Design Science Perspective on NFC Research: Review and Research Agenda

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Near Field Communication (NFC), as one of the emerging and promising technological developments, provides means to short range contactless communication for mobile phones and other devices alike. NFC has become an attractive design science research area for many academicians due to its exploding growth and its promising applications and related services. A better understanding of the current status of NFC research is necessary to maintain the advancement of knowledge in NFC research and to identify the gap between theory and practice. In this paper, we present a literature review on NFC. To facilitate the analysis of the literature, we propose a research framework and organize the NFC literature into four major categories (theory and development, applications and services, infrastructure, ecosystem). We contend that due to the nature of NFC (industry high stakes, multidisciplinary research, artifacts development), the design science research paradigm serves an appropriate ground to investigate an extent to which relevance and rigor is achieved. By employing the proposed research framework and design science perspective, we set up a research agenda (research directions and promising research questions) which may help practitioners and academics to achieve a substantial progress in NFC.

Povzetek: Predstavljen je strokovni okvir za NFC, komunikacijo kratkega dosega.

1 Introduction

Today the rapid development and adoption of information technologies (IT) is changing the way of doing business significantly. The growing interest on electronic commerce to perform business transactions brought vital improvements, especially in wireless technologies [80]. Near Field Communication (NFC) has become one of the promising wireless technological developments in the information and communication industry. NFC technology is a short-range, high frequency, low bandwidth radio technology. It allows us to transfer data within few centimeters. As shall be discussed later on, along with three operating modes (reader/writer, peer-to-peer and card emulation [81]), key advantages of NFC over other wireless technologies include simplicity and inherent security [13, 19]. The integration of NFC technology into mobile devices offers many reliable applications such as payment, ticketing, loyalty services, identification, access control, content distribution, smart advertising, peer-to-peer data/money transfers, and set-up services [85].

NFC has become an attractive research area for many academics due to its exploding growth and its promising applications and related services. Noticeably, for the last few years, there has been a considerable amount of increase in the number of research papers and activities concerning NFC. However, a better understanding of the current status of NFC research area is necessary to maintain the advancement of knowledge in NFC research and to identify the progress of NFC research. Thus, a literature research framework is necessary to fulfill the needs. In the present research, such a framework is established and used to make sense of NFC endeavors and to propose promising research directions with a number of research questions.

Scholars, including [83], address a relevance issue in information systems (IS) research and emphasize an importance of studying information technology (IT) artifacts as design science research (DSR). [92] maintains that DSR enables a focus on the IT artifact with a high priority on relevance in an application domain. In this regard, NFC as an innovative artifact

exemplifies the central role of the IT artifacts in IS research. As shall seen later on, most of the research on NFC yields such artifact types as constructs, models, methods and instantiations [86]. Thus, to examine the progress of NFC research one needs to examine how well rigor and relevance is achieved and what research issues need to be addressed. We contend that due to the nature of NFC (industry high stakes, interdisciplinary research, artifacts development), design science research paradigm serves an appropriate ground to investigate an extent to which relevance and rigor is achieved. By employing the proposed research framework and design science perspective, we set up a research agenda which may help practitioners and academics to achieve a substantial progress in NFC.

The contribution to this study is two-fold. First, it goes beyond a typical literature review and establishes a framework by which we articulate the status of Body-of-Knowledge for NFC. By employing a DSR perspective, the paper proposes a research agenda and brings up promising research questions. Second, the paper contributes to IS research by showing how DSR can be used to examine the progress of NFC as an emerging research field.

The paper is organized as follows. First, we clarify what the basis of this research is and what relevant research is used to explicate the research rationale in this paper. Second, we present the research approach and method adopted to establish the framework and set up the research agenda. Third, the framework is proposed and used to explicate the BoK for NFC. Fourth, the DSR perspective with a number of criteria is used to examine the progress of NFC. Fifth, the research agenda is provided to support academics and practitioners and, finally, the conclusion is drawn.

2 Relevant Research and Methodology

2.1 Organizing Frameworks in Relative Research Areas

[84] maintain that an effective review is essential to create a solid foundation for advancing knowledge. Such a foundation provides a reference Body-of-Knowledge (BoK) and facilitates both an academic progress and effective use of research outcomes.

Reviewing academic literature for an emerging research area like NFC is a challenge because the accumulated knowledge may not be mature enough for synthesis. On the other hand, it is necessary as to one can make sense of existing research endeavors and relate ongoing research to the BoK. Such a review work about the NFC research area has not been performed so far rigorously. The present research attempts to fulfill this need.

While we determine the basis of our review, we need to look into those review studies which can contribute to establishment of the NFC framework. Thus, we examine review studies in IS in general, NFC relevant reviews in particular. As shall seen in the next section, we used the former to determine a review approach, that is what review approach should be adopted for examining NFC. The latter includes review studies on electronic commerce (e-commerce), RFID or any wireless technology related topics, and is important to elaborate in a such way that subject-specific insights can be gained and may help in determining the organizing framework. We shall discuss briefly what and how frameworks have been established in representative studies.

Regarding with electronic commerce (e-commerce), it is broader, yet helps in identifying a relevant research area to NFC which provides a sense of organizing boundary for implications of NFC with respect to such perspectives as business, organization, technology. Indeed, one can find several review studies and frameworks on electronic commerce in terms of essential concepts along with these perspectives. For instance, in [3] and [4], the proposed research frameworks are based on four dimensions (applications, technology, support, and implementation along with other issues).

Likewise, mobile commerce (m-commerce) literature reviews are also good sources for understanding the implications of mobile technology on modifying existing e-commerce frameworks [3]. [2] identified the gaps between theory and practice and future research directions for m-commerce papers through a well structured classification framework and analyses.

[87] conduct one of the prominent survey studies on wireless technologies. The organizing framework maintains high level conceptions on underlying notions, characterization of types of applications, design principles and architecture issues. Such an overarching survey concludes with summarizing existing research attempts and the very need of this technology for further development and use in practice.

Regarding review studies on Radio Frequency Identification (RFID), as a related technology to NFC, [1] organized studies as "technological issues, applications areas, policy and security issues, and other issues". As stated in [3], such a study is considered to be a reference study for those researchers interested in this area.

While the examined review studies are useful for determining an organizing framework, the key questions still remain as follows: how to develop such a framework for NFC? What theoretical perspective helps to examine and facilitate the progress of NFC?

2.2 NFC as Design Science Research

Upon the establishment of a research framework, one needs to examine the progress and opportunities for NFC. To do this, we seek to identify an appropriate research perspective. Thanks to recent discussions on prominent orientations in conducting IS research, which is about behavior- versus design oriented research [92]. The discussions appear to be escalated in recent issues of top IS journals such as MISQ, ISR, and EJIS where scholars, including [83], argue origination and values of

design-oriented IS. This present research does not delve into philosophical argumentations for research perspectives, rather aims to get the most out of the rich discussion on how appropriate research perspective may benefit examining progress of NFC.

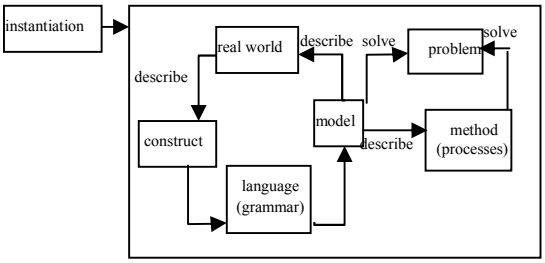

Figure1: IT artifact instantiation (adopted from [86])

In seeking an appropriate research perspective, it appears that NFC is an excellent research area to exemplify design-oriented research characteristics. First and foremost characteristic is the research focus on IT artifacts. It can been seen that BoK for NFC is mainly dominated by studies focusing on emerging and innovative artifacts (see section 3). This is no surprise since prevailing research motivation in NFC research area is problem-solving oriented and results in type of artifact - that is, constructs, models, methods and instantiations (See figure 1). [82] shows how instantiation inherits complex relations among *construct* (deriving from and a real world phenomenon and leading too language), *model* (formulated by a language and representing the problem under investigation), and *method (*explicating the process of achieving the solution). We shall explicate these relations with some illustrative examples, but there is one thing to note that a real world is primarily a triggering source. In the context of NFC research, this source was evident that industry leaders such as Nokia, Philips and Sony jointly developed NFC as an alternative or complementary communication model to overcome issues with wireless technologies such as RFID, Bluetooth [11].

Noticeably, the focus on IT artifacts has a lot to do with a design rationale and aims to solve a particular problem which brings up the value of relevant research. This is the secondary characteristic in that design oriented research strives for high relevance by examining an extent to which proposed artifacts meet expected utility. In recent years including [81, 82, 83], scholars in the IS research domain have raised the issue of lacking relevance. Regarding the need for relevance, the difference of behavioral science and design science research should not be considered as dichotomy, but complementary approaches with differing research rationale. [86] suggests that while behavioral IS research aims at 'truth', i.e., at the exploration and validation of generic cause–effect relations, IS design science research aims at 'utility', i.e., at the construction and evaluation of generic means–ends relations. That is, the notion of relevance is equally important matter for design and behavior research. Thirdly, design science research may benefit from a systematic process of IT artifact development (e.g., deductive or inductive) at higher abstraction, which in turn contributes substantially to the structuring and integration of the body of knowledge.

Guideline	Description	DSR Cycles	Key Questions
Guideline 1. Design as an artifact	Design science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation	Design Cycle	What is the artifact? How is the artifact represented?
Guideline 2. Problem relevance	The objective of design science research is to develop technology-based solutions to important and relevant business problems	Relevance Cycle	What is the research question (design requirements)? Has the research question been satisfactorily addressed?
Guideline 4. Research contributions	Effective design science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies	Rigor Cycle	What new knowledge is added to the knowledge base and in what form (e.g..peer-reviewed literature, meta-artifacts, new theory, new method)?
Guideline 3. Design evaluation	The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods	Relevance	How is the artifact introduced into the application environment and how is it field tested? What metrics are used to demonstrate artifact utility and improvement over previous artifacts?
Guideline 5. Research rigor	Design science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact	Rigor Cycle and Design Cycle	What design processes (search heuristics) will be used to build the artifact? How are the artifact and the design processes grounded by the knowledge base? What, if any, theories support the artifact design and the design process?
Guideline 6. Design as a search process	The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment		
Guideline 7. Communication of research	Design science research must be presented effectively to both technology-oriented and management-oriented audiences	Relevance Cycle	No specific questions identified.

Table 1: DSR Guidelines, Cycles and Checklist (adopted from [92])

As stated in [92], design science is inherently a problem solving process that creates and evaluates IT artifacts intended to solve identified organizational problems. They provide seven critical guidelines for researchers to achieve effective design-science research in Information Systems (IS). Later on, [92] introduces three cycles and checklist questions to make the guidelines more operational in empirical sense.

The relevance cycle refers to how research is initiated in light of application context so that the requirements for the research as inputs and as well as for acceptance criteria are explicitly defined. The rigor cycle is concerned with knowledge related to both experience and expertise defining the state of art in the application domain and artifacts, processes. The design cycle indicates actual artifact development and its evaluation. In Table 1, we relate guidelines to cycles and checklist questions.

As the research cycles indicate, knowledge and understanding of design science research guidelines is the critical part of our research study. In fact, these guidelines are not mutually exclusive. In accordance with [92], the first requirement is that design science research has to provide an innovative, purposeful *design artifact* in the form of a construct, a model, a method, or an instantiation. The design artifact has to solve a specific problem or to develop technology based solutions which is refers to *problem relevance* as the second requirement. Indeed, these two guidelines generally mentioned in a typical design science paper due to their nature. *Design evaluation* as the third requirement maintains the evaluation of utility, quality, and efficiency of the proposed design artifact through observational, analytical, experimental, testing or descriptive methods [92]. In our assessments, we mainly focused on which techniques for design evaluation were used in detail, and the quality of the design evaluations.

In essence, the design artifact itself must be *rigorously* defined, formally represented. *Applicability and generalizability of the artifact* has to be mentioned explicitly which is the sign of research rigor. Such a rigorous research work with clear contributions and efficient *design evaluations* has to facilitate a search process (i.e. the search for the best or optimal design artifact). Furthermore, the proposed design artifact must be presented both to *technology-oriented as well as management-oriented audiences* [92]; each side needs sufficient detail about the design artifact. Such communication of design science research provides repeatability of the proposed artifact and further research works for technology oriented audiences. At the same time, management oriented audiences appreciate such an artifact's nature, make assessments within their specific organizational context.

In later sections, these guidelines and checklist questions are used to examine NFC studies and induce a research agenda in light of three cycles. For an illustration purpose and contextualizing design science guidelines, consider the following three NFC studies which are examined from the design science guidelines (see Table 2).

2.3 Research Methodology

Building a research framework requires identification of essential characteristics for NFC. The literature review and relevant organizing framework studies serve a good basis to induce a framework. [84] state that the literature review is expected to answer questions such as: What are the key theories, concepts and ideas?, How is knowledge on the topic structured and organized? What are the major issues and debates about the topic? How have approaches to these questions increased our understanding and knowledge? In IS literature, several examples such as [81] can be found where reviews are often concept centric, which is also the case in this study.

Namely, core concepts underlying the research matter are used to determine the organizing framework.

Since NFC is a rather emerging technology, research papers on NFC are relatively recent. First NFC related papers appear in the scientific publication in 2005. Thus

Guidelines	**Keywords**	**[14]**	**[79]**	**[80]**
Guideline 1. Design as an Artifact	Constructs, Models, Practices, Representations, Methods, Instantiations, Prototypes	Platform to securely manage smartcard applications in NFC devices	Prototype of a snowboarder community platform	NFC application to support health monitoring
Guideline 2. Problem Relevance	Problem Solving, Optimization, Profit Maximization	Clearly mentioned; need for secure managemen t	Mentioned: for social interaction and provides product information	Clearly mentioned: the requirements; providing accurate measurement devices
Guideline 3. Design Evaluation	Observational (Case Studies), Analytical, Experimental, Functional or Structural Testing, Descriptive (Scenarios)	Not evaluated, only implications of the platform	Not evaluated; implications of use cases are mentioned	Not clearly mentioned
Guideline 4. Research Contributions	New Metrics, System Development Methodologies, Design Tools, Prototypes or Improvement of Existing Foundations	Not explicit	Not explicit	Clear and verifiable contributions are provided
Guideline 5. Research Rigor	Applicability, Generalizability, Appropriateness, Feasibility of the Design Artifact, Well Design Evaluations	To some degree	Not explicit	Not explicit
Guideline 6. Design as a Search Process	Iterative Process, Searching for The Best, Optimal Design, Future Work or Studies	Facilitates search process	Facilitates search process	Facilitates search process, needing more future technical study
Guideline 7. Communicatio n of Research	Communication to both audiences; Managerial and Technology Oriented Audiences	Communica tes all types of audiences	Communicate s all types of audiences	Communicate s all types of audiences

Table 2: Exemplary NFC Studies Examined by a Design Science

the scope of this survey is limited to the time frame of 2005-December 2011; this period is considered as the representative NFC literature.

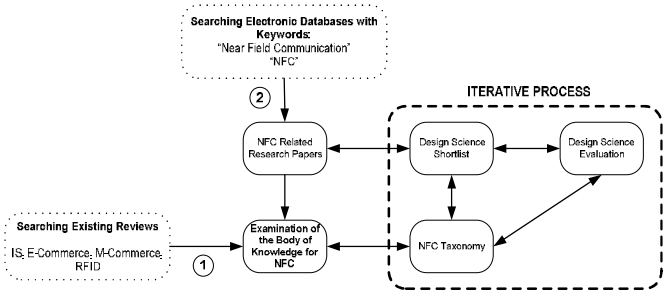

Figure 2: Search Strategy

Our literature review includes articles in journals and conference proceeding papers (especially, published by IEEE, ACM, and other academic associations). We exclude master's theses, doctoral dissertations, textbooks, unpublished working papers, and white papers. Researchers and practitioners often use journal papers to acquire information and to disseminate new research findings [4], thus most of the existing literature reviews exclude conference proceeding papers, too. However, we did not exclude conference papers in our literature review as the proceeding papers provide also a high level of research, both in width and breadth after journals. At the same time, we exclude some writings those are published as editorials, industry and news reports or book reviews.

After performing the search for the papers as defined above, we have found 202 articles (see figure 2, Step 2). The literature search was based on two descriptors; "NFC" and "Near Field Communication". It was conducted using the following electronic databases:

1. IEEE/IEE Electronic Library
2. Association for Computing Machinery
3. ISI Web of Knowledge
4. Academic Search Complete
5. Computer and Applied Science Complete
6. Science Direct
7. Emerald Full Text

By using the academic sources above, we listed all studies related to NFC along with their relevance. After the collection of 202 NFC related papers, a shortlist from these studies is created for a design science evaluation; 25 studies were selected by two researchers. Two strategies were followed during the selection of studies for a design science evaluation; elimination of similar papers in terms of *topic coverage, varieties* and selection of the papers which cover the subjects *in-depth*. To illustrate how strategies have been implemented, consider [48] [73]. These two studies basically focus on NFC applications in health care. Thus, in terms of topic coverage and specific aspects of NFC, they are concerned about similar research issues though their coverage varies. To make use of an extent to which the subject is examined, we look at a degree to which in-depth articulation and re-contextualization of underlying theories or accounts. Nevertheless, our shortlist also gives information about title, author, source, domain and key research issues of the papers. 25 NFC related papers were reviewed from the design science point of view.

In accordance with Design Science Research Guidelines [92], two researchers conducted separate evaluations of these papers to see any discrepancy with their evaluations. The papers in question were examined and evaluated again to ensure more objective, systematic and rigor assessments. Meanwhile, with the collection of NFC related papers, two researchers started to work on the taxonomy of NFC research and categorization of each study. The research strategy followed for this study was an iterative process, backward strategy (see figure 1) while working on the classification of the NFC literature. We tried to find and add new studies about NFC to our review and design science shortlist. In doing so, we are able to provide academicians and practitioners with a comprehensive base for better understanding of NFC research.

The distribution of the papers by their publication year is presented in figure 3. As shown in figure 3, research on NFC as a promising design science research area grew significantly in recent years, especially after 2008.

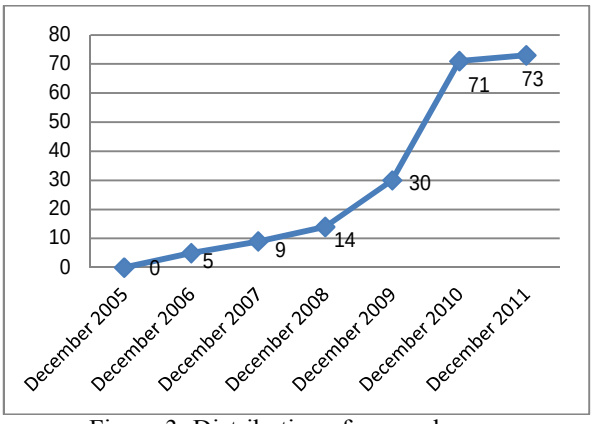

Figure 3: Distribution of papers by year

We should also note that the research methodology that is employed for this academic literature review has some limitations. The first limitation is about the limited number of journal papers found for the literature review. Due to its characteristics, NFC research results are yet to be mature enough, so this limitation is naturally inevitable. The second possible limitation is that the evaluation of 25 research papers through design science guidelines was done by human-reasoning with articulations. This is also due the fact that the adopted evaluations criteria are aimed to facilitate our examination without quantitative measures even two researcher did separate evaluations and compare their results with a number of review cycles.

3 Framework for Research on NFC

The proposed framework is based on a concept-centric literature review [84]. Concepts are consolidated in terms of subject categories. We identify four major categories (see figure 4) and bidirectional relationships between categories.

These are NFC Theory and Development, NFC Infrastructure, NFC Applications and Services and NFC Ecosystem. In the following, we shall describe them and their sub-categories with corresponding studies.

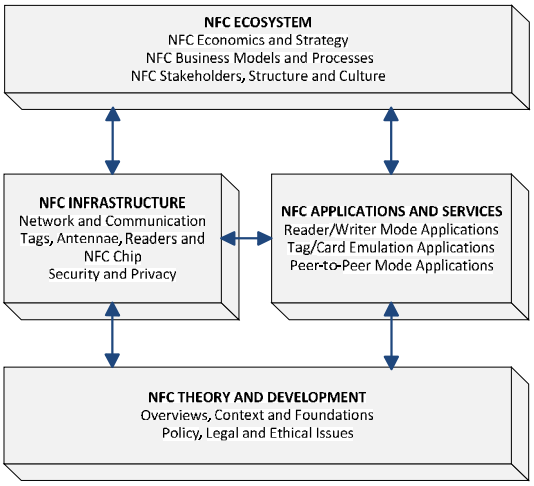

Figure 4: Classification Framework for NFC Research

3.1 NFC Theory and Development

This is the fundamental level of the proposed NFC research framework. It includes the studies related with the development of NFC technology and applications. We examine this level along with two aspects. The first one is "Overviews, Context and Foundations" which includes general introductions, assessments, reviews about NFC, foundations or standards on NFC technology, performance analysis and measurements and new guidelines for the development of NFC enabled applications or services. The second one is "Policy, Legal and Ethical issues" such as security and privacy issues, regulations, and legal requirements. These papers generally focus on more behavioural issues and behavioural sciences which seek to develop and justify theories, rather than developing a design artifact. It is true that these theories underpin and are affected by design decisions [92]. NFC Development papers dealing with this level influences upper levels that focus on design science in NFC research.

3.2 NFC Infrastructure

In fact, this intermediate level is introduced as NFC technology which is examined in terms of three major aspects; "Network and Communication" issues (e.g. data aspect, new communication protocols, OTA transactions), hardware issues dealing with "Tags, Antennae, Reader and NFC Chip", "Security and Privacy" issues (e.g. vulnerability analysis, availability, confidentiality, integrity, authentication, authorization, non-repudiation) that focus on developing design artifact rather than behavioural issue. This layer is positioned with pre-defined business related with to existing technology infrastructure, applications and existing ecosystem. That is, the proposed framework shows the direct linkages of "NFC Infrastructure" with other categories. Moreover, NFC infrastructure related research facilitates new business needs due to the search process nature of NFC.

3.3 NFC Applications and Services

Another middle level of NFC framework as NFC enabled Applications and Services. This is influenced from other three categories and provides a problem space or new business needs. NFC technology covers a wide range of applications and these applications provides real implementations or prototypes with rigor design artifact evaluations such as experimental, testing or field studies etc. We investigate NFC applications from the standpoint of NFC operating modes. "Reader/Writer Mode Applications" provides NFC devices to read and modify data stored in NFC compliant passive (without battery) transponders, "Card Emulation Mode Applications" provides NFC devices to behave like a standard smartcard (e.g. payment and ticketing applications), "Peer-To-Peer Mode Applications" enables two NFC devices to establish a device to device link-level communication to exchange contacts or any other kind of data [81]. Indeed, design artifacts which propose composed applications or services operating in two or more modes can be seen in NFC literature.

3.4 NFC Ecosystem

NFC Ecosystem as the highest level of the NFC Research Framework can be also referred as a part of the problem space or environment of NFC research, the improvements or changes in middle and fundamental layers affect NFC Ecosystem significantly. We examined NFC ecosystem in three major categories. "NFC Economics and Strategy" and "NFC Business Models and Processes" are about business requirements, analysis and managerial sides of the NFC technology. Third aspect is the "NFC Stakeholders, Structure and Culture" which deals with more social sides of NFC technology such as roles, characteristics and capabilities (e.g. user acceptance, usability, adoption, reliability, manageability) of stakeholders (e.g. Mobile network operators, service providers, end users), cultural context of NFC enabled services. Stakeholders play a crucial role in facilitating the NFC research and development. In accordance with [2], in a NFC ecosystem, there are the goals, tasks, problems, and opportunities that define business needs as they are perceived by the stakeholders. These perceptions are shaped by the roles and capabilities. The characteristics of stakeholders are evaluated within the context of economics and strategies, structure and culture, business models and processes.

4 Framework for Research on NFC

4.1 Findings from the literature

A total of 74 studies were classified with respect to our proposed framework. These articles were analyzed by year of publication and by topic area. At the same

time, 25 design science research papers which are selected from these 74 papers were evaluated through design science guidelines. These two particular analyses will provide us promising guidelines for pursing rigorous and business relevant research on NFC and its applications, services.

A majority of NFC research papers (186 out of 202 or %92 of the total) were published in conferences or symposiums, even though in the last two years more journal publications are available. This shows that there is a clear need for more rigorous NFC research articles to be published in journals. Once the progress of NFC research is reached to more established results, academics and practitioners may benefit from this mature Body-of-Knowledge.

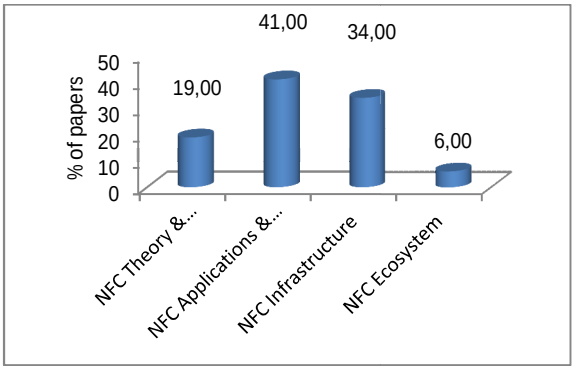

Figure 5: Distribution of Papers by Categories

The distribution of NFC research papers by subject is shown in figure 5. A majority of the NFC research is related to NFC Applications and NFC application development, while a few of them were on "NFC Ecosystem", covering only 12 published papers out of 202.

Table 3 indicates the status of existing Body of Knowledge with respect to the proposed framework. As mentioned before, the majority of NFC research as "NFC Applications & Services" (41%) is examined in a standpoint of operating modes of NFC, in three broad topics. More than half of the academic papers in this category deal with applications and services of NFC that is operating in reader/writer mode (41 academic papers). At the same time, the academic literature related with "Reader/Writer Mode Applications" is the largest proportion (20 %) of the NFC literature (e.g. retailing, health, education, supply chain management, museums, social networking, shopping, electronic voting, multimedia controller, smart posters etc.).

The second largest topic is "Card Emulation Mode Applications" (e.g. payment, mobile coupons, ticketing, electronic key) with 20 academic papers out of total. The fewest number of papers were on the "Peer-to-Peer Mode Applications".

The second largest category of NFC literature is related to "NFC Infrastructure" (34%) which provides "Tags, Antennas, Readers and NFC Chip" issues made up the largest topic (38%) within this category. The other topics discussed were "Security" (26%) and "Network and Communication" (19%). In fact, within this category distribution of NFC Infrastructure literature among topics is quite proportional.

The third category as "NFC Theory and Development" is examined in two broad topics. "NFC Overviews, Context and Foundations" with 27 related academic papers is the large proportion of this category. The other topic on theory and development discussed in NFC literature is "NFC Policy, Ethical and Legal Issues" (11 academic papers). These findings reflects the fact

Classification Criteria	# of Papers	Some References	% by subject	% by all subject
NFC Theory and Development				
NFC Overview, Context and Foundations	28	[11, 16, 19, 22, 43, 47, 49, 54, 64, 67, 72,74]	69	13
NFC Policy, Ethical and Legal Issues	11	[8, 9, 40, 91]	31	6
Total	**39**		**100**	**19**
NFC Applications and Services				
Reader / Writer Mode Applications	41	[15, 17, 21, 25, 30, 31, 32, 33, 35, 48, 50, 51, 58, 61, 66, 73, 75, 77, 78]	60	20
Tag Emulation Mode Applications	20	[14, 20, 34, 45, 55, 57, 59, 60, 62, 79]	30	10
Peer-to-Peer Mode Applications	7	[65]	10	3
Total	**68**		**100**	**33**
NFC Infrastructure				
Network and Communication	19	[27, 28, 36, 39, 44, 46, 70]	24	9
Tags, Antennas, Readers and NFC Chip	38	[7, 24, 41, 52, 53, 69, 71]	45	19
Security and Privacy	26	[12, 18, 23, 38, 26, 42, 68, 76]	31	13
Total	**83**		**100**	**41**
NFC Ecosystem				
NFC Economics and Strategy	1	[90]	0.09	0.4
NFC Business Models and Processes	5	[6, 13, 37, 89]	4.1	2
NFC Stakeholders, Structure and Culture	6	[10, 29, 57, 63]	50	3
Total	**12**		**100**	**5.4**

Table 3: Classification of the reviewed NFC literature.

that NFC is relatively a new, promising research area, so that there is a clear need for more academic study on regulations, privacy, and legal issues surrounding NFC to sustain its development.

As seen in Table 3, there were relatively fewer academic research papers on "NFC Ecosystem" (5,4% out of the total). This category is examined in three broad topics, unfortunately there were not any "specific" academic paper dealing with NFC Economics and Strategy for NFC technology's development, improvement. There were research papers mostly that are surrounding "NFC Business Models and Processes" (5 research papers out of 202) and "NFC Stakeholders, Structure and Culture" (6 research papers out of 202).

In fact, most of NFC related papers contribute to new ideas, such as on security, hardware or business models while proposing a new, unique NFC enabled application or a new Communication Protocol. In such situations, we tried to discover the paper's main contribution, focus point, and made the appropriate classification scheme. Table 3 gives a summary of all of the reviewed academic papers clearly according the proposed classification scheme. This table should be beneficial and helpful resource for anyone who is searching for NFC related papers on a specific area. Meanwhile, Table 3 includes a representative study for each sub-category of the NFC Framework except for the category of "NFC Economics and Strategy", which is not present in the literature yet.

Based on the descriptive findings above, we shall induce some insights in the following:

- It is not surprising that most of the academic research papers were related to "NFC Applications and Services", especially operating in reader/writer mode. The reason of this model is that development and implementation of such services or applications are viable than developing applications operating in other modes. Unfortunately we did not find many rigorous research papers on "Peer-to-Peer Mode Applications".

- The second largest proportion of the papers is related with the "NFC Infrastructure". Our review shows the importance of focusing on technical issues of a new technology again, rather than issues related to realizing economics, business values or strategies for NFC development, dissemination and marketing. As seen in Table 1, literature dealing with technical issues on NFC is useful for anyone who is studying on "NFC Infrastructure". We expect more specific research to be conducted on business issues, economics of NFC technology.
- While developing new NFC enabled applications or services, ecosystem of NFC technology clearly needs to be considered. Such new applications or services can bring new business models, processes with new players. Especially the capabilities, characteristics and roles of stakeholders need to be evaluated and modified when necessary, in order to satisfy the requirements of new business models and processes. Cultural differences on adopting NFC enabled technologies could be an interesting area for investigation.
- In terms of theory and development, most of the research papers those are published in journals were overviews and assessments on NFC technology rather than proposing a new design artifact. The articles in journals that we found are not sufficient for development of NFC literature. We expect more rigorous design science research on NFC to be published in journals. Policy, ethical and legal problems which can be referred as societal and behavioral issues were another important and demanding research areas for development of a new, emerging technology. However, it is hard to find papers dealing with the public policy or legal problems (e.g. taxation problems, trust, fraud, privacy issues for internet privacy, financial privacy). [91] provide a review of the regulations and policies governing NFC in Europe and Asia and related incentives. We agree with [91] that "for NFC to thrive, privacy must be considered in the design of the technology, the platforms, and the services". Indeed, this should prompt academic researchers to adopt design science research paradigm to investigate this area.

4.2 Findings from the DSR Perspective

Based on the aforementioned design criteria, Table 4 shows the evaluations of representative papers for each NFC research category. For the rest of the short-listed papers, the complete evaluations can be found in the Appendix.

The findings from the design science guideline evaluations show that most of the NFC design science papers propose an artifact which provides an utility for a specific and relevant business problem. These two requirements for a design science research are sufficiently considered and explained in the research papers. Needlessly to say that explicitly emphasized business problems will be more beneficial and useful for interested researchers and practitioners.

As mentioned before utility and efficiency of the proposed artifact must be demonstrated with appropriate methods. Design evaluation guideline needs to be highly considered while performing NFC academic research. Most of the papers (of 25 research papers) use more descriptive (e.g. scenarios, use cases to demonstrate its utility) or analytical (e.g. architecture analysis) methods while developing an applications or service, rather than performing experimental or testing methods. Design evaluations are performed in most papers through scenarios or use cases, instead controlled experiments or simulations will be more useful for representing the proposed artifact rigorously.

As seen in our review, nearly all of the NFC research papers provide research contributions explicitly or implicitly, due to their nature. For instance, an NFC design science paper [14] provides varying contributions in terms of security, network and communication while proposing a new NFC enabled service.

		Paper	Guideline 1: Design as an Artifact	Guideline 2: Problem Relevance	Guideline 3: Design Evaluation	Guideline 4: Research Contributions	Guideline 5: Research Rigor	Guideline 6: Design as a Search Process	Guideline 7: Communication of Research
NFC Theory and Development	NFC Overviews, Context and Foundations	[74]	An NFC test system architecture	Clearly explained in requirements section	Evaluations through analytical, experimental	Contributes due to its nature	Rigorous; applicable and generalizability	Explicitly design search	Communicates all audiences
	Policy, Ethical and Legal Issues	[8]	Context-based adaptation system	Mentioned; to reduce the distraction caused by mobile phones	Evaluated; analytical and descriptional, cases	Clearly contributes due to its nature	Rigorous; prototype implementation in office environments	Explicitly design search	Communicates mostly technical audiences
NFC Applications & Services	Reader/Writer Mode Applications	[75]	Maintenance systems with NFC	Mentioned; to improve recurring maintenance processes	not mentioned; only implications of the system	Contributes due to its nature; design artifact	Somewhat rigorous work, implementation	Somewhat search process	Communicates all audiences
	Tag Emulation Mode Applications	[79]	Apps for University environment	Mentioned the requirements but not so much satisfactory	Evaluation is done through descriptional -scenarios	Contributes due to its nature	Somewhat rigorous; applicable	Not a complete search process	Communicates technical audiences
	Peer-to-Peer Mode Applications	[65]	Hot in City application	Implicitly defined the business requirements	Descriptional and architectural, implications of the system	Contributes implicitly	Somewhat rigorous work, real implementation	Somewhat search process	Communicates mostly technical audiences
NFC Infrastructure	Tags, Antennae, Readers and NFC Chip	[7]	Guidelines for estimation of the capacity performance	Not a specific problem; only analyzed the capacity performance of the inductive coupling NFC system	Good analysis, evaluation based on theoretical background	Contributes due to its nature	Rigorous work	Not a complete search process	Communicates technical audiences
	Network and Communication	[27]	Verify Protocol	Explicitly, well defined requirements	Analysis of protocols, analytical and descriptive methods mostly	Clear Contributions	Rigorous, real implementation, applicable, performance evaluations	Highly search process	Communicates mostly technical audiences
	Security and Privacy	[25]	UICC and payment applications	Mentioned explicitly	Not explicitly mentioned, experiments evaluations	Clear contributions	Somewhat rigorous, a real project's intermediate results actually	Somewhat search process	Communicates all audiences
NFC Ecosystem	NFC Business Models and Processes	[13]	Platform management model for NFC ecosystem	Mentioned properly	Descriptively analyzed the model	Contributes actually	Somewhat rigorous, like a proposal	Not a complete search process	Communicates all audiences
	NFC Stakeholders, Structure and Culture	[50]	Approaches for adaptability of RFID-NFC	Clearly specified	Evaluated; architectural and descriptional	Somewhat contributes	Not clear	Not Clear	Communicates all audiences

Table 4: Design Science Guideline Evaluations of Representative NFC Studies

In regard to the research rigor perspective which is concerned with the construction and evaluation of design artifact, the design artifact's applicability and generalizability should be addressed. There is a clear need for rigorous NFC research papers, where design rationale and cycle should be explicit. This is needed to achieve an effective communication for exploiting research results in the appropriate communities (engineering- or management-oriented audiences).

5 Research Agenda for NFC

NFC as an emerging research area has attracted the attention of both practitioners and academics. As cited before, academic research activities on NFC area have increased significantly after the year 2006. We believe that, this study is the first academic literature review on NFC technology. With this literature review, we want to shed light on the current status of NFC research. This review identified 109 academic papers composed of studies from 2006 to 2012. The results from NFC classification scheme and from design science guideline evaluations have several important implications.

It is true that NFC technology has become a promising, challenging research area in recent years. There is a clear need for more journal publications to provide business related and rigorous research papers on NFC technology.

Among all these possible questions, we expect that calls for the following three subjects may draw considerable attention from academics and practitioners as well:

NFC Ecosystem and Business Models. The notion of ecosystem appears to be granted in both in NFC World (both academics and practitioners' point of view). Business requirements and ecosystem rational are hardly taken into account in the proposed models, which questions how, if possible at all, comparative are these proposed models? Whether commonalities and differences on the model element at the foundation level or not? Nevertheless, what needed is an explicit interrogation of what constituents (primitives) the very notion of ecosystem in the NFC context. The challenge for NFC stakeholders today is to promote and combine creativity in order to bring substantial improvements in terms of economic and social aspects. One needs to address some challenges for establishing a successful ecosystem. In this regard, possible follow-up would be: How are you going to get all those potential participants to believe that they can work together effectively and creatively? What will be the key roles? How will you let each group innovate relatively freely, but ensure that as the project proceeds all of the contributions will come together?

NFC Secure Element Analysis. NFC enabled services must assure users and service providers that the transaction takes place in a protected environment. This protection is achieved by use of a secure element (SE), which can be referred as the components in the device providing the security required to support various business models. The SE is concerned with technical issues (combination of hardware, software, interfaces and protocols) and management issues as well. Furthermore, there are various architectural options for a SE depending on its implementation options such as Embedded Hardware as non-removable SE, Stickers, Secure Micro SD cards and UICCs as removable SEs, Trusted Mobile Base as a combination of software programs on dedicated hardware. Several questions can be raised to address NFC SE issues such as: how to manage SE for

Framework Element	Some Research Opportunities
NFC Ecosystem - NFC Economics and Strategy - Business Models and Processes - Stakeholders, Structure and Culture	- Proposing an underlying value typology for NFC applications - Evaluating the impacts of NFC on business process and value-added activities - Determining generic stakeholders and meta-model describing interactions among them in an NFC ecosystem - Empirically testing ecosystem models and a comparative analysis in various industry and country settings, comparative study - Evaluating cultural factors on adopting NFC enabled applications and services - Macro and micro economic analysis of developing a specific NFC enabled application - Determining the effects of NFC use at multiple levels, including overall business, operations, individual
NFC Infrastructure - Network and Communication - Tags, Antennae, Readers and Chips - Security	- Evaluating existing NFC enabled device internal hardware, network, and communication standards, and their implementation - Proposing new architectures/standards or extensions whenever required - Evaluating proposed hardware, network, and communication models and standards for NFC - Designing and modifying security architectures /standards - Evaluating proposed security models for NFC - Examining Compatibility Issues with NFC-enabled devices and solutions - Testing performance, processing, data storage and data communication NFC applications with different infrastructures
NFC Applications, Architecture and Services - Reader/Writer Mode - Tag/Card Emulation Mode - Peer-to-Peer Mode	- Developing new applications, architecture and services - Evaluating the proposed applications and services - Identifying novel applications for each NFC mode - Evaluation of proposed artifacts in terms of their benefits, contribution analysis - Proposing NFC artifacts in the form of applications, model, and instantiation - Secure Element Alternatives
NFC Theory and Development - Context and Foundations - Policy, Legal, Privacy and Ethical issues	- Developing meta-elements for NFC policies, regulations and legal standards at the individual and organization level - Adopting appropriate accounts to identify legal, privacy, and ethical issues concerning NFC use - Empirically testing NFC adoption in different contexts (various users profiles, application characteristics) - Providing useful methods, models, guidelines for developing NFC enabled applications

Table 5: Research Agenda with respect to potential research questions.

concurrent applications? What criteria should be taken into account to assess possible SE implementation option? Who share what data in the SE for privacy, loyalty service provisioning?

User Perception on and Privacy Issues with NFC. Industry reports have been published to indicate countries adoption situation in present and upcoming years. It seems that in compare to similar technologies (e.g., RFID), the adoption lifecycle for countries is to be shorter. But, [88] states "The most surprising result of the survey was the respondents' low expectations in regards to customer acceptance". This is in clear contrast to the reports on NFC trials which generally describe participants as enthusiastic about the technology". Thus, there is still an open question concerning Is the customer ready for NFC use? Surely, various factors including appropriate ecosystem, market fragmentation, and service availability are essential for successful NFC roll out. In literature, adoption factors in IT in general and mobile technology in particular are studied [88]. One needs to investigate if and how such factors affect intention to use NFC services. Industry organizations will benefit from those studies using empirical setting to assess user behaviors on NFC use. Case studies, including [91], bring up important issues with control, consent and accountability related to NFC.

6 Conclusion

As stated in [92], it is important for behavioral and design science researchers to understand new emerging technologies such as RFID, NFC. With recent endeavors of practitioners and academics concerning the use of Near Field Communication (NFC), one can expect a bright future of NFC along with business opportunities. But, several challenges remain ahead for enhancement of Body-of-Knowledge for NFC. This study goes beyond a typical literature in that it employs Design Science Perspective to articulate BoK for NFC, examines its progress and proposes a research agenda with promising research areas and questions.

Noticeably, with the development of more and innovative NFC enabled applications, the need for standards and policies is increased. At the same time, strategy for diffusion and adoption of NFC systems and economy of NFC systems need to be considered while developing new services, which includes the costs of designing, developing, controlling and updating such systems.

The framework proposed is found to be useful to organize a number of existing studies (i.e., 202 papers in the last five years), we expect that more sub-topics should be added and updated in the framework. Since most of the studies in the BoK focus on artifact development and its instantiation, the design science research perspective serves an appropriate ground for assessing its progress. Accordingly, the three cycles of DSR have not been equally realized in the present BoK. There should be a call for those studies paying attention on especially rigor and design cycles. More specifically, as [2] stated, NFC studies ought to consider a research rationale in terms of what design processes (search heuristics) will be used to build the artifact? How are the artifact and the design processes grounded by the knowledge base? What, if any, theories support the artifact design and the design process? Furthermore, we expect more studies where design evaluation is to be explicit by using observational, experimental techniques.

Based on the organizing framework, we put forward a list of research opportunities. One can see that every framework element has a potential to investigate its research topics further. As the review shows that application, architecture element has been a center of attention so far, we expect that more emphasis would be given on NFC ecosystem, underlying theory and its adaption. In this regard, we suggest that secure element analysis, NFS ecosystem and business model, user perceptions on NFC are worth to invest as specific research areas from the academics and practitioners points of views.

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APPENDIX

Paper	Guideline 1: Design as an Artifact	Guideline 2: Problem Relevance	Guideline 3: Design Evaluation	Guideline 4: Research Contributions	Guideline 5: Research Rigor	Guideline 6: Design as a Search Process	Guideline 7: Communication of Research
[6]	NFC ecosystem and business analysis	Mentioned; to combine the business process approach with their significant technology developments	Only implications of the ecosystem are mentioned	Clearly contributes due to its nature	Not clear	Not clear	Communicates all audiences
[9]	Security and privacy requirements of an NFC based application	Clearly specified, mentioned	Not explicitly done, case study	Contributes due to its nature	Somewhat rigorous; needs more technical evaluations	Not a complete search process	Communicates mostly technical audiences
[12]	Secure element controller apprach	Clearly mentioned; states the problem	Evaluated through cases, analytical	Clearly contributes due to its nature	Rigorous work	Explicitly design search	Communicates technical audiences
[14]	M-coupons and protocols	Explicitly mentioned the motivation for m-coupon, business needs	Well evaluated through analytical methods	Contributes explicitly	Rigorous but need more performance evaluations	Search Process	Communicates mostly technical audiences
[15]	Mobile Sales Assistant (MSA)	Mentioned	Evaluated the system descriptively	Contributes implicitly	Somewhat rigorous, prototype implementation but not enough	Not a complete search process	Communicates all audiences
[17]	Electronic data capture (EDC) system	Clearly mentioned; to design and develop an additional path for clinical data acquisition	Clear system evaluation, in terms of usability and feasibility, observational	Contributes due to its nature	Somewhat rigorous; needs more technical evaluations	Not a complete search process	Communicates mostly technical audiences
[18]	Secure mobile payment solution	Clearly mentioned need for secure transactions	Evaluation, architectural analysis etc.	Explicitly contributes	Rigorous, real implementation, prototype	Explicitly design search	Communicates all audiences
[20]	NFC-based Virtual Ticketing application	Explicitly mentioned, its ease of use and to its higher security level	Evaluates through architectural and usability analysis (testing), statistical analysis	Contributes explicitly	Rigorous, real implementation, prototype	Not a complete search process	Communicates all audiences