Implementation and Certification of ISO/IEC 29110 in an IT Startup in Peru

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This article presents the implementation of ISO/IEC 29110 in a four-person IT startup company in Peru. After completing the implementation of the ISO/IEC 29110 project management and software implementation processes using an agile approach, the next step was to execute these processes in a project with an actual customer: software that facilitates communication between clients and legal consultants at the second-largest insurance companies in Peru. Managing the project and developing the software took about 900 hours. Using ISO/IEC 29110 software engineering practices enabled the startup to plan and execute the project while expending only 18 percent of the total project effort on rework (i.e., wasted effort). In this article, the authors also describe the steps and the effort required by the VSE to be granted an ISO/IEC 29110 certificate of conformity. The startup became the first Peruvian VSE to obtain an ISO/IEC 29110 certification. The ISO/IEC 29110 certification facilitated access to new clients and larger projects.

Key words

agile methods, certification, implementation, ISO, ISO/IEC 29110, process, rework, software, standard, startup, very small entity (VSE)

EDITOR'S NOTE: An earlier article co-authored by Professor Laporte ("Development of a Social Network Website Using the new ISO/IEC 29110 Standard Developed Specifically for Very Small Entities") appeared in the September 2014 issue (Laporte, Hébert, and Miniau 2014) and provided an overview of the ISO/IEC 29110 standard. Readers are encouraged to refer to that material as context for this article.

INTRODUCTION

In Peru, software development companies have shown significant economic activity. Over the past few years, they have had a growth rate of 15 percent per year (2003 to 2011), with sales figures for the same period that increased from $85 million to $239 million. Of all the companies that are part of this industry, 63 percent are micro-enterprises and 27 percent are small businesses (PromPeru 2011; PromPeru 2013).

This information is consistent with the results obtained in a study sponsored by the World Bank in 2010 (Kushnir, Mirmulstein, and Ramalho 2010) on micro, small, and medium enterprises (MSMEs) worldwide. After analyzing 132 economies, the study concluded that there are more than 125 million MSMEs, 13,763,465 of which are located in Latin America and the Caribbean. In 46 of the 132 economies analyzed, MSMEs are considered to be companies with up to 250 employees. While it is not possible to have a classification standard for all countries, where feasible, MSMEs are classified as follows: micro-enterprises: one to nine employees; small enterprises: 10 to 49 employees; and medium enterprises: 50 to 249 employees.

For the Peruvian context, the classification of MSMEs, illustrated in Figure 1, is based on the number of employees and the level of annual sales by company.

Peru has 1,340,703 MSMEs, which represents 99.4 percent of all enterprises in the country. Of the total number of MSMEs, 1,270,009 (94.2 percent) are micro-enterprises and 68,243 (5.1 percent) are small businesses. Figure 2 shows the classification of MSMEs in Peru based on the number of employees.

More than 98 percent of Peruvian MSMEs have fewer than 10 workers, and 7,595,000 people work in companies with up to 10 workers. Over 37.6 percent of all MSMEs in Peru are concentrated in the service sector, with about 14,000 companies associated with the information technology and communications (ITC) industry (Produce 2012).

As one can see, micro- and small businesses are the foundation of the economy in Peru. However, within this sector the vast majority of companies lack the standards and proven practices that could help them increase their competitiveness. A study by ISO Working Group 24 on the use of standards in small software development organizations found that more than 67 percent of companies consider it important to be recognized or certified; however, a large number of companies surveyed also indicated that standards must be practical, easy to understand, and have templates and examples that can be implemented quickly and at low cost (Laporte, Alexandre, and Renault 2008). A similar study in Dublin on recently formed (within 24 months) startups and small software organizations found that there is a widespread perception that the processes described in software standards are too complicated, have no guides for easy implementation, are not easy to integrate, and require additional resources not usually available in business (Laporte et al. 2014).

To meet these challenges, a set of standards and guidelines has been developed to meet the needs of the very small entities (VSEs) involved in software development. The ISO/IEC 29110 international standard was created to help raise the capabilities and competitiveness of these organizations through improvement of the process and, consequently, the products and/or services provided. The implementation of the ISO standard in software development VSEs represents a new world of opportunities, especially in emerging economies. It could be a "passport" to doing business in international markets.

The purpose of this article is to present the implementation of the ISO/IEC 29110 standard at a four-person software development VSE in Peru. The project was led by the Universidad Peruana de Ciencias Aplicadas (Peruvian University of Applied Sciences) (UPC). Three projects by graduate students at UPC contributed to the successful implementation of the standard. The VSE used agile methods and practices for its projects (e.g., Scrum, test-driven development, continuous integration). The ISO standard was adapted to the use of these agile practices. The results of this adaptation (i.e., processes, work products, and support tools) were applied to a real project for one of the customers of the VSE: the second-largest insurance company in Peru. Not only were the skills of the VSE improved, but the VSE only had wasted effort (i.e., rework) of 18 percent of the budgeted tasks (equivalent to the rework percentage of organizations with a high level of maturity in the implementation of software projects). This project is also an excellent

FIGURE 1 Classification of companies in Peru (adapted from Produce 2012)

Company type	Number of employees	Annual sales
Micro Enterprise	1-9	Up to a maximum of 150 UIT[1]
Small Enterprise	10-49	More than 150 UIT to 1,700 UIT
Medium Enterprise	50-249	More than 1,700 UIT to 2,300 UIT

[1]A UIT (tax unit) equals approximately USD$1,310 in 2014

FIGURE 2 Classification of MSMEs in Peru based on the number of employees (adapted from Produce 2012)

Number of employees	Number of firms	Percentage
Up to 5	1,296,195	96.7
From 6 to 10	24,249	1.8
From 11 to 20	12,260	0.9
From 21 to 50	5,600	0.4
From 51 to 250	2,399	0.1

example of a successful outcome of collaboration between a university and a business in Peru.

In the following sections, the authors describe the approach used to implement project management and software processes that meet the requirements defined in ISO/IEC 29110. The authors also explain the certification process that culminated in obtaining an international certification issued by a Brazilian auditor. Finally, the lessons learned, a list of recommendations for the use of the ISO/IEC 29110 standard implementation, and future work are presented.

IMPLEMENTATION OF THE ISO/IEC 29110 STANDARD

In this section, the authors describe the contributions of one graduate student project and two undergraduate student projects from the School of Systems Engineering and Computer Systems of the UPC to the implementation of the standard in a Peruvian VSE. Various activities were conducted to familiarize students with the standard. Tools were developed or updated to facilitate implementation at the Peruvian VSE.

Translation and Optimization of ISO/IEC 29110 Deployment Packages

The first challenge was the translation of the set of deployment packages (DP) developed to support the Basic profile into Spanish. A DP is a set of artifacts developed to facilitate the implementation of a group of engineering practices in a VSE. Therefore, through the deployment and implementation of a DP, a VSE learns the concrete steps needed to implement the standard and demonstrate compliance with the ISO/IEC 29110 standard (Laporte et al. 2013). DPs, translated into Spanish, can be downloaded freely. Figure 3 shows the set of translated DPs.

The architecture and detailed design DP supports the analysis, design, and documentation of software architecture in a VSE. The requirements analysis DP was updated with a tool to specify measurable nonfunctional requirements (quality attributes) of a software product.

The processes, templates, and examples defined in each DP served as initial reference for the definition of the processes and work products of the VSE selected to implement the standard.

Creating Tools and Work Product Templates for ISO/IEC 29110

A second challenge was the creation of templates for each work product. A work product is an artifact associated with the execution of a process. There are 22 work products defined in the management and engineering guide of the ISO/IEC 29110 Basic profile (ISO 2011a). The guide describes which activities contribute process objectives, and ISO/IEC 29110 part 4 (ISO 2011b) identifies which work products are associated with each activity. The ISO/IEC 29110 Basic profile is composed of two processes: a project management (PM) process and a software implementation (SI) process. Each process consists of a set of objectives, activities, and tasks, as well as the documents, also called work products, that are produced during a project. The PM process is composed of the following four activities: planning, execution, evaluation, and closing. The SI process is composed of the following six activities: initiation, analysis, design, construction, integration and testing, and delivery. Figure 4 shows an example of these relationships for two activities of the SI process.

For each work product, the authors identified relationships to provide evidence as to how the work product contributes to the achievement of the objectives with which it is associated. One example of the analysis of a work product, a traceability record, is shown in Figure 5.

The results of the analysis were used to generate a preliminary version of work product templates and contents. They also helped identify improvement opportunities in Section 9 of the guide (that is, ISO/IEC 29110 Part 5).

There are work products that are not documents (e.g., the Project Repository). Templates were developed

FIGURE 3 Deployment packages translated into Spanish by students from Peru (Laporte et al. 2014)

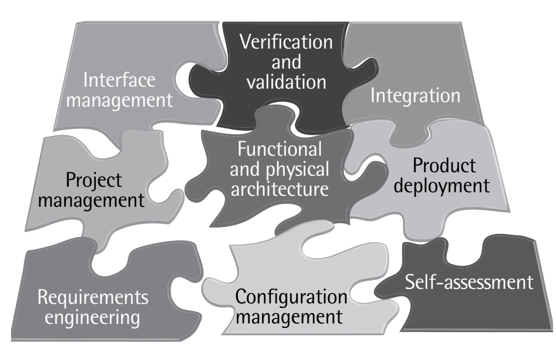


FIGURE 4 Example of relationship between the activities, objectives, and work

Process	Activity	Process objectives related to the activity	Input work product	Output work product	
SI process	SI.2 software requirements analysis	SI.02 SI.06 SI.07	Project plan	Change request Requirements specification Software configuration	Validation results Verification results
	SI.3 software architectural and detailed design	SI.03 SI.06 SI.07	Requirement specification	Change request Software design Test cases and test procedures	Traceability record Verification results Software configuration

FIGURE 5 Example of analysis of a work product and its associated objectives

Work product	Related objective	Objective description highlighting relevant information	Analysis
Traceability record	SI.03	Software architectural and detailed design is developed and baselined. It describes the software components and internal and external interfaces of them. **Consistency and traceability to software requirements are established.**	There must be traceability between software requirements and software design and architecture.
	SI.05	Software is produced performing integration of software components and verified using test cases and test procedures. Results are recorded in the test report. Defects are corrected **and consistency and traceability to software design are established.**	There must be traceability between test cases, test procedures, software components and software design.

for work products that can be represented by a document. Each template was generated by reviewing the existing templates and examples of ISO/IEC 29110 DPs. In some cases, the original version of the DP template was reused; in other cases, it was necessary to make an adjustment or create the template from scratch when there were none in the DP. Figure 6 shows some of the work products and reference documents that were used to develop the final templates.

FIGURE 6 Examples of reference documents used to develop work product templates

Work product	Template reference document	Final template
Project plan	Template of project management DP	The reference document was modified
Requirement specification	Template of requirement specification DP	The reference document was modified
Traceability record	"Software Traceability: A Roadmap" (Spanoudakis and Zisman, 2004)	The reference document was modified
Software design	"Adventure Builder – Software Architecture Document" (SEI 2013)	The reference document was modified

Finally, checklists were developed to assess fulfillment of the objectives and each of the PM and SI process activities. With the checklists, it was easier to verify whether the tasks performed by an organization contribute to the achievement of the activities and the objectives with which they were associated.

A VSE is able to use various development methods, have different roles, and carry out different tasks to implement the activities for PM and SI processes, and can still meet the requirements of ISO/IEC 29110. For this case study, the VSE used agile methods for the implementation of the software project for the insurance company.

Selection of Support Tools for PM and SI Processes

It is an increasingly widespread, common practice for VSEs to use software tools for their projects. For this reason, the authors decided to conduct an analysis of the various software tools that could provide support for ISO/IEC 29110 PM and SI processes. Generic and specific criteria have been developed to assist in the evaluation of the tools identified.

General evaluation criteria were developed to evaluate the tools identified, such as: type of application (proprietary, open source, or free), compatibility with

FIGURE 7 Example of evaluation criteria and weights of support tools for the PM and SI processes of ISO/IEC 29110

Software support tool (SST) evaluation criteria	Weight
Will the company continue to invest and improve their products?	2.5
Does the tool have awards or recognitions from other companies or customers of special VSEs?	2
Is the tool compatible with other free or open source products?	2.5
Can the tool be installed with full functionality on all major platforms including Windows, Linux, and Mac OS X?	2
Can the tool be used in the cloud and provide services on demand?	2.5
Is the price of this product in line with the use of the product and are there special payment plans for VSEs?	2

Key

Weight:
3 Very high importance
2.5 High importance
2 Medium importance
1.5 Low importance
1 Very low importance

Score:
1 Fully satisfies
0.75 Substantially satisfies
0.5 Partly satisfies
0 Does not satisfy

FIGURE 8
Scores obtained in the evaluation of companies providing support tools for ISO/IEC 29110 PM and SI processes

Assessed company	Final score
Company A	38 points
Company B	46 points
Company C	36 points

different platforms (Web, desktop, mobile, cloud), compatibility with other tools, compatibility with various operating systems, cost and terms of payment, and market positioning and recognition.

Specific evaluation criteria were also developed, such as: the ability of the tool to version documents, generate reports, monitor errors, manage resources and access, manage project tasks and milestones, track project progress, interact with different development tools, allow continuous integration, and support different development methods.

The evaluation criteria were weighted based on the needs and characteristics of the target audience: software development VSEs. An example of six evaluation criteria and their weights is shown in Figure 7.

To calculate the final score for each criterion, the weight criterion is multiplied by the score obtained for the criterion. The possible values of scores are also shown in Figure 7.

After applying the set of general criteria to 13 leading providers of support tools for PM and SI processes, only three organizations with global presence in the market were identified. Next, the specific evaluation criteria were applied to each of these three organizations. The results obtained are shown in Figure 8. Out of a total of 60 points, the organization selected scored 46.

After identifying the organization with the highest score, a specific tool provider for PM and SI processes was identified. A Canadian company with specific support products for the implementation of ISO/IEC 29110 was selected. After making the necessary arrangements to obtain a formal authorization to use the software tool for academic purposes, the authors developed installation guides, user manuals, and demos that would later serve for the initial implementation of the standard at the selected VSE.

Implementation of the ISO/IEC 29110 Basic Profile in a Peruvian VSE

The VSE, selected to implement ISO/IEC 29110, was created in 2012 by two alumni of the UPC Software Engineering program. The company consists of four people, among whom are the owners who act as the chief executive officer (CEO) and chief technology officer (CTO). The company specializes in providing software development services and automation of business processes with information system solutions.

During its two years of existence, the VSE has been involved in more than 80 projects, most of which have lasted less than two months. The VSE used agile practices to implement software solutions such as Web 2.0 responsive design systems, mobile applications (using the iOS platform, Android, Windows Phone, or Multiplatform), cloud applications (cloud computing) systems using emerging technologies, and platforms such as Microsoft Kinect, Leap Motion, and Oculus Rift. They also carried out design projects and developed hardware solutions that integrate electronics and software.

Implementation of the Basic profile started in 2013 with an initial coordination meeting, at which the commitment of management, the technical VSE team, and participating students were obtained. After analyzing the mandatory requirements defined by the standard, the authors performed a gap analysis of the VSE software development process versus the requirements of the standard. The requirements defined for the implementation of the Basic profile of the ISO/IEC 29110 are (adapted from ISO 2011b):

- Meet the entry conditions established in ISO/IEC 29110-4-1 (i.e., profile specifications)
- Comply with the processes established by ISO/IEC 29110-4-1: Project-Management Process and Software Implementation Process
- Comply with the process activities established by ISO/IEC 29110-4-1
- Comply with the objectives of the processes set out in ISO/IEC 29110-4-1
- Comply with the products listed in ISO/IEC 29110-4-1

Using checklists developed previously, an initial analysis was performed to verify that the VSE met the entry conditions for the Basic profile. For each condition analyzed, the respective input evidence was identified. An example of the evaluation of two input conditions for the Basic profile is shown in Figure 9.

As a result of the preliminary analysis, it was determined that the VSE met the entry conditions of the Basic profile. However, after evaluating the activities, objectives, and work products of the standard, improvement opportunities were identified for each of these aspects.

A student project team was responsible for capturing and documenting how the VSE performs the activities of the software life cycle. The goal was to take, as a starting point, the current PM and SI processes of the VSE in order to identify the practices already used.

Meetings were held at which checklists were used—one checklist per process activity—to verify that the tasks of each activity, carried out by the VSE, contribute to the achievement of the objectives of its associated process. Meetings and interviews were supplemented by visits to the development team at their workplace. Together with representatives of the VSE, the authors consolidated and analyzed the information collected in order to define, if necessary, an updated version of the tasks that would ensure compliance with the requirements of the standard.

Similarly, the work products produced by the VSE were analyzed. Based on templates developed by the students, the work product templates for the PM and SI processes were defined. These templates were adapted to support the work system of the VSE: agile software development. In several cases, document templates were adapted to be partially or fully supported by a software tool.

Tools to support new tasks and workflows that were not part of the way of working at the VSE prior to the implementation of the standard were also implemented. These tools were integrated with other existing tools of the organization. Figure 10 shows the main tools used by the VSE following implementation of ISO/IEC 29110.

Although it would be desirable to document the PM and SI processes either on paper or electronically, it is not a requirement of ISO/IEC 29110; however, as part of this implementation process, new PM and SI processes were documented using a business process modeling language (BPML). Processes were also detailed by documenting

FIGURE 9 Examples of entry conditions and results obtained in the evaluation of the VSE

Assessment question entry condition	Response obtained
Is there a project contract with statement of work?	The VSE has two ways to establish a contract: 1. The client contacts the VSE. If it is a valid opportunity, a draft version of the contract is created. The contract is updated with the agreements reached as a result of negotiations between the VSE and the client. This contract becomes the statement of work (SoW). 2. The VSE is submitted to a tender of the Organismo Supervisor de las Contrataciones del Estado Peruano (Supervisory Board of Peruvian Government Procurement [OSCE]). The SoW is the Terms of Reference (ToR) document, in which the scope, duration, and requirements of the project are determined.
Are the feasibility of cost, schedule, and technical aspects evaluated before the project starts?	When the customer contacts the VSE, the terms for the schedule, budget, and technologies used in the project are agreed during negotiations. In case of open call for tenders by the OSCE, the ToR document contains the costs and technical requirements needed for the project. It also established the set duration of the project and major milestones of project deliverables.

each of their activities, roles, and input-output artifacts. Indicators and metrics, such as the number of change requests (especially those that have an impact on the cost to the client) and the percentage of errors by the developer after testing software components, were also defined for both processes, in coordination with the VSE, so that it was possible to assess their execution and facilitate the continuous improvement of the processes of the organization. Finally, a traceability matrix was also created between each ISO/IEC 29110 work product and the documents and/or equivalent tools used by the VSE. At this stage, the VSE was ready to carry out the processes implemented in a real software development project for the first time.

Implementation of PM and SI Processes in a Real Software Development Project

After completing the implementation of the processes, the next step was to select a real software development project in which to execute all of the activities involved in the software development cycle.

The project selected was the Legal Consultation System (SCOLE). SCOLE is a software solution that facilitates communication between clients and legal consultants at one of the largest insurance companies in Peru. The solution had to be implemented on a Web platform and deployed into a cloud environment. Some examples of SCOLE's technical constraints are shown in Figure 11.

Initial negotiations were conducted with the customer via emails and meetings. The agreements were recorded in the minutes of meetings, and the information generated would become input for the statement of work (SOW) and project contract signed in 2014. At the end of the negotiations, the VSE representative recorded the statement of work in its support tool.

The technical leader and project leader of the VSE then defined the project plan based on this statement of work. Since the VSE was using agile methods to implement its software projects, customer requirements were expressed as user stories. The set of user stories are a typical artifact of the SCRUM agile method: the product backlog. This artifact was part of the project plan to be approved by the customer.

A representative of the VSE reviewed the project plan before it was sent to the customer for approval. The results from any revisions were recorded in the VSE intranet. At this stage, the technical manager had already defined and created the structure of the development environment that would be used by team members assigned to the project. User stories were also recorded in the tool using the product backlog of the project as a reference.

FIGURE 10 Software support tools used by the VSE at the end of the implementation of ISO/IEC 29110 Basic profile

Software support tool (SST) for PM and SI processes	SST description
SST 01	Tool for managing tasks and resources within the projects of the organization.
SST 02	Tool for managing documents associated with the organization and project. This tool integrates with SST 01 to support the project documentation tasks.
SST 03	Plugin to the SST 02 for creating a workspace project that provides a structure to work with templates of the main work products and their contents defined in Part 5 of the standard.
SST 04	Collaborative work tool for control repositories, automated test execution, creating deployable artifacts and reporting status.
SST 05	Software development tool for creating desktop applications, web applications and mobile applications. It integrates with the SST 04 to facilitate collaboration among members of a project team.
SST 06	Tool for storing information in the cloud platform. It also allows the storage of databases and create backups of the databases in the cloud.

FIGURE 11 Examples of technical constraints of the SCOLE project

Constraints	Description
Software development tool	Visual Studio 2012
Database engine	Microsoft SQL Azure
Server infrastructure	Microsoft Azure
Framework	MVC4
Visual design	HTML5, CSS3

The technical restrictions referenced in Figure 11 and other requirements, especially nonfunctional requirements, constituted the necessary input to develop the architectural design of the software.

The definition of the tasks associated with each user story in the product backlog was carried out by the project team at the beginning of each iteration (i.e., a sprint). The technical leader was responsible for the architectural design and documentation.

Once the materials and equipment needed for the execution of the project were available, such as sticky notes, markers, and an acrylic board (to draw the burn down chart or the task progress of the project, both of which are agile practices) and the physical locations and computers were assigned to each of the employees, the project sprints started. The VSE had determined that the duration of a sprint would be one week. The project had six sprints.

Each sprint was executed using the new PM and SI processes. At the start of each sprint, a planning meeting was held between the client and the project team to determine the user stories to be implemented. Tasks to implement the selected user stories were also defined and recorded in the VSE support tool. Each team member knew the tasks he or she was responsible for executing and implemented the required software components, taking into account the architectural design of the system. Unit test cases for components and functional user story test cases were created. There was a test environment in which the test cases were executed. The results of all tests were recorded automatically. All software components, test cases, test procedures, and user stories were linked through a traceability matrix. A subset of the traceability matrix for one user story is shown in Figure 12. The table illustrates the links, starting with one user story, to the tasks related to the user story, to the person responsible for the tasks, to the software component, to the test cases, and finally to the test results.

At the end of every sprint, a review meeting was held with the client, during which he or she could make comments or request changes. An interactive guide, which was the user manual along with the operation and maintenance manuals, was reviewed internally and then formally submitted to the client at the end of the project. The SCOLE project ended successfully with the delivery of the software product and other artifacts defined in the project contract. The VSE also received the record of acceptance and a customer satisfaction survey that the VSE usually sends to their clients. This is a tool for feedback and marketing; the customer can rate the service received on a scale of 1 to 5 and provide feedback to the VSE through a suggestions/comments field.

The cost of quality approach was used to categorize the effort spent on the project (Krasner 1998). The prevention, execution, review, and correction efforts, measured in hours, required by the project team to implement the software solution are shown in Figure 13 (Laporte and O'Connor 2014).

FIGURE 12 Subset of the traceability matrix for one user story

User story SDCLR-009	Task related	Responsible
SDCLR-009: As a consultant, I need to manage my standard replies to streamline the process for responding to clients using a predefined template.	T01 – Review and analysis of database	Employee 1
	T02 – Design prototyping	Employee 1
	T03 – Creating software components	Employee 1
	T04 – Unit and functional tests	Employee 2
Support tool: Jira Agile	Support tool: Jira Agile	

Software components – SDCLR-009	Physical location
Visual components	Folder Views/Questions: Respuesta.cshtml and Respuestas.cshtml files
Logic components	Folder ViewModel/Questions: RespuestaViewModel.cs and RespuestasViewModel.cs files
Controller components	Folder Controllers: QuestionController.cs file
Persistence components	Folder model: Respuesta.cs file
Support tool: Visual Studio 2012/Microsoft team foundation	

SDCLR-009 test cases	Test results
SDLR-0009-CP-01: List template answers	Success (SDLR-0009-CP Log)
SDLR-0009-CP-03: Add template responses with empty file	Success (SDLR-0009-CP Log)
. . .	. . .
Support tool: Test Link	

FIGURE 13 Effort to prevent, execute, detect, and correct errors by a team of four people

Task	Prevention (hours)	Execution (hours)	Review (hours)	Correction of defects (hours)
Environmental installation (Windows Azure, management tools, development environment, and project repository)	**14**			
Project plan development		**15**	**3**	**7**
Project plan execution and project assessment and control		**108**		
Project plan execution: sprint planning and execution		90		
Project assessment and control: sprint review, sprint retrospective		18		
Specification development		**107**	**28**	**58**
Statement of work		12	3	7
Specifying user stories and product backlog		95	25	51
Architecture development		**35**	**10**	**14**
Test plan development		**45**	**8**	**11**
Code development and code testing		**253**	**70**	**62**
User guide and maintenance document development		**14**	**5**	**7**
Software product deployment		**6**		
Project closure		**2**		
Total (hours)	**14**	**585**	**124**	**159**

The team effort to implement the project was 882 hours. The effort devoted to prevention activities such as installation of the environment (servers, tools, and so on) was 14 hours and task execution took 585 hours.

The rework percentage was 18 percent (i.e., 159 hours/882 hours). It should be noted that it was the first time the VSE had executed the new processes in a real software development project, so there was a learning curve that resulted in additional hours spent on rework for different project tasks. Despite this situation, the result was close to the performance of an organization that has implemented the Capability Maturity Model (CMM®) and is at maturity level 3.

The implementation of the PM and SI processes directly impacted the rework percentage of the VSE. Many PM and SI tasks were optimized. These tasks not only contributed to the fulfillment of the ISO/IEC 29110 objectives, but they allowed the VSE to optimize its agile development process. As an example, the interactions between the customer (i.e., the product owner-agile role) and the development team allowed for better specification of some user stories. Customer feedback is very important to the development team, since added value is delivered on a weekly basis (i.e., the duration of a sprint). The feedback received from the customer is captured as lessons learned are implemented.

The results of this project demonstrate that a VSE, using ISO/IEC 29110, can quickly reach a high level of quality in its software development projects, similar to organizations with a high level of maturity.

One of the constraints of this project was that team members were not able to work full time. This explains why the project lasted about 10 months. Despite this constraint, the implementation time was quite short compared to the time required for the implementation of other equivalent models. For example, implementing the practices to achieve a CMMI-DEV level 2 (SEI 2010), according to data from the Software Engineering Institute (SEI), can take about two years.

The authors are now in a position to state that ISO/IEC 29110 is a standard that meets the needs of VSEs; it is simple to implement and does not require excessive documentation or a major investment of resources and time.

ISO/IEC 29110 CERTIFICATION OF THE PERUVIAN VSE

For most businesses, but particularly for VSEs, international certifications can enhance credibility, competitiveness, and access to national and international markets (Laporte, Houde, and Marvin 2014).

A certification is carried out by specialized organizations known as certification bodies. These independent organizations are also identified as "third party" because they are independent of companies that provide implementation services and the companies that demand these services.

Accreditation bodies evaluate and certify the technical competence and independence of the certification bodies. An accreditation body is an organization that, usually by a national government, assesses certification bodies and certifies their technical competence to carry out the certification process. Each country independently organizes its rules and conformity assessment and metrology regulations. In the case of Peru, the national accreditation body is INDECOPI through its National Accreditation Service (INDECOPI-SNA). In the case of Brazil, the national accreditation body is the National Institute of Metrology, Quality, and Technology (INMETRO).

To promote the recognition of qualifications between countries, there are international organizations such as the International Accreditation Forum (IAF). The IAF is the world association of conformity assessment accreditation bodies in the fields of management systems, products, and services, and to date, it has more than 60 member countries. Both the INDECOPI-SNA and INMETRO accreditation bodies are members of this organization. This establishes a global certification infrastructure.

The ISO/IEC 29110 standard has an established certification process and Brazil has led its development. This process has been created taking into account the needs of software and systems development VSEs, so that audits should not be too expensive or time consuming. The certification scheme described in ISO/IEC 29110-3-2 (ISO 2013) is based on ISO standards for certification bodies requirements and auditor capability requirements (see Figure 14).

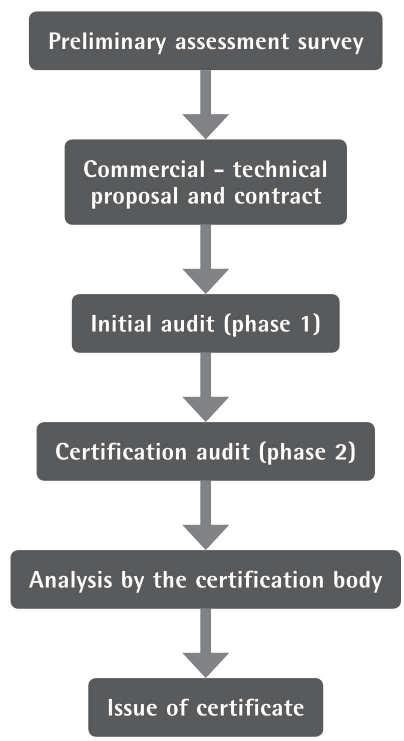
The ISO/IEC 29110 certification process is composed of four stages. In the first stage, the VSE applies for the audit process and if it is successful, a commercial and technical agreement is entered into with the accreditation body. Then the second stage begins, and if it is successful, the final result is the initial certification of the VSE for a period of three years. The third stage involves the completion of two surveillance audits one and two years after obtaining the initial certification. Finally, the fourth stage is the recertification of the VSE once the three-year certification cycle has elapsed.

After implementing the Basic profile of ISO/IEC 29110 at the Peruvian VSE, it was time to look for an organization that was part of the global infrastructure of the certification system. That organization would certify the quality of the processes implemented and ensure the international recognition of the certification. The auditing organization selected was a Brazilian organization. Once contact was established and after exchanging preliminary information, a certification contract was signed. The audit process to which the Peruvian VSE was subjected is summarized in Figure 15.

FIGURE 14 ISO standards referenced in the ISO/IEC 29110-3-2 standard certification scheme

Standard	Description
ISO/IEC 17000:2005	Conformity assessment – vocabulary and general principles
ISO/IEC 17021:2011	Conformity assessment – requirements for bodies providing audit and certification of management systems
ISO/IEC 17065:2012	Conformity assessment – requirements for bodies certifying products, processes, and services
ISO/IEC 19011:2011	Guidelines for auditing management systems

FIGURE 15 Summary of the audit process followed by the Peruvian VSE



The audit process was conducted in two phases. During phase 1, the existing documentation of the software development process life cycle of the VSE was assessed. During phase 2, the implementation and use of the PM and SI processes of the ISO/IEC 29110 Basic profile were evaluated. At the end of each phase, the certification body issued a report with any observations and nonconformities, if applicable.

The VSE received comments from the auditors regarding the recording of test results and the corrective actions taken. The VSE technical team implemented the comments; procedures were updated and disseminated within the development team.

Phase 1 and phase 2 of the audit were conducted in April 2014, and in July 2014 the auditing organization issued the conformity certificate for the project management and software implementation processes of the ISO/IEC 29110 Basic profile. The certificate is valid for three years. Surveillance audits will be performed in 2015 and 2016, and the recertification process will be initiated in 2017.

In Figure 16 the authors list the cost and the effort of the VSE for phase 1 of the audit process. The audit cost does not include the auditor's travel expenses. The VSE spent 22 hours for phase 1 of the certification process.

Figure 17 lists the cost and the effort of the VSE for phase 2 of the audit process. The cost of the auditor was $1,000. The audit cost does not include the auditor's travel expenses. The VSE spent 63 hours for phase 2 of the certification process.

The total cost of the audit (i.e., $1,500) is quite small compared to an audit for a CMMI-DEV Level 2 assessment. For example, the cost in the Brazilian market is about $25,000. As illustrated in Figure 18, it is estimated that the cost of each one of the two surveillance audits, excluding the travel costs of the auditor, will be about $1,200.

The 85 hours spent by the management and employees of the VSE for the audit (i.e., 22 hours for phase 1 and 63 hours for phase 2) is quite small compared to preparing for a CMMI-DEV Level 3 assessment. For example, in the Brazilian market, assessment preparation involves recording hundreds of pieces of evidence, a team of six people working full time for about three months, which is more than 2,000 hours of effort in total.

The Peruvian VSE became the first organization in South America (outside of Brazil) to obtain an ISO/IEC 29110 certification for its software development processes.

FIGURE 16 Cost and effort for phase 1 of the audit

Cost and effort of the pre-audit (phase 1)	Cost (USD)	Effort (hours)
Cost of the certification body (i.e., the auditor)	**$500**	
Effort of the VSE		**15**
Effort of management		5
Effort of employees		10
Miscellaneous		**7**
Phase 2 planning and auditor travel		7
Total	**$500**	**22**

FIGURE 17 Cost and effort for phase 2 of the audit

Cost and effort of the audit (phase 2)	Cost (USD)	Effort (hours)
Cost of the certification body (i.e., the auditor)	**$1,000**	
Effort of the VSE		**60**
Effort of management		20
Effort of employees		40
Miscellaneous		**3**
Coordination of transfers/food, closing lunch, etc.		3
Total	**$1,000**	**63**

FIGURE 18 Cost and effort of the surveillance audits

Cost and effort of each surveillance audit	Cost (USD)	Effort (hours)
Cost of the certification body (i.e., the auditor)	**$1,200**	
Effort of the VSE		**40**
Effort of management		10
Effort of employees		30
Miscellaneous		**5**
Auditor transportation/coordination of transfers/food, closing lunch, etc.		5
Total	**$1,200**	**45**

Currently, the VSE continues to optimize its processes as part of its continuous improvement process and will be prepared for the surveillance audits to be carried out in 2015 and 2016.

The ISO/IEC 29110 conformity certificate has become a major differentiator with regard to the main competitors of the VSE. The VSE has gained access to larger software development projects and increased its customer base. Given the growth evidenced by the organization, the VSE has also increased its number of workers to date, from four to 10 employees.

CONCLUSIONS

The authors recommend the use of ISO/IEC 29110 in VSEs that wish to improve their management engineering and software development practices. ISO/IEC 29110 is a standard that does not prescribe the use of any particular software development life cycle or method; on the contrary, it offers VSEs the ability to use a framework tailored to their needs.

The Peruvian project has shown that when using ISO/IEC 29110 it is possible to plan and implement development projects using proven software engineering practices and, at the same time, promote the creativity of developers. Agile practices already used by the company prior to the implementation of the standard were reinforced and formally established following the implementation of ISO/IEC 29110. People who think that standards are a burden or an obstacle to creativity should analyze the results obtained in the project implemented at the Peruvian VSE and reconsider their assumptions.

Using support tools (proprietary and open source) to support PM and SI processes was important in facilitating the implementation of the ISO/IEC 29110. Many work products of the standard were implemented using the tools. Similarly, deployment packages, once they were adapted to the organization's way of working, were also useful for the implementation process.

The implementation of ISO/IEC 29110 can provide levels of quality equivalent to those of other frameworks and does not require a major investment of resources and time. For example, the 18 percent project rework percentage lies within the range of an organization that has been assessed at CMM level 3. The success achieved by the VSE is an example of what can be achieved by other software VSEs in Peru, which are mostly micro-enterprises. The Peruvian VSEs could improve the quality of their products and become more competitive. ISO/IEC 29110 does not require excessive documentation or major investment of resources and time to implement.

The ISO/IEC 29110 certification gave the Peruvian VSE access to new clients and larger projects. For a country such as Peru, the implementation and certification of ISO/IEC 29110 could help change the country's productivity index. VSEs could increase software product exports and improve the quality of life of Peruvians. VSEs that are looking for investors, partners, or customers should think about implementing ISO/IEC 29110 and aiming to obtain certification.

Undergraduate and graduate students from the UPC actively participated in the implementation of ISO/IEC 29110 in a startup VSE. Not only are they now in a better position to evaluate, from a practical point of view, the ISO/IEC 29110 standards, guidelines, and deployment packages, but they have also created and improved existing tools to ease the process of implementing the standard. This project is also a demonstration of successful collaboration between a university and an IT company in Peru.

As a final point, although the Peruvian startup VSE was successful in implementing ISO/IEC 29110, some VSEs may face a few challenges. As an example, a VSE that uses a low formalism approach such as agile should carefully review the objectives of the PM and SI processes of ISO/IEC 29110 to assess the fit between the approach currently in use by the VSE versus the approach of ISO/IEC 29110. As an example, a VSE that is used to accept changes requested by a customer, without assessing their impacts, may find it difficult to meet one objective of the PM process. Also, since the published ISO/IEC 29110 management and engineering guides and deployment packages provide, for illustration purposes, process descriptions using a sequential notation, a VSE using an iterative or incremental approach may have some difficulties in mapping the PM and SI processes to fit its current software development approach. The implementation of ISO/IEC 29110 should be easier for startup VSEs that have just been created (Laporte, Hébert, and Mineau 2014). These VSEs usually have no established processes and are usually more open to an approach, such as the approach proposed by the Entry profile of ISO/IEC 29110 (ISO 2012), that will help them to properly plan and execute a project.

Additional Information

The following website provides more information, as well as articles written by members of working group WG24 and deployment packages for software and systems engineering: http://profs.etsmtl.ca/claporte/English/VSE.

ISO has published the Systems Engineering Basic Profile Guide (ISO 2014). More information about this new standard can be found in (Laporte, O'Connor, and Fanmuy 2013).

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