and Analysis of Experiments. 8 edn. John Willey & Sons, Inc, New York

Moral C, De Antonio A, Ferre X (2017) A visual UML-based conceptual model of information-seeking by computer science researchers. Information Processing & Management 53:963-988

Morente-Molinera JA, Wikström R, Herrera-Viedma E, Carlsson C (2016) A linguistic mobile decision support system based on fuzzy ontology to facilitate knowledge mobilization. Decision Support Systems 81:66-75

Muhdi L, Daiber M, Friesike S, Boutellier R (2011) The crowdsourcing process: an intermediary mediated idea generation approach in the early phase of innovation. International Journal of Entrepreneurship and Innovation Management 14:315-332

Okoli C (2015) A Guide to Conducting a Standalone Systematic Literature Review. Communications of the Association for Information Systems 37:Article 43

Paré G, Trudel M-C, Jaana M, Kitsiou S (2015) Synthesizing information systems knowledge: A typology of literature reviews. Information & Management 52:183-199

Pedersen J, Kocsis D, Tripathi A, Tarrell A, Weerakoon A, Tahmasbi N, Jie X, Wei D, Onook O, De Vreede GJ (2013) Conceptual Foundations of Crowdsourcing: A Review of IS Research. 46th Hawaii International Conference on System Sciences (HICSS):579-588

Prokesch T, Wohlenberg H (2014) Results From A Group Wisdom Supporting System. Proceedings of the European Conference on Information Systems (ECIS) 2014:Paper 7

Rouse AC (2010) A preliminary taxonomy of crowdsourcing. Proceedings of the 21st Australasian Conference on Information Systems:Paper 76

Rowe M, Poblet M, Thomson JD (2015) Creating value through crowdsourcing: the antecedent conditions. In: International Conference on Group Decision and Negotiation. Springer, pp 345-355

Sánchez D, Moreno A (2008) Learning non-taxonomic relationships from web documents for domain ontology construction. Data & Knowledge Engineering 64:600-623

Satzger B, Psaier H, Schall D, Dustdar S (2011) Stimulating skill evolution in market-based crowdsourcing. In: Rinderle-Ma S, Toumani F, Wolf K (eds) BPM 2011. LNCS, vol 6896. Lecture Notes in Computer Science. Springer Berlin Heidelberg, pp 66-82

Schenk E, Guittard C (2009) Crowdsourcing: What can be Outsourced to the Crowd, and Why? In: Workshop on Open Source Innovation, Strasbourg, France.

Schenk E, Guittard C (2011) Towards a characterization of crowdsourcing practices. Journal of Innovation Economics 7:93-107

Schnitzer S, Neitzel S, Schmidt S, Rensing C (2016) Perceived Task Similarities for Task Recommendation in Crowdsourcing Systems. In: Proceedings of the 25th International Conference Companion on World Wide Web. International World Wide Web Conferences Steering Committee, pp 585-590

Seeber I, Merz A, De Vreede G-J, Maier R, Weber B (2017) Convergence on Self-Generated vs. Crowdsourced Ideas in Crisis Response: Comparing Social Exchange Processes and Satisfaction with Process. In: Proceedings of the 50th Hawaii International Conference on System Sciences. pp 687-696

Shanks G, Tansley E, Weber R (2003) Using ontology to validate conceptual models. Communications of the ACM 46:85-89

Sjøberg DI, Hannay JE, Hansen O, Kampenes VB, Karahasanovic A, Liborg N-K, Rekdal AC (2005) A survey of controlled experiments in software engineering. IEEE Transactions on Software Engineering 31:733-753

Soh C, Markus ML, Goh KH (2006) Electronic marketplaces and price transparency: strategy, information technology, and success. MIS Quarterly:705-723

Thuan NH, Antunes P, Johnstone D (2016) Factors Influencing the Decision to Crowdsource: a Systematic Literature Review. Information Systems Frontiers 18:47-68

Thuan NH, Antunes P, Johnstone D (2017) A Process Model for Establishing Business Process Crowdsourcing. Australasian Journal of Information Systems 21:1-21

Thuan NH, Antunes P, Johnstone D, Ha XS (2015) Building an Enterprise Ontology of Business Process Crowdsourcing: A Design Science Approach. PACIS 2015 Proceedings AISeL Paper 112

Tokarchuk O, Cuel R, Zamarian M (2012) Analyzing Crowd Labor and Designing Incentives for Humans in the Loop. IEEE Internet Computing Magazine 16:45-51

Tranquillini S, Daniel F, Kucherbaev P, Casati F (2015) Modeling, Enacting, and Integrating Custom Crowdsourcing Processes. ACM Transactions on the Web (TWEB) 9:Article 7

Uschold M, King M (1995) Towards a methodology for building ontologies. In: IJCAI95 Workshop on Basic Ontological Issues in Knowledge Sharing, Montreal.

Vukovic M (2009) Crowdsourcing for enterprises. In: 2009 World Conference on Services-I, Los Angeles, CA. IEEE, pp 686-692

Vukovic M, Laredo J, Rajagopal S (2010) Challenges and experiences in deploying enterprise crowdsourcing service. In: Benatallah B, Casati F, Kappel G, Rossi G (eds) ICWE 2010. LNCS, vol 6189. LNCS. Springer Berlin Heidelberg, pp 460-467

Yuen M-C, King I, Leung K-S (2015) Taskrec: A task recommendation framework in crowdsourcing systems. Neural Processing Letters 41:223-238

Zhao Y, Zhu Q (2014) Evaluation on crowdsourcing research: Current status and future direction. Information Systems Frontiers 16:417-434

APPENDIX A

Demographic information. Please complete the following demographic information

Name: ____________________________________

Gender:	☐ Male		☐ Female	
Major:	☐ IT/IS		☐ Industrial Management	
Year of study:	☐ First	☐ Second	☐ Third	☐ Fourth

Exercise 1: Please read the four scenarios and answer each of the following questions (30 minutes)

Reference number____________________________________

Group: ☐ Using the tool ☐ Without the tool

Scenario 1: Company X has a project to digitise clients' credit information (payment history, credit cards, mortgages, car finance, and hire purchases). In this project, the main tasks are to digitise 500 scanned reports, which requires general computer skills. The estimated time for each task is five minutes. These tasks are independent and can be performed individually.

- Should this task be crowdsourced?

☐Yes ☐No ☐No Idea

Please provide from **1 to 3 reasons** for your answer.

Reasons**:**...

....

....

Scenario 2: To control traffic in Wellington city (or Ho Chi Minh city), organisation Y has a project with the main task being to collect traffic information. In this task, traffic data are collected through a smart phone application. The application enables the users to report information about the location, GPS point, pictures of the traffic flows in the location, and users' judgement on the traffic flows. The target of the project is to collect a data set of 10,000 records. The project has ten employees, and the budget allocated for it is 10,000 NZD.

- Should this task be crowdsourced?

☐Yes ☐No ☐No Idea

Please provide from **1 to 3 reasons** for your answer.

Reasons**:**...

....

....

Scenario 3: Z is an architecture firm with several experienced architects. The firm has a project to design bus stops, which will be installed in the whole Wellington city (or Ho Chi Minh city). The requirements of the design include usefulness, innovation, and friendliness. More importantly, the design needs to be accepted by the citizens. The design can be either a completed design in detail or an illustrated sketch. Budget allocated for the project is 10,000 NZD.

- Should this design task be crowdsourced?

☐Yes ☐No ☐No Idea

Please provide from **1 to 3 reasons** for your answer.

Reasons**:**...

....

....

....

Scenario 4: U Hospital is a national hospital dedicated to cancer treatment, which focuses on predicting cancer and tailoring treatments to each patient. Every week, the hospital receives 1,000 clinical records from the local hospitals with the requests for cancer prediction. The main tasks in cancer prediction include examining the classification of cell mass biopsy images, determining the malignancy of tissue samples, and identifying cancer cells. With many such tasks, the hospital is looking for additional workforce to handle the image examination.

- Should this mange examination task be crowdsourced?

☐Yes ☐No ☐No Idea

Please provide from **1 to 3 reasons** for your answer.

Reasons**:**...

....

....

....

(Note: You may ask for more paper)

Exercise 2: Please read the two scenarios and answer each of the following questions (30 minutes)

Reference number___________________________________[1]

Group: ☐ Using the tool ☐ Without the tool

Scenario 5: Organisation A has 10,000 pictures about wild animals that were captured by motion-triggered cameras in 40 wild locations in New Zealand. This organisation sets up a project aiming at identifying the animals and their names in the pictures (if there are any). As the number of tasks is very large, the organisation **decides to crowdsource.** The main job in the project is to view the picture, identify whether there are any animals in the picture, and input the animal name (if known). The budget for the project is 2,000 NZD.

- Should this project divide tasks into sub-tasks?

☐Yes ☐No ☐No Idea

Please provide **the reasons** for your answer.

Reasons**:**..

....

....

What is the workflow to establish the project (step 1, 2,….)?

Workflow**:**..

....

....

Scenario 6: The Crowd Logo project aims at designing a logo for a technical university. This logo should represent the spirit of the university, which includes open mind, creativity, and leading technology. To collect expertise from outside, **the project decides to crowdsource** and invites the crowd to join a logo design competition. Everyone can submit their design, consisting of a logo, a slogan, and an explanation on the meaning of the logo. The budget for the project is 5,000 NZD.

- How to motivate the crowd to participate in the competition?

Way(s) to motivate**:** ....

....

....

- Normally, this kind of competition receives a large number of submissions. How can this project assess the quality of the submissions?

Quality assessment**:** ....

....

....

[1] The reference number is re-printed, and is the same for exercise 1 and exercise 2