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Studies of the Integration Readiness Levels in the Context of Industrial System Projects

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Information Systems
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Abstract

Eveliina Sivlén

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Integration technologies and concepts have evolved over the last decade, leading to a multitude of architectures and products in Information Technology (IT) branch. System integration and IT integration are essential parts of a most technological projects. The systems become more complex and the interfaces, at least most of them, need to be defined in a specific way and the various details matter in implementation projects. The system integration is defined as the process of bringing together the component subsystems into one system and ensuring that the subsystems function together as a single system. In this study, an information system's focused prescriptive metrics entitled Integration Readiness Levels (IRLs) is investigated in the perspective of utilization in the context of industrial system projects.

Laurea University of Applied Sciences participates in the PERSEUS (Protection of European borders and Seas through the Intelligent Use of Surveillance) project. One of the target of the project is to integrate a system for the sea frontiers' control. The project has the goal of developing and testing a European system for maritime surveillance through the integration of the existent European and local systems and its improvement using technological innovations. The IRLs has been used earlier by NASA (the National Aeronautics and Space Administration).The Lime Survey questionnaires by ISDEFE (Ingeniería de Sistemas para la Defensa de España) are used to evaluate a system.

The research question is How the IRLs framework can be understood and how it can be realized in industrial systems projects at Fifth Element's Ltd? The main target of the study was to find out how the IRL framework can be understood and how it can be realized in industrial systems projects at Fifth Element. The study addressed international research and implement a public paper of the research. The study was made mainly as qualitative case study research. The empirical data collection is mainly based on questionnaires of IRLs framework interviews (n=5). The study provided valuable information on how IRLs framework suits for industrial system projects. As the result the framework could be realized to Fifth Element's projects, but as it is the questionnaire felt too comprehensive and need some modifications before taken to case company's use. This study will have benefits to the PERSEUS project, as previous studies have focused primarily on military systems, rather than on commercial companies. A future research could provide necessary information on the IRLs' and on how the questionnaire should be used. The future research could be made as an action research. In that research could be observed how this framework fits in to case company's processes in practice and what the benefits to the company would be using the framework. Future research will hopefully be able to validate and refine the propositions of this study in the case company.

This Master's thesis present results of three studies of year 2014. The first and the third study introduce the original study. The first is the real study and the second the review and analysis of the study. The third paper presents cross-case analysis where the main study is a part of. The studies also include theoretical framework of variations of integrations and IRLs framework.

Keywords, Integration readiness level; maturity; prescriptive metrics; business and information sys-tem and integration project

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Tiivistelmä

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Integraatiovalmiuden ymmärtäminen ja hyödyntäminen teollisissa järjestelmäprojekteissa

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Integraatioteknologiat ja -käsitteet ovat kehittyneet viime vuosikymmenen aikana, mikä johtaa suureen määrään uusia ja monimutkaisia IT-arkkitehtuureja(Information Technology) ja -tuotteita. Järjestelmien integrointi on nykyään olennainen osa useimpia teknologiahankkeita. Kun järjestelmät monimutkaistuu, rajapintojen määrittelyssä vaaditaan erityistä tarkkaavaisuutta, ja pienilläkin yksityiskohdilla on väliä. Integraatio-osuutta projektissa ei välttämättä alkuun kuitenkaan pidetä kovin kalliina projektin kannalta, mutta täytyy muistaa, että rajapintamoduulien määrä kasvaa nopeasti, jos järjestelmään kytketään paljon sovelluksia. Tämän tutkimuksen näkökulma on teollisissa järjestelmähankkeissa.

Laurea osallistuu PERSEUS –hankkeeseen (Protection of European borders and Seas through the Intelligent Use of Surveillance). Se on hanke, jonka yhtenä tarkoituksena on kehitellä suosityksua eurooppalaisiin merirajavalvonnan integraatioratkaisuihin. PERSEUS-hankkeessa käytetään NASA:n (National Aeronautics and Space Administration) kehittämää Integration Readiness Levels –viitekehystä (IRLs), jonka avulla pyritään selvittämään erilaisten järjestelmien integraationvalmiutta. IRLs:n tutkimista varten espanjalainen ISDEFE (Ingeniería de Sistemas para la Defensa de España) on kehittänyt kyselylomakkeen, jonka avulla erilaisten järjestelmien integraation valmiusastetta pyritään kartoittamaan.

Tämän työn tutkimuskysymys on Miten IRLs ymmärretään ja on hyödynnettävissä teollisuuden järjestelmähankkeissa; Fifth Element Oyssä? Tutkimuksen tavoite oli selvittää kuinka kyselykaavake ymmärretään Fifth Elementillä ja koetaanko se käyttökelpoiseksi menetelmäksi selvittää järjestelmäintegraation valmiustasoa. Tutkimus toteutettiin laadullisena tapaustutkimuksena ja empiirinen data saatiin haastattelujen avulla (n=5). Tutkimuksen tulos oli, että IRLs -kehikko ymmärretään hyvin kohdeyrityksessä. Jotta sen voisi ottaa yrityksessä käyttöön, olisi hyvä ottaa huomioon haastattelujen perusteella saadut kehitysehdotukset. Tutkimuksella on hyötyä PERSEUS -hankkeelle, sillä aiemmat tutkimukset ovat kohdistuneet pääasiallisesti sotilaallisiin järjestelmiin, ei niinkään kaupallisiin yrityksiin. Tutkija ehdottaa jatkotutkimukseksi toimintatutkimusta, jonka avulla voisi saada selville, miten viitekehys sopisi käytännössä kohdeyrityksen prosesseihin ja mitä hyötyä yritykselle tästä olisi. Tuleva tutkimus voisi toivottavasti vahvistaa ja tarkentaa tutkimustuloksia tutkimuksen kohdeyrityksessä.

Opinnäyte esittää kolmen osatutkimuksen tulokset vuodelta 2014. Ensimmäinen osatutkimus käsittelee itse tieteellistä tutkimusta. Toinen osatutkimus käsittelee kahdenlaisen arvioinnin: tutkijan tekemän arvioinnin, jonka hän teki opiskelutoverinsa työstä sekä opiskelijatoverin että ECTI-CON 2014 -konferenssin antamien palautteiden pohjalta tehdyn arvioinnin tutkijan tieteellisestä paperista. Kolmas osatutkimus esittelee yhteistutkimuksen. Lisäksi tutkimuksissa tehtiin kirjallisuuskatsaus, jonka avulla kerättiin tietoa IRLs -kehikosta sekä saatiin rakennettua tutkimuksen teoreettinen viitekehys integraation teorioista yleisesti.

Asiasanat: järjestelmä integraation valmiustaso; kypsyys; ohjailtavuus; mittaristo; liiketoiminta ja tietojärjestelmät; ja integraatio projekti

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I was planning to do the Master degree for many years. In the end of the year 2012 I was participating to a seminar held by Laurea University of Applied Sciences, where the Master degree was presented more detailed and I could not resist to apply to the school. Then in the beginning of year 2013 the studies started.

First, I would like to thank my supervisor, Principal Lecturer Dr Rauno Pirinen, for his advice, guidance, and support. His supervisory, endless encouragement and faith in me have been extremely important during my master studies. In addition, I am thankful for him for introducing me to the topic. It has been a great opportunity for me to participate on the PERSEUS research project. The project has given me the possibility to acquire new information and apply my existing knowledge in a new context, in addition I have benefited through personal growth and development. I am also grateful to the pre-examiners, Lecturer Tarja Chydenius and Principal Lecturer Satu Luojus from Laurea University of Applied Sciences who have provided me with valuable comments and suggestions for improvements.

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Eveliina Sivlén

List of Studies

Study I [P1] E. Sivlén & R. Pirinen: Utilization of the Integration Readiness Level in the context of Industrial System Projects. In Press.

Study II [P2] E. Sivlén: The review of IRLs´s study (2014) Utilization of the Integration Readiness Level in Operative Systems. Unpublished manuscript.

Study III [P3] R.Pirinen, E.Sivlén & E. Mantere: Samples of Externally Funded Research and Development Functions in Higher Education Institutions: Case Integration Readiness Levels. In Press.

List of Abbreviations & Symbols

IRLs	Integration Readiness Levels
IT	Information Technology
SRL	System Readiness Level
TRL	Technology Readiness Level
ISDEFE	Ingeniería de Sistemas para la Defensa de España
PERSEUS	Protection of European borders and Seas through the Intelligent Use of Surveillance
NASA	National Aeronautics and Space Administration
ISO	International Standards Organization
SME	Subject Matter Experts
ECTI-CON 2014	The 2014 International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology
SAP®	Systeme, Anwendungen und Produkte – an ERP system producer
SUP®	SAP Unwired Environment
RFID	Radio-frequency identification
CMMI	Capability Maturity Model Integration
GPRS	General Packet Radio Service
WLAN	Wireless Local Area Network
BAPI	A Business Application Programming Interface
EBS	Enterprise service bus integration
ERP	Enterprise Resource Planning Systems
CRM	Customer Relationship Management
SoS	System of Systems
R&D	Research and Development

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1 Introduction

The PERSEUS (Protection of European borders and Seas through the Intelligent Use of Surveillance) represents a sample of demonstration research project implemented by the Seventh Framework Programme (FP7) Security Research Theme. The collaborative research environment of this study involves ISDEFE (Ingeniería de Sistemas para la Defensa de España) in Madrid, Spain (questionnaires) and Laurea University of Applied Sciences in Espoo, Finland. PERSEUS is coordinated by INDRA Sistemas S.A. with 29 international research participators from 12 different EU countries, most of them having maritime frontiers.

The purpose of PERSEUS is the protection of the European seas and its frontiers with the intelligent use of technology and the project's goal is to develop and test a European system for maritime surveillance through the integration of the European and local systems and its update and improvement using technological innovation (Project PERSEUS). The Lime Survey questionnaire by ISDEFE is used to address integration activities in a System Maturity Scale to evaluate a System. Here, the questionnaire Sauser, Forbes, Long, & McGrory (2009) was used in base to the interviews to gather the information for the research question. The first interview as a pilot study was used as testing how much guidance is needed in the interviews of main body of performed study.

Limitation of the study was that the key focus is to find out how the questionnaire and IRLs were understood and realized in Fifth Element's industrial system projects, then a proposal for improvements of standard was produced.

Integration technologies and concepts have evolved over the last decade, leading to a multitude of architectures and products in Information Technology (IT) branch (Chandra & Juarez 2009, 44). As in this case, system integration and IT integration are an essential part of a most technological projects. The systems become more complex and the interfaces, at least most of them, need to be defined in a specific way and various details matters in the implementation projects. The system integration is defined as the process of bringing together the component subsystems into one system and ensuring that the subsystems function together as a single system (Gilkey 1960, 60). According to Zimmermann (1969, 1) "system integration is the programming function that, during the development of a system, interfaces the separately programmed and tested functions".

Integration Readiness Levels (IRLs) measures integration maturity or adequate maturity between two or more items or subsystems and furthers work on integration measures, assessments (Chien 2010).The main purpose of this study was to find out how the existing IRL framework on questionnaire (Lime Survey) is suitable and may be developed to fit into the

Fifth Element Ltd. projects. The company Fifth Element was understood as a suitable one as it has wide experience of integration projects, also in industrial system context.

A qualitative research was mainly based in analysis of interviewed data and literature. The Lime Survey questionnaire was sent by email to eight employees of the company, which has been planning and implementing Fifth Element's systems (Appendix 1). Among them, five people were selected and validated for interviews. The interviews were recorded, transcribed and then analysed. Study is being done to resume International Standards Organization (ISO/DIS 16290) definition of the IRLs and their criteria of assessment as well as utilization and distribution in context of industrial system projects. The utilization of IRLs been studied earlier in project PERSEUS but more research in context of industrial system was needed. The target of this study is to give valuable research evidence for PERSEUS from viewpoints of research in industrial systems.

The main research question is: How the Integration Readiness Levels (IRLs) can be understood and realized in industrial systems projects at Fifth Element?

The study is made as a case study research. According to Yin (2009, 18) a case study is the preferred research strategy when the research questions are in the "how" or "why" form, when the researcher has little control over the event, and when the focus is on a contemporary phenomenon within some real-life context. In this study all these conditions match what Yin (2009, 18) defines as favourable conditions for choosing a case study as the research strategy. With this method a qualitative analysis could be made from the research question and gives in-depth understanding of the research phenomenon (Yin 2009).

Sauser, Gove, Forbes and Ramirez-Marquez (2010) tested their nine level setting of IRLs questionnaire. The outcome of is as the general proposal for IRLs analysis for various environments. However, Sauser et al. (2010, 7) states, that future research is necessary to fully confirm the usefulness of IRLs. The IRL framework has been developed in Stevens Laboratory of Engineering. First it was presented as a seven-level scale based on Open Systems Interconnection protocol (Sauser et al. 2010) and at the moment IRL framework consists of nine levels (Project Perseus. Pdf. 2013). The primary objective of this research was to find out how the IRLs can be understood and how it can be realized in industrial systems projects at Fifth Element. This research was evaluated using review sessions with another researcher that also made her study of the same topic. Also researcher got evaluation from seminar ECTI-CON 2014 that was used to approve the study. The evaluation accommodated triangulation to the study.

This Master's thesis comprises three individual studies from three different empirical integration contexts. They were researched during the year 2013. These studies are reported as three peer-reviewed papers as follows.
In the context of industrial system project, Study I "How the Integration Readiness Levels (IRLs) can be understood and realized in industrial systems projects at Fifth Element?", presents the findings of an exploratory case study of IRLs in 2013 among case company Fifth Element. Study I studies two specific research questions: 1) How the Integration Readiness Levels (IRLs) can be understood in industrial systems projects at Fifth Element?, and 2) How the Integration Readiness Levels (IRLs) can be realized in industrial systems projects at Fifth Element?

In the context of Operative Systems, Study II, "Review of anonymous study (2014) Utilization of the Integration Readiness Level in Operative Systems", presents findings from two review studies 1) made to Anonymous researcher, and 2) an evaluation work from researcher's previous version of the study. Study II studies two specific research questions: 1) How the Integration Readiness Level metrics can be validated and to be used in integration projects?, and 2) How the Integration Readiness Levels (IRLs) can be understood and realized in industrial systems projects at Fifth Element?. As the result, the findings discovered in the review process were used to improve researchers' studies.

Finally, in the context of Study III, "Samples of Externally Funded Research and Development Functions in Higher Education Institutions: Case Integration Readiness Levels", addresses the integration of externally funded research and development (R&D) functions and the development of R&D-related collaborative learning in higher education institutions. The in-depth cross-case study analysis addressed the research question of two cases: How the Integration Readiness Level (IRL) metrics can be understood and realized in information systems projects. The target of this study was to learn how the existing IRL metrics and their definition, criteria, references, and questionnaires can be realized and validated in information systems integration projects. As a result, it can be concluded that the IRL questionnaires could be complemented with an expanded checklist that would allow for the removal of some of the subjectivity that exists in many of the maturity metrics.

According to Nunamaker, Minder & Purdin (1991) theory building includes development of new ideas and concepts, and construction of conceptual frameworks, new methods, or model. This theory building phase was included in every studies because every study presented something new to the research domain. The theory building phase played a bigger role in the first and third studies. The next sub chapters aim to define the theoretical frameworks for the Study I. The theory part starts to present the IRL framework and then it ends to literature review of theories of different types of integrations.

The main theoretical discipline in this study is the IRLs and IT integration theories. They provides the conceptions to support this study based on earlier research around the themes. The domain of IRLs provides the boundary conditions for making the IT integrations more efficient. This subchapter starts with a review of the high-level theory bearing relevance on this study, the IRLs framework and continues then with various integration theories. The system of Systems (SoS) is deployed in creating the understanding of the processes and actors. Journal rankings were used to support the selection of the major journals that were examined more thoroughly. Other related journals and journal articles were obtained through search with key words from different databases and from the references of the articles from the selected journals. According to Eisenhardt (1989, 532 – 550), reviewing emergent theory involves asking what is similar, what is different, and why. Theoretical approaches: Integration Readiness Level references by 17 IRLs experts and Integration total of 15 earlier studies.

1.1 Integration Readiness Levels

In this Master's thesis the PERSEUS and IRLs related references were reviewed. Earlier researches from PERSEUS project presents that IRLs has been used mainly by NASA (National Aeronautics and Space Administration) and military (Sauser 2010). The IRLs metrics were introduced by the Systems Development and Maturity Laboratory at the Stevens Institute of Technology and developed for the engineering field to assess the progress of an information system's integration and communication.

The Integration Readiness Levels metric has been defined as a "systematic measurement of the interfacing of compatible interactions for various technologies and the consistent comparison of the maturity between integration points" (Sauser et al. 2010). IRLs' history can said to began from the concern of adding technologies into a system and building a review of aerospace and defence-related literature to identify the requirements for developing a 7-level integration metric, Integration Readiness Levels (IRLs) (Sauser et al. 2009). Sauser et al. (2009) defines the requirements for an integration metric followed:

1. Determine the integration maturity between two or more configuration items, components, and/or subsystems;
2. Reduce the uncertainty involved in maturing and integrating a technology into a system;
3. Meet system requirements during the integration assessment so as to reduce the integration of obsolete technology over less mature technology;
4. Provide a common platform for both new system development and technology insertion maturity assessment.

Note that while the methods that the evaluators use for TRL (Technology Readiness Level)/IRLs estimation can be various, the evaluators must be properly trained in the use of TRL/IRLs (Tan, Ramirez-Marquez J-E & Sauser 2010).

Standards are important for the success of technology distribution and the process of standard perform involves many different authorities whose way of operate is a complex combination of business and administrative work (Rada, Carson, Haynes & Moore 1994, 1). One of the IT standard is the International Standards Organization (ISO). In compose standards to a system it is important to identify the domain where the standard should be implement and it should memorable that the standards should be managed during the life cycle of the system to ensure the continuance and operability of the system.

The aim of IRLs is to standardize the process of integration consequently; the flow of integrations could be executed as fluent as possible. According to Sauser et al. (2009) "in creation of the IRLs checklist, two forms of assessment were used to specify the decision criteria that may define each IRLs: (1) review of systems engineering and acquisition standards, policy, research, and other guidance documents for example DoD 5000.02, INCOSE Systems Engineering Handbook, IEEE 15288, and (2) discussions with subject matter experts (SME) in systems engineering, program management, and acquisition across government, industry, and academia". Where two important points are: the list of maturity metrics under each IRLs is not in order of criticality and that the lists are not considered to be comprehensive or complete (Sauser et al. 2009).

1.2 Studies of Integration Readiness Levels

IRLs were defined as a series of levels that articulate the key maturation milestones for integration activities. The introduction of an IRLs to the assessment process not only provides a check as to where a technology is on an integration readiness scale but also presents a direction for improving integration with other technologies (Perseus Project 2013, 14 - 15).

IRLs is designed to assess the risk associated with integrating technologies. Building upon similar efforts to define an integration maturity scale, the IRL has been refined to include nine levels as presented in PERSEUS project. The nine levels of IRL can be understood as having three stages of integration definition: semantic, syntactic and pragmatic (Sauser et al. 2009). In this view, semantics is about relating meaning with respects to clarity and differentiation. IRLs 1-3 are considered fundamental to describing what we define as the three principles of integration: interface, interaction and compatibility (Sauser et al. 2009). Table 1 describes the sematic stage.

Table 1: Sematic Level

3.	There is Compatibility (i.e. common language) between technologies to orderly and efficiently integrate and interact.	IRL 3 represents the minimum required level to provide successful integration. This means that the two technologies are able to not only influence each other, but also communicate interpretable data. IRL 3 represents the first tangible step in the maturity process.
2.	There is some level of specificity to characterize the Interaction (i.e. ability to influence) between technologies through their interface.	Once a medium has been defined, a "signalling" method must be selected such that two integrating technologies are able to influence each other over that medium. Since IRL 2 represents the ability of two technologies to influence each other over a given medium, this represents integration proof-of-concept.
1.	An Interface between technologies has been identified with sufficient detail to allow characterization of the relationship.	This is the lowest level of integration readiness and describes the selection of a medium for integration.

Furthered, the next stage presented in Table 2 is syntactic; this is defined as conformance to rules. IRLs 4-7 are about assurance that an integration effort is in compliance with specification.

Table 2: Syntactic Level

7.	The integration of technologies has been Verified and Validated and acquisition/insertion decision can be made.	IRL 7 represents a significant step beyond IRL 6; the integration has to work from a technical perspective, but also from a requirements perspective.
6.	The integrating technologies can Accept, Translate, and Structure Information for its intended application.	IRL 6 is the highest technical level to be achieved, it includes the ability to not only control integration, but specify what information to exchange, unit labels to specify what the information is, and the ability to translate from a foreign data structure to a local one.
5.	There is sufficient Control between technologies necessary to establish, manage, and terminate the integration.	IRL 5 simply denotes the ability of one or more of the integrating technologies to control the integration itself; this includes establishing, maintaining, and terminating.
4.	There is sufficient detail in the Quality and Assurance of the integration between technologies.	IRL 4 goes beyond simple data exchange and requires that the data sent is the data received and there exists a mechanism for checking it.

The final stage pictured in Table 3 is pragmatic, which relates to practical considerations. IRLs 8-9 are about the assertion of the application of an integration effort (Sauser et al. 2009). The addition of IRLs not only provides a check to where the technology is on an integration readiness scale, but also a direction for improving integration with other technologies (Sauser et al. 2009).

Table 3: Pragmatic Level

9.	Integration is Mission Proven through successful mission operations.	IRL 9 represents the integrated technologies being used in the system environment successfully.
8.	Actual integration completed and Mission Qualified through test and demonstration, in the system environment.	IRL 8 represents not only the integration meeting requirements, but also a system-level demonstration in the relevant environment. This will reveal any unknown bugs/defect that could not be discovered until the interaction of the two integrating technologies was observed in the system environment.

Establishing further verification and validation to the decision criteria, Sauser et al. (2009) deployed a survey that asked SMEs to evaluate each decision criteria in the context of its criticality to the specified IRL. Defined criticality criteria were:

1. Critical – IRL cannot be assessed without it;
2. Essential – without it, IRL can be assessed but with low to medium confidence in the results;
3. Enhancing – without it, IRL can be assessed with medium to high confidence in the results;
4. Desirable – without it, IRL can be assessed with very high confidence in the results;
5. N/A – the metric is not applicable to the IRL assessment (Sauser et al. 2009).

For each decision criteria Sauser et al. (2009) calculated the relative and cumulative frequencies of the criticalities. Relative frequency is the proportion of all responses in the data set that fall in the category (i.e. decision criteria for any IRLs). Cumulative relative frequency allows for additional information to be understood about the sensitivity of the response frequency based on a class interval (i.e. Critical/Essential versus Enhancing/Desirable). This is meant to help to identify whether the criticality categories originally identified are too fine and should be modified (Sauser et al. 2009).

Sauser et al. (2009) conclude that to review and modify the current list of IRL metrics while using the criticality assessment as a baseline. Sauser et al. (2009) continue that this effort should address two aspects of the IRL checklist: the metrics themselves and the weight that

should be assigned to each based on criticality data. According to Sauser et al. (2010) IRL is not a complete solution to integration maturity determination; it is although a tool that increases the stakeholder communication, something that has proven to be critical in all that the previously done case studies presented. The case studies indicate:

1. IRL lacks the ability to assess criticality and R&D (Research and Development) effort;
2. IRL assessment of complex, net-centric systems requires a more quantitative algorithm to reduce multiple integrations to a single assessment;
3. IRL does not evaluate cost and schedule.

1.3 Literature Review

In addition, different databases were also used to search for studies with different combinations of keywords that included: System integration, Information Integration and Enterprise Integration etc. The books and articles which are discovered on the subjects were read through and studies related to any approach of system integration were chosen for closer review to gather more understanding of the topic. These expanded studies are presented in the Table 4.

Table 4: Literature Review

Key word	**Definition**
System Integration	Integration means the melding of divergent and even incompatible technologies, applications, data, and communications into uniform information technology architecture (Bajgoric & Moon, 2009).
Information integration	Information integration is the foundation for supply chain integration. It is formed of six elements: process and activities, information technology in use, information attributes, information sharing, practices corporate foundation and time-related issues (Uusipaalvalniemi 2009).Sharing of relevant data and information among the supply chain partner (Lee & Whang 2000).
Enterprise integration	The integration of computer networks, business applications, and business integration of process networks (Kosanke & Nell 1999).
System of Systems	An initial set of such features, which includes the aforementioned operational independence of its elements and the emergent behaviour of the system as a whole (Maier 1998).

As Table 4 describes, written sources used in this research include academic articles, books and studies. The aim of the literature review was to gain more understanding of the topics: system integration, information integration, enterprise integration and System of Systems. Chandra & Juarez (2009, 44) state that there are three broad integration strategies related to the technical integration: 1) point-to-point; 2) enterprise application integration; and 3) en-

terprise service bus (ESB) integration. The push towards the adoption of complete enterprise-wide integrated systems solutions is becoming a foremost issue in organizational IT integration strategies. For example, companies can make massive investments in Enterprise Resource Planning Systems (ERP) extended backwards to the fully integrated supply chain, and forwards with Customer Relationship Management (CRM) systems (Wainwright & Warning 2004, 329 - 346).

Information Systems integration means the melding of divergent and even incompatible technologies, applications, data, and communications into solid information technology architecture, for example problems were solved by developing specific hardware and software solutions that integrate different platforms or enterprise wide systems like ERP or EAI (Bajoric & Moon 2009). Uusipaavalniemi (2009, 33) presents that information integration and information sharing which is need information systems and technologies to enable efficient information flow. Processes and activities support the smooth flow of information from a supplier to customer toward the focal firm and vice versa. Information flow is one of three flows in integrated supply chain management. The other two flows are material flow and physical flow (Lee & Whang 2000, 374).

Companies use different back- end system to exchange data. Enterprise integration, data exchange between the internal information systems of the transacting organizations is fully automated: no human intervention is needed. This can be seen as the most efficient way to manage data exchange. In order to exchange data directly between two separate information systems communication standards as backend information systems and enterprises are fundamentally heterogeneous, autonomous, and distributed and enterprise integrations has to be as coordinator and addressing these three properties(Bussler 2003, 4 - 5).

The term System of Systems (SoS) has been widely used in diverse domains and widespread in nature (for example biology, and ecology) and artificial systems (for example computer, engineering, and society). More recently, it has been also adopted in the software domain. In general, they can be considered as a set of independent, useful systems integrated into larger systems that deliver unique capabilities and functions (DoD 2009).

The modern systems of systems have five common characteristics: operational independence of the individual systems, managerial independence of the systems, geographical distribution, emergent behaviour, and evolutionary development. From these characterizes it is possible to come closer on a generalized conception of a SoS as building a collection of independent, actual and developing systems that function comprehensive through SoS defined interfaces and performance parameters to achieve a new level of performance and capability (Sage and Cuppan 2001, 325 - 345).

1.4 Operative Environment

The case company Fifth Element is a relatively small Finnish software company, which offers consulting services and creates solutions for its customers operating in multiple industries. One of the main client industries is the forest industry. Currently the total of employees are 62 and the company has three offices in Finland: Espoo, Jyväskylä and Kouvola.

One of the target for Fifth Element is to implement a shared software service for transport companies in forest industry. The software service will enable planning and managing the raw wood material supply chain from the departure warehouse to the final destination. The aim of the service is to support transport companies in achieving a high utility rate of equipment. This is achieved by having up-to-date information from the field and connections to customer organizations' systems. Concentrating on delivery amount management and efficient stock cycle are benefits from the point of view of forest companies ordering transport services.

The interviewees of the study had worked with different integration projects, which all differed from each other to some extent. To facilitate the integration work company use tools like Fuse ESB and ActiveMQ. The interviewees have skills also of many different data bases for example Postgre SQL, SQLserver + compact edition (mobile) and SQLlite (mobile other than MS), programming and markup languages e.g., Java, Net. and xml. html and development environments eg. Spring 3.x Framework (application framework + webgui), Apache, Tomcat, Visual Studio and SAP Mobile Platform. They are experienced also in mobilizing SAP® (SAP SUP®), where the fields of expertise are at the moment: Wireless Warehouse, Mobile Maintenance, Field Service Management and Mobile solutions for Transportation.

In context of this study, wireless Warehouse systems often utilize automatic identification and data capture technology, such as barcode scanners, mobile computers, WLAN (Wireless Local Area Network) and potentially radio-frequency identification (RFID) to efficiently monitor the flow of products in the warehouse. Once data has been collected or picked, there is a real-time wireless transmission to the SAP's database. The database can then provide useful reports about the status of goods in the warehouse.

It is noteworthy, that Fifth Element has realized the Capability Maturity Model Integration (CMMI) as based Quality Management. In this case, the CMMI is built with practices and goals seen in thousands of real organizations worldwide (CMMI). The aim is to use practice and evaluate own performance to become more productive and to get more value to the customers in sustainable manner. The principle of Fifth Element is: "We can give your company a new way of working and communicating with your stakeholders by combining the web, mobile and maps as part of your company's operating model." See also, (Fifth Element).

The Figure 1 presents an example of an integration process in the case company. There are three system integrated to each other; the mobile device, frontend system and Industrial System with sql server database and customer's production data for example warehouse data.

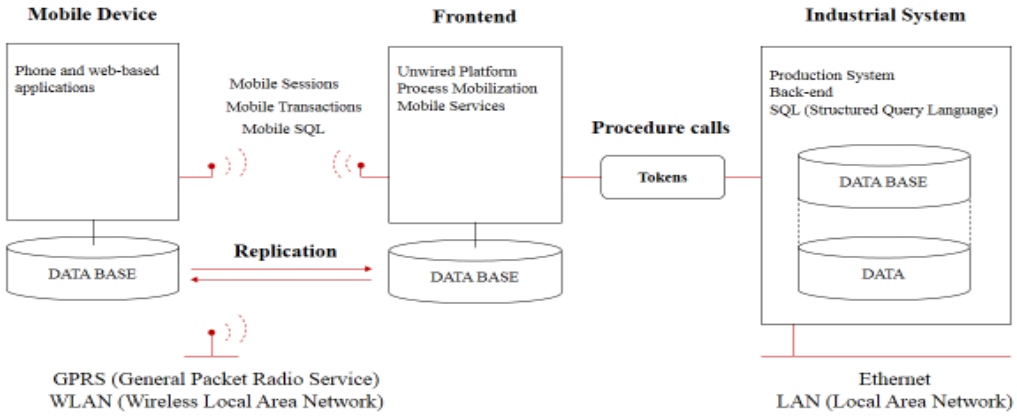

Figure 1: An Example of Configuration of an Integration Process

The figure 1 shows an integration process flow in a mobile system project. This figure proposes also a realization of the study. It is an example of a mobile SUP (SAP Unwired Platform) process. The mobile device will take a GRPS (General Packet Radio Service) or WLAN connection to connect first to the customer's unwired platform and then to industrial systems for example to SAP. The device replicates with its database and some work can also be done offline because of the device's database. This database would be helpful in situations where the connections are unstable. An operation can be started offline and when the connection is later working again the user can finish the execution of the operation online. The figure also describes the SUP authentication. The security configuration is done here following the SAP SSO2 Token protocol. When the user signs in to the mobile device her/his username and password will be authorized from SAP's user database there are not stored ant user information register in the frontend or in the mobile device.

The integrations performance here is straightforward; the remote-enabled functions acts as an interface to customer's industrial systems. It accepts a number of possible search input and fetches relevant data to return the correct results from for example SAP BAPI (A Business Application Programming Interface). Results are then processed in a format that better suits for the mobile solution in unwired platform. A number of lookup information is also retrieved and returned to support the mobile process. Desired functionality of the system: A set of functions that allow the required processes to be executed remotely and in an efficient manner that supports mobile device's interfaces. Assumptions and Constraints: To make use of

SAP standard functionality possible. Functions and structures are developed specifically for SAP Mobile.

1.5 The Structure of the Thesis

The study consists of four chapters. The first chapter introduces the background to the research topic and presents the research problem, questions, approach, methods, and describes the scope and limitations. Also the case company is presented on the first chapter. The chapter also presents the theoretical foundations for knowledge transfer to IRLs and different IT integration. The chapter summarises the implications from the theory.

The second chapter is a detailed description of the research approach, methodology, and how the study was carried out. The third chapter is a description of the studies. The last chapter, four, consists of the analyses and results, and provides the answer to the research questions. The chapter sets out the theoretical and empirical contribution, evaluation, suggestions for further research, and a summary. The structure of this Master's thesis is presented in Figure 2.

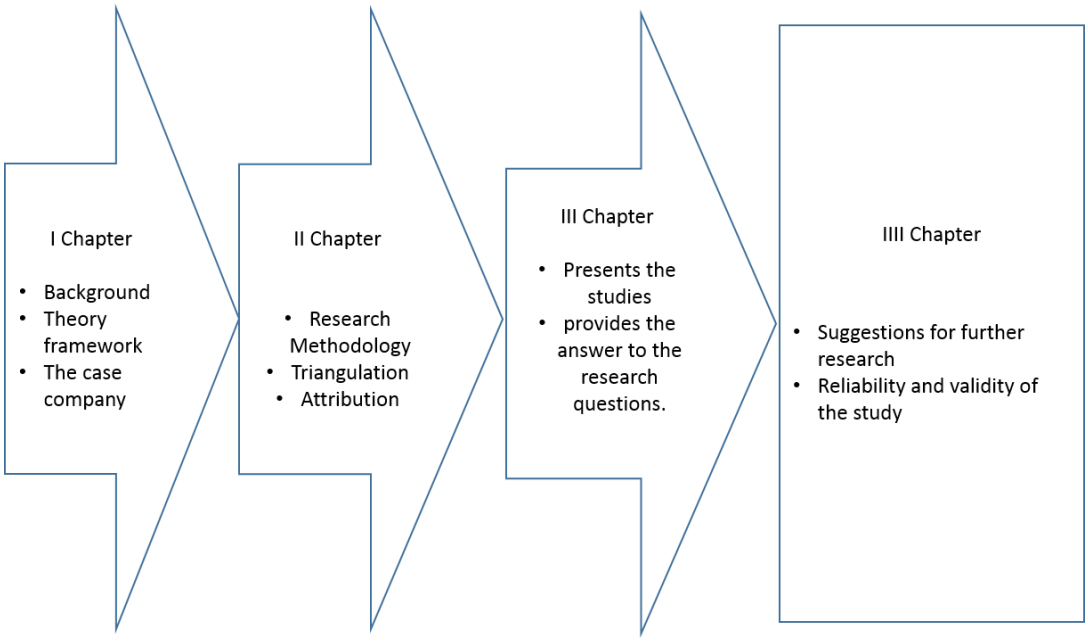

Figure 2: The Structure of the Thesis

2 Research Methodology

This chapter opens with a discussion on the choice of using the case study method. In this chapter: First, the research approach is presented. Second, planning of the study, research question and unit of analysis are presented. Third, the designing and preparation of the study are described. Then fourth the data collection and conduction of the interviews are described. And last fifth, performed analysis is explained. Picture adopted from Yin (2009, 1) presents the process of the study.

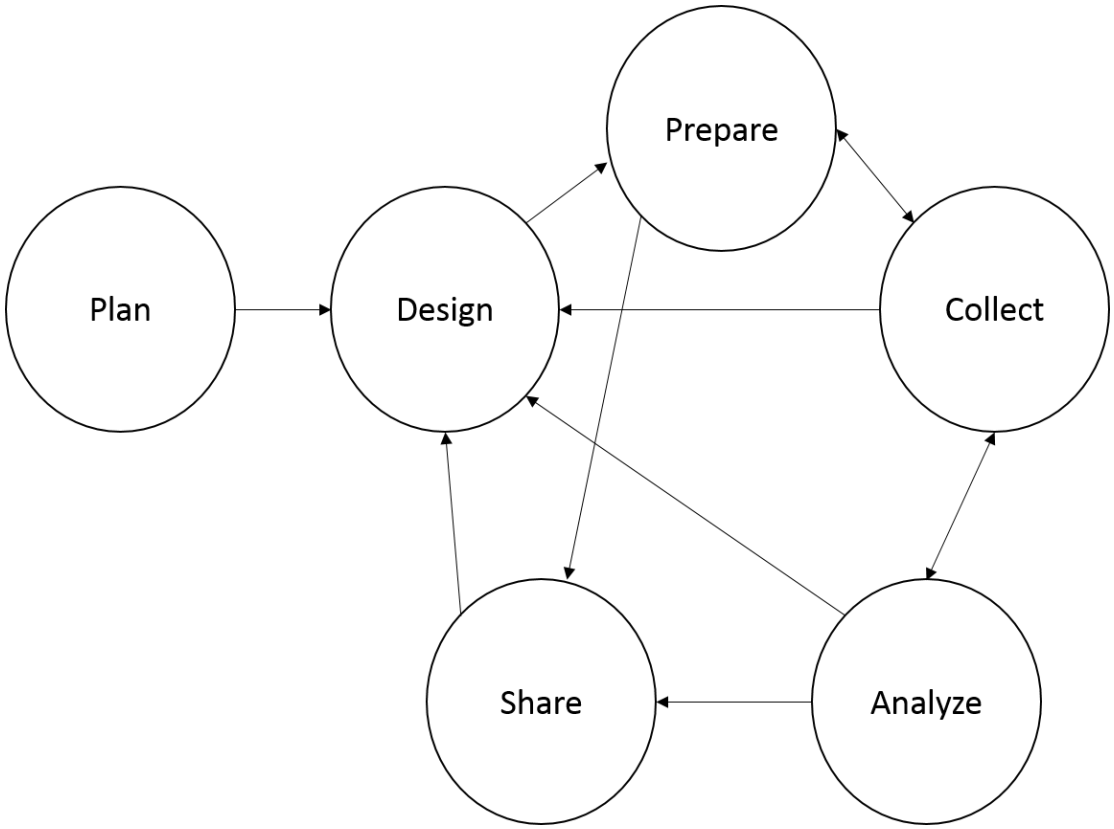

Figure 3: The Research Process (adopted from Yin 2009, 1)

2.1 Research Approach

The research conducts as a qualitative study because the aim is to find and expose how the IRL framework was understood and utilized in industrial systems projects at Fifth Element. Then, this qualitative type research focuses to increase the understanding of a certain area and it is explanatory in nature (Creswell 2003, 22). In this case, the qualitative research does not aim to make statistical generalizations but try to describe an event and understand certain activities or to give meaning for a phenomenon (Yin 2009, 18). The used qualitative method seeks answers to “why” or “how” questions. A qualitative case study was chosen as

the research method also to ensure an in-depth and holistic understanding of the research phenomenon and that "what" question can be answered qualitatively in a case study (Yin 2009, 18).

Yin (2009, 9 and 13) also states that he case study approach is particularly powerful when "how" or "why" questions are researched, when the investigator has little control over the events, and when the focus is on contemporary events within some real-life context. As presented earlier in this study, there is a need to clarify how the Integration Readiness Levels (IRLs) can be understood and realized in industrial systems projects context. According to Stuart, McCutcheon, Handfield, McLachlin & Samson (2002, 419–433), a case study methodology is suitable and relevant where either theory does not yet exist or is unlikely to apply, where theory exists but the environmental context is different. This study is combining existing theory and through applying it in a new environmental; industrial system project context.

In particular, the case study method is applied in three forms: exploration (following Yin 2009; Study I), description (following Yin 2009; Study II), and proposition building (following Yin 2009 and Dubé & Paré, 2003; Study III). In additional, Stuart et al. (2002) suggest problems in overall lack of rigor, especially in terms of obscurity in study targets, acknowledging prior studies, case selection criteria, data analysis process and the findings.

These risks have been considered in this Master's thesis by doing a time schedule and target for each particular study and careful review of prior knowledge in the specific context of each study. Rigor has been further enhanced by attending to the evaluation criteria of study quality in general and using Yin's (2009) recommendations related to the use of case study protocol including triangulation and final cross-analysis. Finally, transparency has been supported by disclosing analysis procedures on data as entire as possible. (Yin 2009; Miles and Huberman 1994).

2.2 Planning of the Study, Research Question and Unit of Analysis

Planning of the study started almost directly when the researcher heard about the PERSEUS project at a lecture of Institute Laurea University of Applied Sciences in the spring time at 2013. In the planning phase researcher build a big picture of the study that then specified and expanded during the research process. The research question started to clarify and the research method also. The collection of the theory part of the study also started in planning phase to build the theory framework to the study.

A case study is an empirical research that investigates a contemporary phenomenon in depth in its real-life situation, and when the boundaries between the phenomenon and context are

not clearly evident (Yin 2009, 18). In this study, case study research is understood as a linear but iterative process; including six phases: 1) identify research question (s); 2) formulate the research design; 3) prepare to collect case study evidence; 4) collect the data; 5) analyse the data; and 6) share your case study report (Yin 2009, 1). Doing the research is highly important to plan and identify the research question. What is the case in the study? (Yin 2009, 32). In this study the research question was: How the Integration Readiness Levels (IRLs) can be understood and realized in industrial systems projects at Fifth Element? Then, the unit of analysis (the Case of the study) was as a well-documented industrial systems integration projects (n=80), which were executed by 5 experienced experts.

2.3 Design and Preparation of the Study

In the design phase of the study a mind map technique was used. A mind map is a diagram used to visually outline information. A mind map is often created around a single word or text, placed in the centre, to which associated ideas, words and concepts are added (Budd 2004, 35-46). In this study the research question was in the circle of the map and lead the process. The mind map was also helpful not only to design phase of the study but also to prepare the study. Rowley (2002, 16–27) states that a research design is the formal logic that links the data to be gathered and the conclusions to be outlined to the initial questions of a study.

The research was time scheduled and projected in the design phase. The method of the study and data acquisition was chosen also. Here, the Teamworkpm web application was used for project's template for following the process of the study. Total of five interviews (n=5) were held, of which one (n=1) was a face-to-face interview and four (n=4) were online interviews by Cisco's Webex®, a web conference tool. Because that the interviewees was not located near to the interviewer aka the researcher of this study, the WebEx was useful when doing the interview remotely. It was also handy when you could share your desktop and record the interviews online. All interviews were single person interviews. The first interview was used as a pilot interview to perceive how much guidance and time needed in the interviews of performed study. The interviews were informal. Lime Survey questionnaires (by ISDEFE) are used to address integration activities in a System Maturity Scale to evaluate a System based on IRLs.

The questions asked similar as Lime Survey questionnaires in the interviews. The interviews lasted for approximately 45 min each. The interviews were recorded and researcher also used notes to clarify answers and response (n=50). After the interviews the recordings were transcribed and translated to English. The aim of the interviews was to provide information about

how the Lime Survey used in interviews was understood and could be utilized in Fifth Element's projects.

As a result of the research process, a theoretical framework for IRLs and system integration are developed to describe, analyse and develop information integration and to answer the research questions of the study. It should be noted, that although for expositional purposes the theoretical framework in this study is presented first and then followed by the case study, the research process itself has been more iterative, going back and forth between the data and theory.

2.4 Interviews

The case company was understood as a suitable one as it has wide experience of integration projects. The management of the company was also interested to support the study and to allow the data collection. Interviews were conducted in a period of first two weeks in October 2013 (Weeks 40 and 41). The average time for an interview was 45 minutes. The questionnaire and the list of interviewees in alphabetical order can be found in Appendix 1 and Appendix 2. The questionnaire was in English and the language of the interviews was Finnish. All interviews were recorded and transcribed.

Although building on a theoretical framework, this study focuses on mainly empirical data and analysis. Interviews were used to underpin the data collection. The interviewees were informed of the purpose of the study and interview themes in advance by email. Then the IRL survey was sent by email to eight employees (n=8) of the case company, which has been planning and implementing Fifth Element's systems. Among them, five people (n=5) were selected and validated for interviews.

2.5 Analysis and Sharing

Yin (2009, 136-158) states five different analytic techniques: 1) pattern matching; 2) explanation building; 3) time-series analysis; 4) logic models; and 5) cross-case synthesis. The analysis of this study was made by using pattern matching technique it attempts to demonstrate the causal links between the elements and level of integration, between the level of integration and between elements of IRLs. The aim in the analysis is that the material collected and the analysis of the study will form a puzzle. Analysing qualitative data consist: coding data; assigning labels to codes and; grouping codes into themes or categories (Creswell, Plana & Vicki 2007, 127). The pieces of the puzzle have to be understood and organized so that the pieces create a logic entirety with a shape of a big and in-deep picture (Kananen 2013, 110).

The analysis part of the study was an iterative process and moved backward and forward between the research activities and data collection and theory.

Each interview was first transcribed. Then the analysis included reading through the transcribed interviews was done. It was done by making first summaries to have an overall picture of the material and then similar or identical answers were colored with certain color (saturation). Classification was made from the interviews to a particular question. The found results were then categorized and then the construction of the study was build. The Phase of Sharing, according (Yin, 2009, 164), consists of reporting the case study, which means bringing its results and findings to closure.

2.6 Triangulation of the Study

According to Yin (2009, 99-101) and Miles & Huberman (1994, 40-48) the multiple strategy approaches are related to triangulation, which means that the same phenomenon is approached concurrently from several different angles. Denzin (1970) extended the idea of triangulation with research methods and designs. He divided four forms of triangulation 1) data triangulation, 2) investigator triangulation, 3) theory triangulation and 4) methodological triangulation. The purpose of the triangulation is to increase reliability and validity of the research. It is used in proving that a specific result is not merely random, since it has been produced by using several different approaches. The validity in this research was ensured through multiple triangulation along four triangulation types (see Yin 2009):

1. Data triangulation; in this research the data source focuses on mainly empirical data and analysis. The empirical data collected through interviews.
2. Investigator triangulation; in this study this was done using a review technique. More than two investigators got familiar to this case study and evaluated it. The material of the evaluations were used to improve the research.
3. Theory triangulation; in this study the existing theories applied from theory frameworks of IRLs- and different IT integrations. The investigation of existing theories were used to gather more data of the topic as well as compare similarities of the theories. Also the workplace literature references with a concrete example of configuration work in case company were used. This literature also presented detailed information of used programming language and different IT and integrations solutions.
4. Methodological triangulation; in this research a qualitative case study was chosen as the main research method. The coding and formation of dimensions was completed with a separate analysis of the gathered qualitative interview data. The selective coding in the final study is based on the categorized dimensions produced in the whole process of the study.

2.7 Attributes of the Study

In this study, the list of research attributes was established for the particular description of methodological rigor in performed case studies.

1. Nature of study: Explanatory study of IRLs in Industrial System Projects (industrial solutions).
2. Research Approach: Deductive investigation of IRLs in Industrial Systems Projects at Fifth Element.
3. Research questions and unit of analysis: How the Integration Readiness Levels (IRLs) can be understood and realized in industrial systems projects at Fifth Element's? / Industrial systems integration projects which are executed and experience by expert (n=5).
4. Importance of study: Contribution of IRLs (ISO/DIS 16290) research in industrial systems viewpoints.
5. Methodological focus: Case study analysis and part of multiple case study analysis (future triangulation).
6. Form of analysis: A qualitative research was mainly based in analysis of interviewed data.
7. Specification of constructs: Integration Readiness Level; Systems Integration, Information Integration; and Enterprise Integration.
8. Theoretical approaches IRLs & IT integrations. The review of IRLs: B. Sauser; W. Tan; J. Ramirez-Marquez; R. Magnaye; E. Forbes; M. Long; S. E. McGrory; W. Nolte; R. Kruse; J. Bilbro; C. Dennehy; P. Desai; J. Holzer; C. Kramer; W. Nolte; R. Widman; R. Weinstein. Authors (n=19) The review of IT integrations: Bajgoric; Moon; Lee; Whang; Kosanke K; Nell; Maier; Wainwright; Warning; Chandra; Juarez; Bussler; Sage; Cuppan. Authors (n=15).
9. Research domain: Operative and implementation environment of Fifth Element. Interviewees overall experience of industrial systems integration included (n=118 years and n=80-100 integration projects; n= 70-80 customer sites).
10. Multiple case design: One organization, integrated projects (n=80-100); every project represents a case.
11. Replication logic: Mainly literal replication logic.
12. Data collection methods: Questions (n=10) and interviewees (n=5). The research data was recorded, coded, reduced, archived and translated from Finnish to English.
13. Questionnaire: Lime Survey questionnaire are used to address integration activities in a System Maturity Scale to evaluate a System. The first interview was used as testing how much guidance is needed in the interviews of performed study.

14. Coding: Each interview was first transcribed and then similar or identical answers were coloured with certain colour (saturation).
15. Notes: Researcher used notes to clarify answers and response (n=50).
16. Team-based research: Number of researchers in research group (n=3).
17. Different roles of investigators: Researcher as outsider (objective) and interviewees as insiders (subjective).
18. Research associations: International Standards Organization (ISO/DIS 16290) and Institute of Electrical and Electronics Engineers (IEEE).

Tables of research attributes used to assess the PERSEUS analysis and investigated cases; based on research frameworks by (Dubé & Paré, 2003; Miles & Huberman, 1994; Pirinen, 2013).

2.8 Summary of Methodology

The methodology of the Study I can be summarized as followed: The database to the research was built already in the planning phase. The research data was recorded, coded, reduced, archived and translated from Finnish to English. The main research question was: How IRLs (Integration Readiness Levels) can be understood and realized in industrial systems projects at Fifth Element? The interviews (n=5) were in Finnish. The questionnaire by ISDEFE was in English and in generally it was understood well. The analysis method, data reductions were referred as described in Yin (2009, 136 - 158).

In the Study II the used methodology was case study research as well but main target was not analyse some phenomena but review the earlier versions of the studies.

Study III, a cross-case study analysis were used and it addresses improvements in the integration process of a complex system, and the term “external validity” refers here to establishing the domain in which the study’s findings and conclusions can be generalized (Miles & Huberman, 1994). In this study, the case study protocol was used with a cross-analysis (Yin, 2009). The title of the study: “Samples of Externally Funded Research and Development Functions in Higher Education Institutions: Case Integration Readiness Levels” and the research question was: “How can the Integration Readiness Level (IRL) metrics be understood and realized in information systems projects?”.

The cases in this study (unit of analysis) are the information systems integration projects (n=163) that are implemented, well documented, and experienced, including the two case studies of this cross-analysis. The methodological focus: multiple case study analysis (n=2), including triangulation and final cross-analysis. The research target of the first pilot study at

Fifth Element (interviewees' overall experience of industrial systems integration including n=118 years and n=80–100 integration projects covering n=70–80 customer sites). And the research target of the second pilot study, Nevtor (interviewees' experience of systems integration including n=57 years and n=121 integration projects covering n=75 customer sites).

3 Contribution of the Study

The Contribution of the Study part of this Master's thesis consists of three original studies reported as three reviewed papers. To better understand and utilization of IRLs studies represents three different contexts: Study I: In Industrial system projects Study II: In Operative Systems and In Industrial system projects and Study III: Cross-analysis of two pilot case studies, comprises externally funded research project and R&D-related studies.

3.1 Study I: Author's Study of Industrial System Project

The first study [P1] followed a descriptive single-case study research design. The specific reason for selecting this design was to enable an in-depth evaluation of an instance of integrations. The timeframe of this research was between May 2013 and December 2013.The IRL framework was presented in details; IRLs were defined as a series of levels that articulate the key maturation milestones for integration activities. The introduction of an IRL to the assessment process not only provides a check as to where a technology is on an integration readiness scale but also presents a direction for improving integration with other technologies (Perseus Project 2013, 14).

The main purpose of this study was to find out how the existing IRL framework on questionnaire (Lime Survey) is suitable and may be developed to fit into the Fifth Element's projects. The company Fifth Element was understood as a suitable one as it has wide experience of integration projects, also in industrial system context.

IRL is designed to assess the risk associated with integrating technologies. Building upon similar efforts to define an integration maturity scale, the IRL has been refined to include nine levels as presented in Table 5 (Perseus Project 2013 14 - 15). The nine levels of IRL can be understood as having three stages of integration definition: semantic, syntactic and pragmatic (Sauser et al. 2009).

Table 5: Integration Readiness Level Framework

Integration Readiness Levels		
Layer	*Definition*	*Description in context of this study*
9	Integration is mission-proven through successful operations, e.g., harmonized operative and industrial realizations.	Integration of the information system and its sustainable maturity management is achieved; information system sharing and information sharing is realized.
8	Integration completed and mission qualified though tests and demonstrations, e.g., test bed, living lab, and final validation.	Integration for service-based sharing level; integration of the information system is realized, implemented, and described, and actor-specific services are activated.
7	The integration and technologies have been verified and validated with sufficient detail to be actionable.	Integration of communication and interaction; readiness for completing the information system integration is achieved and actor-specific services are validated.
6	The integration technologies can accept, translate, and structure information for its intended application.	Readiness of technological functionalities for completing an integration is realized.
5	There is sufficient control between technologies necessary to establish, manage, and terminate the integration.	Integration process management facilities are validated and implemented. Quality system for integration management is activated.
4	There is sufficient detail in the quality and assurance of the integration between technologies.	Readiness of technology for integration management functions is achieved.
3	There is compatibility between technologies to orderly and efficiently integrate and interact, such as a common language.	Compatibility in the infrastructure, architecture level, and ontology is achieved.
2	There is some level of specificity to characterize the interaction between technologies through their interface.	Infrastructure and architecture outlines are planned and agreed; integration "proof of concept" is activated.
1	An interface between technologies has been identified with sufficient detail to allow characterization of the relationship.	Usefulness, scope, and need for integration are understood, and medium is described.

In this view, semantics is about relating meaning with respects to clarity and differentiation. The first study of this Master's thesis included questions to interviewees (n=10) and number of interviewees (n=5). The research question was How the IRLs can be understood and realized in industrial systems projects at Fifth Element? The table 6 presents classification to the

question how IRL (Integration Readiness Levels) can be *understood* in Fifth Element's projects, includes original quotes from the interviewees.

The finding based on the questions of interviews (n=10) and number of interviewees (n=5). The classification to the question how IRLs can be understood in Fifth Element's system projects, includes original quotes from the interviewees. The main findings from the interviews were:

1. The levels 1-2 are too higher- level questions;
2. Too wide and too many questions;
3. Could be realized at Fifth Element as a check list.

3.1.1 Levels 1-2 are too higher-level questions

The interviewees noted that the two first levels of IRLs are excessively higher level questions and the interviewees felt that organizations like Fifth Element should fill the survey from not until third level. These two fist levels felt too basics and goes too deep to system's unnecessary details according to the interviewees.

"Levels 1-2 are in my point of view, too basic kind of stuff." J.V.; "Level 1 is quite general level: making and going through the integration is a high level stuff." T.M.

However, it was noted that the first two levels were unnecessarily if you had integrations modules ready and you are using common interfaces to build the integrations. But overhand the first two levels could be checked faster in that point too.

"Could be started earlier from top levels and skip the first levels. It is thus generally accepted interfaces; existing interfaces that are known and already used to start with or to a particular standard those we consider the system." H.H.

3.1.2 Too wide and too many questions

And second interviewees find that the IRL framework is too comprehensive and have generally too many levels as such.

"It is relatively difficult as such. Too heavy for our business, there we do integrations. These 9 levels are too wide and too multi-level" H.H. "In levels 8-9 were mentioned the customer's business requirements, and against these we are mirrored what type of system is built. No, we generally don't need to answer more than these questions." U.V.

3.1.3 Realization at Fifth Element

Based on experiences, it is common that an integration process is often complex and structured badly. The questionnaire in question can be considered as best practices for integration design process. The classification to the question How IRLs (Integration Readiness Levels) can be understood in Fifth Element's system projects? presents the apprehension of the study and the classification to the question How IRLs can be realized at Fifth Element? Presents the realization to the study.

"Damn good questions." U.W.; "This like a sort check list would of course be good to fit in to our processes. Like a short checklist. So things are checked through and not any essential is forgotten. So my opinion is that this might be helpful for us." J.V.; and "Really good questions. A good list" T.M.

Then, the IRLs could be realized in Fifth Element's system projects like e.g. invoice or project management tool.

"To check and review what we already can and know, and then use the data in background of an invoice." U.V.

The basic scenario could be to use the presented formula as a part of a project management tool for planning integration project tasks. This is because the formula gives an overview of the complete integration process and illustrates what tasks are required in each phase. Based on the findings the presented formula could fit better to Fifth Element's system projects with small adjustments.

The research contribution of according this study is presented in following Table 8.

Table 6: Contribution of the Study

Research contribution of the study		
Item	**Definition**	**Proposal**
1.	1-2 Levels are too higher level questions	The 1-2 levels could be combined
2.	Too wide and too many levels	If the first to levels are combined and re-checked there could be pointed out bullet points that are duplicated
3.	Check list	If there would be yes, no, N/A the survey could be as check list for Fifth Element's. projects

The results of analyses showed that survey as it is too wide for Fifth Element's projects. If the first two levels would be combined the survey felt easier to go through and it felt more compact that way. The interviewees noted also that this kind of check list could be helpful for the customer side of the project. They said that if the customer was responsible of filling this survey with all parties in a project then there would be less projects that are taking too long period of time. That is because the deficiencies could be discovered and addressed as early as possible.

3.2 Study II: Review of the Studies

In this study [P2] the author reviewed fellow student's study of the same subject. The review process included evaluation work where every chapters of the study were reviewed. Time frame to the review process was from January to March in 2014. The focus of the research is an evaluation of anonymized author's study and question of this study was: How the Integration Readiness Level metrics can be validated and to be used in integration projects.

Doing the review the author noted that the research question of the study is novel. She also noted that the statement addresses to a clear research question. She recommend that the definition of central constructs would be added before introduction. The scope of this study was to focus in evaluation of IRLs utilization and its new extensions in practical integration projects. Study addresses into practically relevant problem for author's opinion. The performed analysis was qualitative and included interviews of experts from case company Nevtor Ltd, 5 interviews in which 3 was valid. The interviews represent experience of total of 121 integrated systems. The unit of analysis in this study was an integration project and the main research finding was that: if the IRLs and questionnaires are used, then useful contribution for validation of integration readiness is achieved.

The author suggested that in addition abstract of the study would include also the operational environment and context of study; related research: needs of research; research gap; approach of research such as inductive or deductive research design; implications to the theory; implication to research itself; managerial implications. Also the answer to the research question would also be set in the abstract. Author found that the case study determines a clear research question how and to what extent IRL (Integration Readiness Level) framework would be valid to be used in operative solutions at Nevtor.

Research in the study was carried out by using qualitative approach and it was accomplished in IT Company called Nevtor which is specialized in planning, designing, implementing and supporting business critical infrastructure for customers. The original study was made as ECTI-CON paper. The author would follow the ECTI- CON directions also with the references; it was

said in the ECTI CON paper “The template will number citations consecutively within brackets [1]. The sentence punctuation follows the bracket [2]. Refer simply to the reference number, as in [3]—do not use “Ref. [3]” or “reference [3]” except at the beginning of a sentence: “Reference [3] was the first ...” “. The author found that this research has a novel problem; because this kind of evaluation has been done earlier in project PERSEUS but more research in civil environment was required. This study can give a value not only for PERSEUS project and Nevtor’s business activities but also for all other participants involved with this study. The author recommend that the researcher would include limitations to the introduction part. In author’s opinion the research problem is narrow enough and it focused to the question: How the Integration Readiness Level (IRL) can be understood and realized in Operative Systems Projects at Nevtor?

Review of the research findings and results show, according to the author, that the analysing data is the heart of building theories in case studies researcher also mentioned; even if it is most difficult and least codified part of the process The results is concerned to the interviews gathered from the expertise of three consultants who currently work at Nevtor. The author of the review propose that the researcher would describe briefly how the analysing part was made and how chosen findings were picked to the research. Readers like the author would be delighted to get deeper information of the analysing process as well.

The researcher would also consider to the part of interview findings. At the moment it contains very interesting and well described parts but the red line could be more visible in this phase. There were stated in the results that if the IRL framework would be used as it is, it would extend the project time goals because it has so many details to plan and check. As a result of interviews, the gathered data showed that some parts of framework could be used in business activities at Nevtor. If this IRL framework would be used in business activities at Nevtor, it would need modifications in all its levels. The identification of unresolved questions would be also included at least to conclusions part.

The author found as a reviewer that the study has a special scientific merit and the achieved results are exceptionally significant in this research field. In author’s opinion the researcher used a clear argumentation and coherent presentation. The author suggest that the one sentence’s chapters in this study could be included to the other chapters so the text would be more solid and easier to read. The author found study was interesting and the reliability and validity was justifiable properly. The communication of the study was clear and down-to-earth. The language used were English. The suggestion for a future study was also fascinating and gives this study more value in author’s opinion.

The aim of the review process is to give valuable input to the study and help to improve it. A research based on Study I was sent in the beginning of year 2014 to ECTI- CON 2014 conference in Thailand. But unfortunately it did not accepted to the conference. Then the acceptance rate to the conference was 65%. But the author of the Study I got valuable feedback to improve the paper. The original paper was also reviewed by the supervisor and a fellow student who did a study from the same subject. Evaluation statement of the review works of Eveliina Sivlen case study –document were built to include the reviews to the Study I and also comments how the reviewed feed-back has been taken to notice in the Study I. Also the attributions and amendments of the study were added to the same document.

3.3 Study III: Cross-Case Study Analysis

In this Study III [P3] we focused on to find out, that how the existing IRLs metrics, its definition, criterions, references and questionnaires are useful and can be addressed to realize and validate the integration and communication in an information systems project. This study, as a cross-analysis of two pilot case studies, comprises externally funded research project and R&D-related studies. The study is an extended part of the research of Protection of European borders and Seas through the Intelligent Use of Surveillance (PERSEUS), which is coordinated by INDRA Sistemas with 29 partners. The timeframe of the PERSEUS research is between January 2011 and December 2014. The timeframe of this part study is between December 2013 and April 2014.

The purpose of this study is approached by experiences of two companies which describes well the current situation of small and medium size Development Company and which operates in field of industrial and operative information systems research and development. In the environment of study, the Fifth Element's and Nevtor in Espoo, Finland was successfully used as stakeholders of integration projects.

In this study, the findings for R&D-related learning can be summarized as follows. The building of useful skills and competence has become increasingly complex, focused, multidisciplinary, trust-based, co-created, path-dependent, and globalized; for example, path dependency in IRL development and at PERSEUS represents a case of a multidisciplinary research program and a shared research consortium that targets the large-scale integration, validation, and demonstration of novel systems, and it symbolizes European research collaboration, providing a common learning space to join research and steering in areas of significant European interest.

The compressed findings for R&D related to learning are as follows: 1) the role of students as participators in externally funded R&D projects; 2) student involvement as a sustainable inte-

grative driver facilitates learning, for example an open interaction with an R&D operating environment and agility in responding to the needs of the environment and the workplace; 3) teacher involvement in continuous interaction with the environment allows for quick reactions to the realization of needs and maintains teacher competence; and 4) the focus itself was on the development of permanent collaboration structures and employment in the students' workplace and applied domain.

Some of the central challenges that "makes educational resonance" in the realization of PERSEUS cases integration are as follows: 1) the balancing and modularizing of cognitive load and the challenges of learning in an R&D-related education model; 2) development and continuous change in R&D that pose great challenges for educational alignments; 3) understanding the meaning of student-centred R&D in communities of work and workplaces as research for work in a general sense; 4) the development of incipient internationalization and individual-global interactions; and 5) measuring the effects and development of utility, usefulness, and strategic measuring as an evaluation design structure in higher education institutions.

According to the data of this study, it is commonly agreed in the case studies of Nevtor and Fifth Element that the current form of IRL metrics was useful to the integration purposes and realizations overall. However, IRL metrics were not understood as a complete solution to integration maturity determination but rather a specific validation path and tool for communication between all the project's parties and for mutual confidence and trust, such as for pre-order validation.

When IRL metrics were used acceptably, they contributed to the project's goals in the designated time schedule, and significant strength in the integration was achieved. The first research finding that involved reflection was that "some criteria are more useful than others," and our finding is that most important criteria could be either inserted at the beginning of the criteria list at each level or marked in some way so that users will pay more attention to them. The second finding is that "integration quality, security governance and maturity" are scales rather than levels. According to data this study, the proposal, IRLs validation guidelines for information systems integration are described in the Table 9.

Table 7: Validation of the IRLs

Validation of Integration Readiness Levels					
Layer	*Guidelines for IRL validation*	*Category*	*Scales*		
7	Integrated system has demonstrated operational effectiveness and suitability for intended and representative operational environment achieved and integration-related failure rates have been fully characterized, and realization is consistent with integration requirements and sustainable maturity management activated.	Harmonization	QUALITY ASSURANCE	SECURITY GOVERNANCE	MATURITY
6	Integrated systems are able to meet overall system requirements in an operational environment; system interfaces qualified and functioning correctly in an operational environment. Components are form-, fit-, and function-compatible with operational system and for the intended solution and operational environment.	Activation			
5	End-to-end functionality of systems integration has been successfully demonstrated. Fully integrated prototype demonstrated in real or simulated operational environment; each software interface tested individually under stressed conditions and interface, data, and functional verification completed.	Validation			
4	Individual modules tested to verify that the module component functions work together, software components, operating system, middleware, loaded applications, subassemblies, cross-technology issue measurement, and performance characteristic validations completed.	Proof of Functional Interactions			
3	High-level system interface diagrams have been completed; interface requirements are defined at the concept level; and inventory of external interfaces is completed.	Compatibility			
2	Input and output requirements for integration technologies are characterized; main interface requirements for integration technologies and interface requirements specifications for integration technologies have been defined. Proof of concept, such as infrastructure, architecture, and modular integration strategy are activated.	Modular Integration Strategy			
1	Integration technologies have been identified, and top-level functional architecture and interface points have been defined. Purpose and appropriate needs for useful integration are recognized, understood, and described.	Usefulness			

In Table 9, the “compatibility category” includes high-level system interface diagrams that have been completed in an integration project, interface requirements defined at the concept level, and an inventory of external interfaces. Then, the proof of functional interactions phase comprises the testing of individual modules to verify that the module component functions work together; software components, the operating system, middleware, loaded applications, subassemblies, cross-technology issue measurement, and performance characteristic validations are completed. Then final systems validation, as IRLs between layers five and seven and activation, are followed as described in (Sauser et al. 2010). In the end, the “harmonization category” includes the fact that the integrated system has demonstrated operational effectiveness and suitability for the operational environment, integration-related failure rates and recovery from failure have been fully characterized, the realization is consistent with integration requirements, and sustainable maturity functions have been activated for continuity management (Syrjänen 2009).

The “maturity scale” shown in the Table 9 comprises the IRLs related to maturity as described in (Sauser et al. 2010) and information systems continuity management maturity (Syrjänen 2009), which is based on business requirements and provides a model that improves the continuity of information systems and services. This viewpoint extends the management of solutions where the failure rate increases with time. Syrjänen (2009) also described a model for system recovery in the case of disruptions and interruptions in production process-related systems.

In Table 9, the “quality assurance” scale describes the procedures, processes, and system used to guarantee and improve the quality of operations. In the environments of this study, the quality assurance scale was carried out using jointly defined operation-enhancing and appropriate procedures, methods, and tools, and then it was used to monitor and develop the operations in a systematic way. In this view, the term “quality” refers to the suitability of procedures, processes, and systems in relation to strategic objectives, such as integration strategy. In this context, the quality assurance and quality assurance systems combine the knowledge-based structures with a body of knowledge. Here, IRL level five is “a scale” rather than as IRL layer five. In addition, the security governance in Table 9 is referred to as a scale for future studies of security readiness for the combined information systems integration domain.

The most critical viewpoints and recommendations concerning the usefulness and the realization of IRL metrics can be summarized as follows: integration is a complex topic, and the IRL metrics are not yet a complete solution to integration maturity determination in PERSEUS context; the case studies indicate that the IRL questionnaires lack the ability to assess criticality in overall systems integration, IRL assessment is complex, net-centric systems require a more quantitative algorithm to reduce multiple integrations to a single assessment, and IRL does not evaluate cost, schedule, and long-time maturity, such as the number of failures increasing with time (Syrjänen, 2009).

However, overall, it can help the project to stay on track and provide transparency and confidence for all project parties, especially in procurement. Regardless of the critical viewpoints found by our analysis, we recommend IRL metrics for Pre-Operational Validation and Pre-Order Validation for PERSEUS and their future development in continuums of PERSEUS.

The study also shows that there is significant implications for further research, first in the transition process between development and work operations, such as production processes and work processes. Our understanding is that an integrated information system is still a kind of work system, and the integration of a system can create causalities in the integration of

work and a work system can be more integrated and modularized. The second interesting research theme is that IRLs did not necessarily address sub-levels and utility levels, such as user interface or security readiness, which was described here as a scale. Hence, the implication is that the success of integration is highly dependent on the users' and actors' experience and understanding; for example the amount of work needed to successfully and sustainable integration, including all necessary sub-solutions.

The third research focus would be the development of integrated systems in a sustainable manner, such as the concept of Continuity Readiness Levels; one promising key can be sustainable maturity (Syrjänen 2009). These drivers include cost, schedule, production capability, R&D possibilities, the reduction of multiple integrations, and the rationality of work in a sustainable way. Future research can address how related metrics sets can be improved to evaluate the costs, the schedule or delivery capability, r This study addressed the way of learning by information systems' R&D and integration facilities, such as utility and communication, integration readiness, and networked realization capability.

3.4 Summary of the Studies

The first study [P1] was written fully by the author. The idea for the study was originated by the supervisor and he also made some editing work. The study I [P1] was reviewed by the supervisor and the fellow student.

The second studies [P2] was written and presented by the author. The supervisor made some editing work and gave good directions.

The third study [P3] was written for a conference by the supervisor and was based on the first study [P1] by the author and also on the fellow student's first study. The author conducted related research data and thee supervisor edited the final version.

4 Discussions

In this chapter, the contribution arising from the research is summarized and discussed. Main contribution of this study is based on to the qualitative material relating to interviews. First in this chapter the contribution of research methods are presented. Then reliability and validity of the Master's thesis are introduced. The contribution of the results of the studies are collected in to a Table where the main reductions are presented. Then the chapter end to the discussions of limitations, topic for future research and collaborative learning.

4.1 Research Methods of the Studies

As a research continuum, this study employs cross-case analysis, which means grouping together answers to various common questions and analyzing different perspectives on central issues (Eisenhardt, 532 - 550, 1989). The table 10 describes the contribution of the research methods of the studies.

Table 8: Contribution of the Research Methods

Study	**Type of Study**	**Research Question**	**Qualitative data**	**Theory frame works**
Study I	Exploratory single-case study	How the IRLs can be understood and realized in industrial systems projects at Fifth Element?	Interviews of experts (n=5).	The PERSEUS and IRL related references were reviewed (n=19). In addition, different databases were also used to search for studies with different combinations of keywords that included: System integration, Information Integration and Enterprise Integration and System of Systems
Study II	Descriptive single-case study	How the Integration Readiness Level metrics can be validated and to be used in integration projects.	Interviews of experts from case company Nevtor. (n=5 in which n=3 valid)	In this study approximately academic books (n=10), studies and articles were used to gain deeper understanding when answering to the main question
Study III	Proposition building cross-case study	How the Integration Readiness Levels (IRL) metrics can be understood and realized in information systems projects	The target of the first pilot study at Fifth Element (interviewees' overall experience of industrial systems integration including n=118 years and n=80–100 integration projects covering n=70–80 customer sites); the target of the second pilot study, Nevtor (interviewees' experience of systems integration including n=57 years and n=121 integration projects covering n=75 customer sites;	A study of related literature, and wide experimental knowledge of the integration projects that were used to explain concerning the research question and learning processes and their meaning

The two first studies followed the case study method. The findings have been triangulated by collecting qualitative data from interviews. The theory is built through studies that all contain phases of research design, data collection, data analysis, literature reviews and findings. As a research continuum, this study employs cross-case analysis, which means grouping together answers to various common questions and analysing different perspectives on central issues (Eisenhardt 1989).

4.2 Reliability and Validity

Concepts of reliability and validity presume that the researcher has access to an objective truth. Their origin lies with quantitative research and their suitability to qualitative research has been debated amongst researchers (Hirsjärvi & Hurme 2009, 184-186). Reliability in a case study can be improved by using a case study protocol and developing a case study database. Reliability of the study was strengthened by using a consistent set of interview questions and carefully documenting each research phase into a project database (Yin 2009, 45).

The term "external validity" refers here to establishing the domain in which a study's findings and conclusions can be generalized. In this study, Fifth Element in Espoo, Finland was successfully used as a research domain and as sample of development actor in information systems field.

Hammersley (57, 1990) states that valid means "truth". As the extent to which an account accurately represents the social phenomenon to which it refers. According to Hammersley (1992, 67) reliability refers degree of consistency with which instances are assigned to the same category by different observers or by same observer on a different occasion.

The term "internal validity" refers to the establishment of casual relationships; the targets of the studies focused on increasing the trustworthiness that studies make sense and are credible enough for audiences. Here, the design of this study was based on a combination of a thorough understanding of the theoretical framework, study of related literature and wide experimental knowledge of case company, which were used to explain and meaning concerning the research question.

In this research, the terms "reliability" refer to demonstrating that the operations of a study, such as the data collection procedures, can be repeated with the same results. Due to the operative environment the research organization, the performed interventions and spirit in investigation might be difficult to repeat. However, the transparent data collection and themed data categories can be used for furthered verification of reliability. Silverman (2000, 177) converse on five ways of thinking critically about qualitative data analysis in order to

aim more valid findings. These are according to him: 1) the refutability principle; 2) the constant comparative method; 3) comprehensive data treatment; 4) deviant– case analysis; and 5) using appropriate tabulations.

Study I concerns on construct validity: Since each interviewee was interviewed only once, some important insights might not have been captured during the process. Second, the viewpoint of the study was on understanding and realizing the current IRL framework rather than implementing and improving it. Concerns on external validity: Interviewees invited to the study were selected by expert assessment and is biased towards known for their knowledge and expertise of integrations. Silvermann (2000, 187) states that when interviews are recorded and transcribed the reliability or the interpretation of transcripts may be gravely weakened by a failure to transcribe apparently trivial but often crucial, pauses and overlaps These risks have been considered in this study by using WebEx. The interviews were recorded online, the desktop with the questions shows all the time at the interviews and the entire event can be followed as in first place from Webex database afterwards.

In this study, the case study protocol was established with carefully planning (including for example. project plan portal with time schedule).The researcher also took an objective role when analysing the study. The interview structures and questions were sent to interviews beforehand by email. The data was carefully analysed, and the analysis leading to this conclusions as paper. The case company in Study I, has realized the Capability Maturity Model Integration (CMMI) as based Quality Management. The CMMI is built with practices and goals seen in thousands of real organizations worldwide (CMMI). The case company uses reviews in every project where all the project documents are reviewed by some member from another project. The needed documents are customized depending on the size of the project. The members usually consists of project managers, quality managers or peer developers.

In study III validation, such as operational validation, pre-order validation for procurements, internal validity, and external validity, which can, for example, be useful in national-global dissemination processes, the operational validation of information systems, improving integration success, achieving common ontological understanding, and improving methods of information systems integration itself.

The internal validity of this study refers to the establishment of casual relationships, as Miles & Huberman (1994) described. In this study, the causal relationships are expected to be interactions and relationships among shared learning, IRL measures, and information systems realizations from the perspective of integration readiness, information sharing over borders of various domains, and the use of common shared information systems; for example, information is shared, the information system is shared, and learning is collaborative and shared.

4.3 Discussion of the Results

In the first study [P1] the main contribution is based on to the qualitative material relating to the 5 interviews. IT integrations play an important role in the Fifth Element projects. As concludes in the paper the findings of this study proved that IRLs can be useful also in the industrial systems integration projects but based on the findings, it seems that the presented surveys are too wide and hard to understand in the first place. Consequently if the questions are more simply it could be easier to understand and realized in Fifth Element's projects.

The interviewees noted also that this kind of check list could be helpful for the customer side of the project. They said that if the customer was responsible of filling this survey with all parties in a project maybe there would be less projects that are taking too long period of time because of the integration problems.

In the third study [P3] the author's studies concentrated to the Lime Survey and how it is understood in the case companies while Sauser's study provided some insight into how metrics assesses integration maturity, risk, and operational readiness. The conclusions of author's studies were improvements that would made the Lime Survey more useful. For example also when answering Yes, No and N/A to the questions instead of putting a tick in a rectangle the answers could be more useful and it would be easier to see are every questions checked. But in the other hand it would help the project to be in the track and it would give transparency to all project parties. According to the data of this study, it is commonly agreed in the case studies of Nevtor and Fifth Element that the current form of IRL metrics was useful to the integration purposes and realizations overall.

Sauser et al. (2010) also noted that the IRL could be complemented with a checklist that would allow for the removal of some of the subjectivity that exist in many of the maturity metrics, same result realized also in author's study "If there would be yes, no, N/A the survey could be as check list for Fifth Element's projects". In second author's study this realized e.g. "There needs to be place for criterions that are inserted by user". It is agreed that the IRL is not a complete solution to integration maturity determination even more a tool for communication between all the project's parties. When used correctly the tool helps to achieve project's goal in the designated time schedule. One conclusion was that the some criterions are more important than others. Recommendation is that those more important criterions could be either inserted to the beginning of criterion list in each level or highlighted that user give more attention to them.

The contribution of study III lies in the validation and the utility of ISO standardization related to the ISO DIS 16290 and interconnection, such as 1) the improvement of metrics for information systems integration, such as IRL metrics; 2) advances in global procurement management, such as increased confidence in agreements and descriptions; 3) pre-operational validation in information systems investigations, such as common ontology; 4) the progress of operational validation in information systems implementation; 5) the findings of methodological implications for the implementation of IRLs in the context of the study as a description of the analysed categories; 6) the usefulness to information systems sharing and interconnection in which integration is a demanding and currently addressed target in the applied field; 7) the expansion of large, networked information-intensive services that can extend shared solutions and routes of big data utilization and common global information sharing; and 8) educational advances and challenges of research-related learning in higher education functions, especially in this special session and conference. The table 11 describes the contribution of the results of the Studies.

Table 9: Contribution of the Results of the Studies

Study	Understanding of IRL	Utilization of IRL
Study I	Too wide and too many levels, 1-2 Levels are too higher level questions, the questions can be understood more than one way	Check list
Study II	The questions were relatively open and more new detailed forms and validations criterions (n=8) are proposed as research contribution of this study The format of IRL framework phrases and vocabulary should be less complex. Framework's definition criteria are trivial to understand and needs more definition.	The IRL framework is a good concept if one needs to build up system integration from scratch.
Study III	A technology readiness metric and an integration readiness metric are the two basic elements for thinking, building, improving, and testing of information systems, networked integration, and ontology. IRL metrics are not a complete solution to integration maturity determination; currently, it is a valuable and promising metric as well as a method that increases stakeholder communication, knowledge transition, common ontological understanding, practical advances, and particularly system maturity	The usefulness, sharing, and dissemination of an information system as a common service, product, or solution involving shared information over appropriate borders of applied domains.

As the table 11 describes, the first Study [P1] and the second study [P2] investigated understanding and utilization of IRLs. The third study [P3] presented that IRL metrics can provide a common language and a method that improves the organizational communication of scien-

tists, engineers, management, and any other integration stakeholders within documented systems engineering guidance and overall confidence.

The studies reported herein provide further data on understanding of the IRLs. The studies has shown that IRLs offers support to integration issues. However, our results indicate that it is useful and could be realized in context of industrial system projects as well as in operative systems with small adjustments. However, according to the research data of this study, the one difficulty is that the IRLs criteria can be understood in more than one way: "it would be easier for user if expressions were more formal and described in more detail what kind of activities are needed," as found in the case of Fifth Element. On the other hand, the integrations included diversity, and it was found that descriptions should include more case-sensitive data: "there needs to be a place for criteria that are inserted by user," as found in the case of Nevtor. It is understood that the questionnaires by Sauser et al. (2010) are fitting fine but should be left open-ended for resiliency.

4.4 Implicated Proposal

In study I the interviewees find that survey in question could be useful in integration projects with small adjustments. Here in Table 12 are suggestions for development the survey in question.

Table 10: Suggestions for Developing the Survey

Defect	Area of the questionnaire	Definition
1.	General Information area	The owner information of the whole system could also be given.
2.	General Information area	The version information of the system could be given in the start of the questionnaire.
3.	General Information area	The information (name, position and role in the integration project) of the person who fills in the survey
4.	General Information area	Estimated lifecycle of the system (one-timer e.g.).
5.	Level 1	The risk management plan could be done in the start of the survey.
6.	Level 2 or 3	Build the monitoring to the system
7.	All levels	Information of if the level is achievable.
8.	Level 7	The common errors could be taken into account and wrote down in a document
9.	Level 8	Co-operative plan incl. change management and information of the responsible of the certain step is missing.
10.	All levels	Yes, No and N/A answers to the questions instead just a tick in rectangle. Then the answers could be give more useful data and then you can check that every questions has been gone through.

It was noted that there were missing information in the general information area. The interviewees felt that there could be mentioned the owner of the whole system as well as version history and lifecycle of the system in question. In other words is this system meant to be a one-timer, “proof of concept” etc. Then also information of the person who fills the survey should be given not just the name and position but also the role she/he has in the integration project.

Then the interviewees recommended that the risks would be analyzed in the start of the survey. The risk management plan could be done and the risks should be prioritized and evaluated. A monitoring tool would be helpful to follow for example testing period and helpful also to do re- checking if there will be any errors in the system. The monitoring tool could be installed same time when the implementation work starts. The tool could help to identify errors that occurs when implementing the system or integration.

Information of if the level is achievable in certain project could be useful detail and specially when checking the survey afterwards. The comments area could be used in this case for additional details why that level is not achievable etc. Also when answering Yes, No and N/A to the questions instead of putting a tick in a rectangle the answers could be more useful and it would be easier to see are every questions checked. The interviewees find that the common errors could be taken into account and wrote down in to some project document. The errors could be included to a co- operative plan with the change management plan of the project.

The interviewees noted also that the responsible of certain step could be given to the survey then the task into a step will probably be done also not just to be informative. The survey in question was also criticized that the used language was arduous and the questions could be understood more than one way. Then interviewees noted also that there were not mentioned in the survey when a level is fulfilled. In integration projects the goals and the scope are defined in the beginning of the project and usually first project review is held then. The interviewees recommended that this survey could be taken into account in this first review and there the decisions should be made; which steps need to be considered and when particular level is fulfilled in certain project.

4.5 Limitations and Future Research

In study I [P1], the aim was to find out how the IRL framework was understood and realized in Fifth Element’s industrial system project not to try solving the challenges and problems facing the IRL framework. This study was made as case study research and it focused in the current understanding, situation and the existed IRL framework. The interviews were held using the Lime Survey. Because of the different positions of the interviewees, the framework approach

from the different perspectives and there could not be any relevant difference if there were more interviewees. The research area was very interesting. A future research could provide necessary information on it and on how the forms should be used. The future research could be made as action research and in that research could be observed how this framework could fit in to Fifth Element's processes in practice and what the benefits to the company would be using the framework.

It can be concluded that there is a need to conduct further research where the proposed forms of questionnaires could be piloted and taken in use in Fifth Element. I also recommend that the improvements to the presented forms could be useful. To conclude, this study has increased researcher's knowledge on the complex of integrations in the context of industrial system project. Future research will hopefully be able to validate and refine the propositions of this study in the case company.

4.6 Collaborative Learning

There was a need to increase understanding of systematic and analytic thinking to face the skills needed related to this study. This also provided a start for continuing professional development for the researcher. Pirinen (2014) states that in learning by R&D use of new information requires that it should be assimilated into a sufficiently broad context , so that information is not just repeated but also understood, revised, and given value, which in the end can be understood as learning by future and direct value returns. In this study R&D technique was used and more details about the research and review processes were learned. Additionally the teamwork skills and patience improved during the studies. The researcher agrees that the development of collaborative learning is highly important part of this study. She states that collaborative learning is important also to assists students to share experiences and to support each other.

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Figures

Tables

Appendix

Appendix 1: Lime Survey Questionnaire

Testing - Integration Readiness Level
Responses collected from this survey will be used to address integration activities in a System Maturity Scale to evaluate a System.

This Integration Readiness Level (IRL) questionnaire will be filled in for each pair of interacting technologies integrated in a System or in a System of Systems. Subject matter experts or technicians of both technologies (hw/sw systems) should introduce agreed answers.

Some fields for collecting general information about technologies and industries involved will be presented. Then IRL questions (decision criteria) will be presented by nine levels, just check all that apply for each level. Your participation will be highly valuable There are 22 questions in this survey General information Basic data about a pair of interacting technologies integrated in a specific System or System of Systems (SoS).

1 [GI0]Name of the System or SoS

Please write your answer here:

2 [GI1]First interacting technology

Please write your answer(s) here:

Hardware/software system name	
Company or industry responsible	
Subject matter expert (e-mail)	

3 [GI2]Second interacting technology

Please write your answer(s) here:

Hardware/software system name	
Company or industry responsible	
Subject matter expert (e-mail)	

4 [GI3]Comments and remarks

Please write your answer here:

Level 1

An Interface between technologies has been identified with sufficient detail to allow characterization of the relationship. This is the lowest level of integration readiness and describes the selection of a medium for integration.

6 [L1t]Comments and remarks

Please write your answer here:

5 [L1]Decision criteria

Please choose all that apply:

- ☐ Principal integration technologies have been identified
- ☐ Top-level functional architecture and interface points have been defined
- ☐ Availability of principal integration technologies is known and documented
- ☐ Integration concept/plan has been defined/drafted
- ☐ Integration test concept/plan has been defined/drafted
- ☐ High-level Concept of Operations and principal use cases have been defined/drafted
- ☐ Integration sequence approach/schedule has been defined/drafted
- ☐ Interface control plan has been defined/drafted
- ☐ Principal integration and test resource requirements (facilities, hardware, software,surrogates, etc.) have been defined/identified
- ☐ Integration & Test Team roles and responsibilities have been defined

Level 2

There is some level of specificity to characterize the Interaction (i.e. ability to influence) between technologies through their interface. Once a medium has been defined, a “signaling” method must be selected such that two integrating technologies are able to influence each other over that medium. IRL 2 represents integration proof-of-concept.

8 [L2t]Comments and remarks

Please write your answer here:

7 [L2]Decision criteria

Please choose all that apply:

- ☐ Principal integration technologies function as stand-alone units
- ☐ Inputs/outputs for principal integration technologies are known, characterized and documented
- ☐ Principal interface requirements for integration technologies have been defined/drafted
- ☐ Principal interface requirements specifications for integration technologies have been defined/drafted
- ☐ Principal interface risks for integration technologies have been defined/drafted
- ☐ Integration concept/plan has been updated
- ☐ Integration test concept/plan has been updated
- ☐ High-level Concept of Operations and principal use cases have been updated
- ☐ Integration sequence approach/schedule has been updated
- ☐ Interface control plan has been updated
- ☐ Integration and test resource requirements (facilities, hardware, software, surrogates, etc.) have been updated
- ☐ Long lead planning/coordination of integration and test resources have been initiated
- ☐ Integration & Test Team roles and responsibilities have been updated
- ☐ Formal integration studies have been initiated

Level 3

There is Compatibility (i.e. common language) between technologies to orderly and efficiently integrate and interact. IRL 3 represents the minimum required level to provide successful integration. This means that the two technologies are able to not only influence each other, but also communicate interpretable data. IRL 3 represents the first tangible step in the maturity process.

9 [L3]Decision criteria

Please choose all that apply:

- ☐ Preliminary Modeling & Simulation and/or analytical studies have been conducted to identify risks & assess compatibility of integration technologies
- ☐ Compatibility risks and associated mitigation strategies for integration technologies have been defined (initial draft)
- ☐ Integration test requirements have been defined (initial draft)
- ☐ High-level system interface diagrams have been completed
- ☐ Interface requirements are defined at the concept level
- ☐ Inventory of external interfaces is completed
- ☐ Data engineering units are identified and documented
- ☐ Integration concept and other planning documents have been modified/updated based on preliminary analyses

10 [L3t]Comments and remarks

Please write your answer here:

Level 4

There is sufficient detail in the Quality and Assurance of the integration between technologies. Many technology integration failures never progress past IRL 3, due to the assumption that if two technologies can exchange information successfully, then they are fully integrated. IRL 4 goes beyond simple data exchange and requires that the data sent is the data received and there exists a mechanism for checking it.

12 [L4t]Comments and remarks

Please write your answer here:

11 [L4]Decision criteria

Please choose all that apply:

- ☐ Quality Assurance plan has been completed and implemented
- ☐ Cross technology risks have been fully identified/characterized
- ☐ Modeling & Simulation has been used to simulate some interfaces between components
- ☐ Formal system architecture development is beginning to mature
- ☐ Overall system requirements for end users' application are known/baselined
- ☐ Systems Integration Laboratory/Software test-bed tests using available integration technologies have been completed with favorable outcomes
- ☐ Low fidelity technology "system" integration and engineering has been completed and tested in a lab environment
- ☐ Concept of Operations, use cases and Integration requirements are completely defined
- ☐ Analysis of internal interface requirements is completed
- ☐ Data transport method(s) and specifications have been defined
- ☐ A rigorous requirements inspection process has been implemented

Level 5

There is sufficient Control between technologies necessary to establish, manage, and terminate the integration. IRL

14 [L5t]Comments and remarks

Please write your answer here:

5 denotes the ability of one or more of the integrating technologies to control the integration itself; this includes establishing, maintaining, and terminating.

13 [L5]Decision criteria

Please choose all that apply:

- ☐ An Interface Control Plan has been implemented (i.e., Interface Control Document created, Interface Control Working Group formed, etc.)
- ☐ Integration risk assessments are ongoing
- ☐ Integration risk mitigation strategies are being implemented & risks retired
- ☐ System interface requirements specification has been drafted
- ☐ External interfaces are well defined (e.g., source, data formats, structure, content, method of support, etc.)
- ☐ Functionality of integrated configuration items (modules/functions/assemblies) has been successfully demonstrated in a laboratory/synthetic environment
- ☐ The Systems Engineering Management Plan addresses integration and the associated interfaces
- ☐ Integration test metrics for end-to-end testing have been defined
- ☐ Integration technology data has been successfully modeled and simulation

Level 6

The integrating technologies can Accept, Translate, and Structure Information for its intended application. IRL 6 is the highest technical level to be achieved, it includes the ability to not only control integration, but specify what information to exchange, unit labels to specify what the information is, and the ability to translate from a foreign data structure to a local one.

15 [L6]Decision criteria

Please choose all that apply:

- ☐ Cross technology issue measurement and performance characteristic validations completed
- ☐ Software components (operating system, middleware, applications) loaded onto subassemblies
- ☐ Individual modules tested to verify that the module components (functions) work together
- ☐ Interface control process and document have stabilized
- ☐ Integrated system demonstrations have been successfully completed
- ☐ Logistics systems are in place to support Integration
- ☐ Test environment readiness assessment completed successfully
- ☐ Data transmission tests completed successfully

16 [L6t]Comments and remarks

Please write your answer here:

Level 7

The integration of technologies has been Verified and Validated and acquisition/insertion decision can be made. IRL 7 represents a significant step beyond IRL 6; the integration has to work from a technical perspective, but also from a requirements perspective. IRL 7 represents the integration meeting requirements such as performance, throughput, and reliability.

17 [L7]Decision criteria

Please choose all that apply:

- ☐ End-to-end Functionality of Systems Integration has been successfully demonstrated
- ☐ Each system/software interface tested individually under stressed and anomalous conditions
- ☐ Fully integrated prototype demonstrated in actual or simulated operational environment
- ☐ Information control data content verified in system
- ☐ Interface, Data, and Functional Verification
- ☐ Corrective actions planned and implemented

18 [L7t]Comments and remarks

Please write your answer here:

Level 8

Actual integration completed and Mission Qualified through test and demonstration, in the system environment. IRL 8 represents not only the integration meeting requirements, but also a system-level demonstration in the relevant environment. This will reveal any unknown bugs/defect that could not be discovered until the interaction of the two integrating technologies was observed in the system environment.

19 [L8]Decision criteria

Please choose all that apply:

- ☐ All integrated systems able to meet overall system requirements in an operational environment
- ☐ System interfaces qualified and functioning correctly in an operational environment
- ☐ Integration testing closed out with test results, anomalies, deficiencies, and corrective actions documented
- ☐ Components are form, fit, and function compatible with operational system
- ☐ System is form, fit, and function design for intended application and operational environment
- ☐ Interface control process has been completed/closed-out
- ☐ Final architecture diagrams have been submitted
- ☐ Effectiveness of corrective actions taken to close-out principal design requirments has been demonstrated
- ☐ Data transmission errors are known, characterized and recorded
- ☐ Data links are being effectively managed and process improvements have been initiated

20 [L8t]Comments and remarks

Please write your answer here:

Level 9

Integration is Mission Proven through successful mission operations. IRL 9 represents the integrated technologies being used in the system environment successfully. In order for a technology to move to TRL 9 it must first be integrated into the system, and then proven in the relevant environment, so attempting to move to IRL 9 also implies maturing the component technology to TRL 9.

21 [L9]Decision criteria

Please choose all that apply:

☐ Fully integrated system has demonstrated operational effectiveness and suitability in its intended or a representative operational environment

☐ Interface failures/failure rates have been fully characterized and are consistent with user requirements

☐ Lifecycle costs are consistent with user requirements and lifecycle cost improvement initiatives have been initiated

22 [L9t]Comments and remarks

Please write your answer here:

Appendix 2: List of Interviewees

The following table presents the list of interviewees in alphabetical order. The citations abbreviation in the text (e.g. T.M, U.W etc.).

Name	Position	Abbreviation in the text
Anonymized	Lead developer, leader of the Fifth Element's ICC* board	H.H
Anonymized	CTO	T.M
Anonymized	Developer	J.V
Anonymized	Developer	U.V
Anonymized	Data base architect	U.W

*Fifth Element's Integration Competence Center