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# Software Process Improvement in Industry in a Graduate Software Engineering Curriculum

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*Software process improvement (SPI) is considered one of the most important fields in the software engineering discipline. But despite its importance, increasing its coverage in educational settings is still challenging. By influencing the syllabus for university-level graduate and undergraduate courses to include quality and process improvement, the future professionals, on entering the various industries, could act as ambassadors for process improvement. This article deals with one such example at the École de technologie supérieure (ÉTS), where SPI is taught in lecture format and with a 10-week implementation project in organizations by teams of students from the graduate software engineering curriculum. The SPI course is taught using a "problem-goal-solution" approach where students learn that any process improvement initiative must be based on issues preventing an organization from achieving its organizational goals whether the organization is a company or a not-for-profit organization. An important aspect of this course is the management of technological change where students learn and put into practice in their project the "soft" issues, which are part of most SPI organizational initiatives. In addition to the one-semester graduate SPI course, a few students pursue the work done during the 10-week team project as their graduate project.*

*Key words: agile, certification, guide, implementation, ISO, ISO/IEC 29110, process, software, rework, standard, start-up, very small entity (VSE)*

*EDITOR'S NOTE: An earlier article coauthored by Claude Laporte ("Development of a Social Network Website Using the New ISO/IEC 29110 Standard Developed Specially for Very Small Entities") appeared in the September 2014 issue of* SQP *(Laporte, Hébert, and Mineau 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

Software process is an integral part of the wider profession of software practice, yet at least early in their careers software practitioners are often underprepared for the profession they are about to enter (Exter 2014). The literature points out that, among other aspects, this problem lies in the way software process is typically taught at universities (Ali and Unterkalmsteiner 2014**,** as such courses have inherent constraints in an academic setting including depth and time limitations. These restrictions lead to inefficient training in the many facets of the software life cycle. But despite these recent and disappointing studies, the topic is covered in current curricular efforts in the fields of software engineering. In undergraduate degree programs, according to the *Curriculum Guidelines for Undergraduate Degree Programs in Software Engineering* (LeBlanc and Sobel 2014), software process is one of the 10 key knowledge areas of the curriculum.

Although the coverage of software process education is established in curriculum initiatives, increasing its coverage in educational settings is still challenging. The complexity of the subject, together with the need for a good background of the discipline, is pushing subjects into master's programs, while personal and team software approaches are mostly present in bachelor curricula. Further, as has been noted by Margaret Ross, the UK's most influential software quality educator and commentator, there is a lack of relevant knowledge and experience among teachers and lecturers, coupled with the pressures of other topics on academic course (O'Connor, Mitasiunas, and Ross 2015). Further, she states that most syllabuses are already very full, with constant pressure to introduce additional topics; thus, dedicated units on quality and process improvement are not usual. As a result of this need, a set of software process consultants and practitioners, along with a group of academics, detected this gap and decided to launch a manifesto for software process education, training, and professionalism (Johansen, Colomo-Palacios, and O'Connor 2016).

This article is divided into three sections. First, the authors present an overview of the software process improvement (SPI) course. Next, they briefly describe projects performed by graduate teams of students in organizations. Finally, in the last section, they present individual graduate student projects.

## SOFTWARE PROCESS IMPROVEMENT COURSE

The École de technologie supérieure (ÉTS), a 9000-student engineering school, began offering its graduate SPI course to professional students in 2000. The aim of this specific SPI course is to ensure that software engineering students are aware of the importance of SPI, and that they understand and are able to manage and apply SPI practices in real organizations. The professor who designed the SPI course has more than 20 years of industrial experience, mainly in defense and railway sectors. The course is made up of lectures, practical exercises, and a team project in industry. A continuous process of student evaluation is carried out to ensure that the concepts are well understood.

The SPI course is a three-credit course (that is, nine hours per week including three-hour lectures) over a period of 13 weeks. Each lecture topic is illustrated with industrial examples, international or professional standards, and process improvement model practices. To ensure that students grasp the importance of SPI activities, the business model concept and the cost of quality concept are stressed throughout the course. When performing SPI activities as part of their projects, students must make tradeoffs between technical issues and "soft" issues such as the management of cultural change.

There is a wide spectrum of development approaches for organizations developing software. Figure 1 illustrates the spectrum of approaches on two axes. The horizontal axis illustrates the level of ceremony, from a low ceremony approach with little documentation (for example, agile approach) to a high ceremony approach with comprehensive documentation (for example, plan-driven CMMI® approach). The vertical axis illustrates the approaches based on the level of risk. The top part of the axis illustrates a low risk linear approach using a waterfall approach, while the lower part of the axis illustrates a risk-driven project using an iterative approach. ISO/IEC 29110 (ISO 29110 hereon) is located at about the center of both axes.

Initially, the SPI course used the CMMI model developed by the Software Engineering Institute (SEI). The CMMI® was selected because many organizations, especially defense and aerospace enterprises, were already using it and it was available in French at no cost from the SEI. The ÉTS engineering school is located in Montréal. A survey of the software development companies was done a few years ago in order to obtain a picture of this industry in the Montréal area. As illustrated in Table 1, it was found that close to 80 percent of software development companies have fewer than 25 employees. In addition, more than 50 percent have fewer than 10 employees.

Since a large percentage of students attending the SPI course were working in small organizations, the emphasis on the use of the CMMI® framework was gradually reduced to switch to a new ISO set of standards and guides: the recently published family of ISO 29110. The ISO 29110 standards and guides were developed specifically for enterprises, organizations, and projects having up to 25 people. The ISO 29110 management and engineering guides (ISO/IEC 2011; ISO/IEC 2012; ISO/IEC 2014; ISO/IEC 2015) are available in English and French, at no cost, from ISO. They are also available in Check, Portuguese, Spanish and soon in Arabic.

## ISO 29110

The ISO 29110 standard, "Lifecycle profiles for Very Small Entities," (Laporte, Alexandre, and O'Connor 2008) is aimed at addressing the issues identified previously, as it addresses the specific needs of very small entitities (VSEs) (O'Connor and Laporte 2011a; 2011b), and to tackle the issues of poor standards adoption by small companies (Coleman and O'Connor 2008; O'Connor and Coleman 2009). The approach (O'Connor and Laporte 2014; Laporte, O'Connor, and Fanmuy 2013) used to develop ISO 29110 started with the pre-existing international standard ISO/IEC/IEEE 12207 dedicated to software process life cycles. The overall approach consisted of three steps: 1) select ISO/IEC/IEEE 12207 (ISO/IEC 2008) process subset applicable to VSEs of up to 25 employees; 2) tailor the subset to fit VSE needs; and 3) develop guidelines for VSEs.

The basic requirements of a software development process are that it should fit the needs of the project and aid project success. This need should be informed by the situational context wherein the project must operate and, therefore, the most suitable software development process is contingent on the context (Jenners et al. 2013a; 2013b; Clarke and O'Connor 2012). The core situational characteristic of the entities targeted by ISO 29110 is size; however, there are other aspects and characteristics of VSEs that may affect profile preparation or selection, such as: business models (commercial, contracting, in-house development, and so on), situational factors (such as criticality, uncertainty environment, and so on), and risk levels (Clarke et al. 2015). Creating one profile for each possible combination of values of the various dimensions introduced previously would result in an unmanageable set of profiles. Accordingly, VSEs' profiles are grouped in such a way as to be applicable to more than one category (Laporte, O'Connor, and Garcia Paucar 2015).

Profile groups are a collection of profiles that are related by composition of processes (that is, activities, tasks), capability level, or both. The "generic" profile group has been defined (O'Connor and Laporte 2010) as applicable to a vast majority of VSEs that do not develop critical software and have typical situational factors. This profile group does not imply any specific application domain; however, it is envisaged that in the future new domain-specific subprofiles may be developed.

Figure 2 illustrates the activities of the project management and software implementation processes. The project management process and the software implementation process are described in great detail in the guides. As an example, each activity is composed of a set of tasks with inputs, outputs, and roles. For all inputs and outputs, the guides describe a typical content.

## The Course

The approach used for SPI is covered in the book titled *Making Process Improvement Work* (Potter and Sakry 2002). This approach includes the following four steps: 1) determine the business goals and problems that an organization wishes to solve; 2) determine organizational goals and identify problems; 3) prioritize identified problems; 4) develop and implement an SPI plan. The objectives of the SPI course are:

- Identify weaknesses in organizational software processes
- Prepare a business case of the cost and benefits of the intervention
- Prepare a communication plan and a process improvement plan
- Define or modify a software process
- Identify and manage risks associated with the process improvement project
- Identify the human and organizational factors that may harm or help improve the process
- Document the improvements to the process
- Conduct a pilot project to test the proposed improvements
- Document a project retrospective (that is, document the lessons learned)

The topics presented in class, listed in Table 2, are supported with weekly reading assignments. Throughout the course the students are exposed to the management of technological and cultural changes using a book titled *Managing Transitions: Making the Most of Change* (Bridges 2009). The book describes a change using a three-phase transition model, as illustrated in Figure 3.

During the course, students are introduced to the recently published ISO software development standard ISO/IEC 29110 (ISO/IEC 2012) targeting VSEs. Students use the engineering and management guide included in ISO 29110, which is freely available in English or French from ISO, as a framework to help them understand when software quality practices are used in a development project and why. They also use the guide as a framework for their team project.

The course was designed in such a way that teams of four students can apply the SPI practices presented in the lectures in an organization. Since many graduate students are already working in an organization, it was easy to identify a topic for improvement and obtain management support. To reduce the burden to the organization, this employee is the interface with management.

As mentioned previously, the approach used for the SPI course is focused on solving an organizational problem. The activities performed by the students are:

- Develop a team member's contract (for example, roles, responsibilities, expectations)
- Define the business context (for example, type of product, customers, challenges)
- Identify business objectives, challenges, and barriers
- Develop a business case
- Develop a communication plan
- Measure and analyze organizational issues related to the management of change
- Perform a mini-diagnostic of the performance of a process
- Develop a mini-improvement/installation plan
- Document the solution (for example, a process)
- Implement the improvement plan

A vast majority of students are quite knowledgeable about the technical issues, but they are not knowledgeable about the management of technological change. Since the management of change is a key element of a successful process improvement program, a series of actions was performed to facilitate the development, implementation, and adoption of the processes, methods, and tools (Laporte and Trudel 1998). A set of assessment tools provided, described in Table 3, helped the students understand the "soft" issues of a technological change in an organization (Ribaud, Matthieu, and O'Connor 2015).

These assessments allow the students to better identify potential barriers to a proposed SPI and guide them in developing mitigating actions to increase the likelihood of the success of their improvement project. Table 4 describes the deliverables and the presentations made by students of the SPI course.

## SOFTWARE PROCESS IMPROVEMENT PROJECT IN ORGANIZATIONS

To illustrate the SPI projects done, the authors briefly describe, in Table 5, a few organizations where software process implementation projects were conducted by graduate students of the SPI course.

## INDIVIDUAL GRADUATE STUDENTS PROJECTS

In addition to the one-semester graduate SPI course, a few students decided to pursue the work done during the 10-week project as their graduate project. The following paragraphs briefly describe these projects. The SPI course provided the students with a set of tools that greatly facilitates the introduction of a new technology in an organization.

### Implementation in an IT Start-up of Two Developers

An implementation project was conducted in an IT start-up VSE by a team of two (part-time) developers (Laporte, Hébert, and Mineau 2014). Their Web application allows users to collaborate, share, and plan their trips simply and make them accessible to all. The use of the Basic profile of ISO 29110 guided the start-up to develop an application of high quality while using proven practices of ISO 29110. The total effort of this project was 990.5 hours. As illustrated in Table 6, about 13 percent (that is, 125 hours/990.5 hours) was spent on rework.

In a study performed in a large organization (Laporte et al. 2012), 1100 software tasks in a software development project, representing 88,000 hours of effort, were analyzed to measure the cost of quality (that is, cost of prevention, rework, and evaluation). Figure 4 shows that the cost of rework of this project was 10 percent, the cost of prevention was 2 percent, and the cost of evaluation was 21 percent of the total cost of development. This organization was at level 3 of the CMM maturity model when the cost of quality study was performed.

When compared to the data published by Diaz (2002) and Krasner (1998), the cost-of-quality data (that is, prevention, evaluation, rework) for the two-member start-up enterprise presented in Table 6 indicates that the use of appropriate standards, in this case for a start-up company, can guide all phases of product development such that the wasted effort (that is, rework) is about the same as a more mature organization (that is, about level 3 of CMM).

Similar results were achieved in a software development project by a Peruvian start-up in 2014 (Garcia et al. 2015). The startup was created by two graduates of the Universidad Peruana de Ciencias Aplicadas (Peruvian University of Applied Sciences) (UPC). The four-person startup, named BitPerfect, completed a 900-hour project, using the Basic profile, in six sprints using an agile approach, while expending only 18 percent of the total project effort on rework. The VSE was granted an ISO 29110 certificate of conformity in 2014. The startup became the first Peruvian VSE to obtain an ISO/IEC 29110 certification. The ISO 29110 certification facilitated access to new clients and larger projects. In 2016, the VSE had 23 staff members.

**Implementation of Agile Processes Based in a Large Financial Institution**

The Cash Management IT Department of a large Canadian financial institution is responsible for the development and maintenance of software tools used by traders (Laporte, O'Connor, and Garcia 2016). The software team is composed of six people. Each year, the division is faced with an increase in the number of requests to add, correct, or modify features related to supported applications. Before the implementation of the ISO 29110 agile process (Galvan et al. 2015), customers had the following complaints:

- It is very difficult to know the status of specific requests.
- Very often there is an incident when a change is put in production.
- There are a large number of faults detected by the quality assurance department.
- The development process is painful and the documentation produced is not very useful.

In response to this problem, the actual process was evaluated by comparing the activities of the maintenance process to those of the Basic profile of ISO 29110. Figure 5 illustrates the coverage of the software implementation tasks to the Basic profile.

The project management process has been adapted to the context of the division by injecting a few tasks of the SCRUM methodology. The new agile process, using the Basic profile of ISO 29110, has been tested on three pilot projects.

In this financial institution, an incident is classified as minor or major using a set of criteria, such as the number of impacted systems, the severity, the number of customers impacted, and the criticality of the impact. The criticality is evaluated on a 1-to-5 scale. Figure 6 illustrates the decrease in the number of systems impacted, as well as the total criticality level. Figure 6 illustrates that in June five systems were impacted and the criticality of those five incidents was 17. About nine months later, both the number of incidents and the criticality were very low (that is, one incident and criticality of 1).

**Development and Deployment of Project Management Processes in an Engineering Firm**

A Canadian division of a large American engineering firm made up of about 400 employees embarked on a program to define and implement project management processes for its small-scale and medium-scale projects. The firm already had a robust and proven process to manage its large-scale projects. Its projects are classified into three categories, as illustrated in Table 7. More than 95 percent of the projects of this division fall in the small- and medium-scale categories.

The division documented the business goals as well as the problems it wished to solve. The division used the project management process of the Entry profile of ISO 29110 to document its small-scale project management process, and it used the project management process of the Basic profile to document its medium-scale project management process.

An ISO methodology (ISO 2010) was used to estimate the anticipated costs and benefits over a period of three years. Table 8 shows the results for the first three years of this cost/benefit estimation.

Since the use of ISO 29110 was very successful in the development of the firm’s project management processes, the recently published systems engineering ISO 29110 Entry and Basic profiles will be used to redefine and improve the existing engineering process (ISO/IEC 2014; ISO/IEC 2015). This process will address the activities required from engineering requirements identification to final product delivery.

Figure 7 shows the overall results of the activities assessment of the project management (PM) process of the Basic profile executed by projects managers before the ISO 29110 implementation. The figure displays the percentage of the tasks performed for each of the following activities of the ISO 29110 management and engineering guide (ISO/IEC 2011):

- Project planning (15 tasks)
- Project plan execution (six tasks)
- Project assessment and control (three tasks)
- Project closure (two tasks)

The authors note in Figure 7 that a low level of implementation of ISO 29110 tasks of the Basic profile was achieved for medium-scale projects within the engineering company at the beginning of the improvement program. Also, during the interview with managers, it was noted the PM tasks were not performed systematically. In addition, the assessment revealed that PM practices varied from project manager to project manager and that no guideline had been defined for a few tasks. A similar assessment against the Entry profile was also carried out for the small-scale projects.

As indicated previously, once the project report is almost complete, students must write a short article synthesizing their project. Once the article is almost complete, students must then develop a poster. A few articles are published in French (Jeljeli and Laporte 2016; Tremblay et al. 2015; Trudeau, Laporte, and Lévesque 2014; Hébert, Mineau, and Laporte 2013; Chevalier and Laporte 2013) or in English (Laporte and Chevalier 2016; 2015; Laporte, Hébert, and Mineau 2014), and on the ISO 29110 public website, while posters are displayed in the hallways of the university or posted on the ISO 29110 public website (Laporte 2016 **AUTHOR: THIS IS NOT ON REF. LIST. PLEASE ADD)**. Figure 8 illustrates the poster developed about the implementation in an engineering firm and posted on the ISO 29110 public site.

Graduate students in search of an application project are invited to read the poster and, if interested, download the short article linked to a poster. Undergraduate students are also exposed to a spectrum of typical industrial projects.

## Implementation of ISO 29110 in a Canadian/Tunisian IT Start-up

Metam was founded in 2013 by a software engineering graduate student of ÉTS. The company has one site in Canada and one site in Tunisia. Its business domains are software development services, Web solutions, mobile applications, as well as consulting services to implement ERP solutions. The Basic profile of ISO 29110 was used as the framework for the company’s software processes. It was also used as a foundation to implement CMMI® DEV level 2 practices because it was requested by some military contracts of Metam. In 2016, the young VSE had 16 employees (14 employees working in Tunisia).

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### Implementation of Systems and Software Engineering Processes in a Young Transportation Enterprise

A project was created to define and implement project management and systems engineering processes at CSinTrans Inc. (CSiT), a Canadian company founded in 2011 (Laporte et al. 2016). The company specializes in the integration of communication and security systems in the transit industry such as trains, subways, and buses, as well as railway stations, subway stations, and bus stops. ISO 29110 standard and guides for systems engineering (SE) have been used as the main reference for the development of these processes (Laporte, O'Connor, and Fanmuy 2013).

The SE Basic profile, as illustrated in Figure 9, is composed of two processes: PM and system definition and realization (SR). An acquirer provides a Statement of Work (SOW) as an input to the PM process and receives a product as a result of SR process execution. The SE ISO 29110 standard and guides are designed to work hand-in-hand with their vis-à-vis software engineering ISO 29110 management and engineering guides.

ISO 29110 has helped raise the maturity of the organization by implementing proven practices and developing consistent work products from one project to another. ISO 29110 was a good starting point to align processes with specific practices of CMMI® maturity level 2. ISO 29110 has also helped CSiT in developing light processes as well as remaining flexible and quick in its ability to respond to its customers.

The transportation enterprise decided to develop three process groups (that is, light, standard, and full process), and each process adapted to meet the needs of a specific project. Table 9 shows the three process groups, the characteristics of projects, and the frameworks selected.

As illustrated in Table 9, the Entry profile is the main framework for the light process, the Basic profile for the standard process, and the CMM-DEV is used for the full process. In 2012, at about the beginning of the improvement project, CSiT was composed of four people; in 2016 there were 10 people.

## CONCLUSIONS AND FUTURE WORK

Many improvements have been made to the ÉTS SPI course since it was initially set up in 2000. The challenge was to ensure that all these improvements met the objectives of the course. At ÉTS, students evaluate both the course and the professor. Following the improvements, the SPI course scored 4.34 out of a maximum score of 5, while the average score for the courses of the graduate software engineering program was 3.83. The lowest score, attributed to the quantity of work, was 3.13. The highest score, attributed to the degree to which this course enhances their professional education, was 4.75, while the score of the master degree program was 3.98. The use of ISO 29110 instead of the CMMI greatly facilitated the understanding and implementation of a software engineering framework suitable for most VSEs in the Montréal area.

ISO 29110 is the first international software engineering standard that is teachable and easily understandable and applicable by software engineering students. Fortunately, a few countries have already started to teach ISO 29110 at the undergraduate and graduate levels (Larrucea et al. 2016), and teaching material is being developed (Laporte, Houde, and Blondelle 2016). It is also a standard that encompasses many software engineering practices learned in different courses, and it integrates both management and technical practices in the same framework. Finally, an additional but non-negligible advantage for both professors and students, the ISO 29110 management and engineering guides are freely available on the ISO website. The guides are available in Check, English, French, German, Portuguese, Spanish and soon in Arabic. Further tools to aid the teaching of ISO 29110 are currently being developed (Sanchez-Gordon et al. 2016).

Further possibilities to explore to help the take up of SPI education include the concepts of gamification, where gamification can be considered as a framework where the participants are systematically motivated with targets that have small and quantifiable increments based on continuous feedback and interactions. Early studies have shown positive indicators of its application in standards and SPI education (Aydan, Yilmaz, and O'Connor 2015; Yilmaz and O'Connor 2016).

The authors think the current SPI course lectures and projects in industry provide a solid foundation for software engineers, even though SPI is still perceived as a low priority by most SMEs and VSEs. However, the profession of software engineering is still young--and Rome was not built in a day.

## ADDITIONAL IINFORMATION

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

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## BIOGRAPHIES

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**Figure 1 Positioning of the ISO 29110 (adapted from (Kroll and Kruchten 2003))**

| Size (Number of employees) | Software companies | | Total number of jobs | |
|---|---|---|---|---|
| 1 to 25 | 540 | 78% | 5,105 | 29% |
| 26 to 100 | 127 | 18% | 6,221 | 36% |
| over 100 | 26 | 4% | 6,056 | 35% |
| **TOTAL** | **693** | **100%** | **17,382** | **100%** |

**Table 1 Size of software development companies in the Montreal area (Gauthier 2004)**

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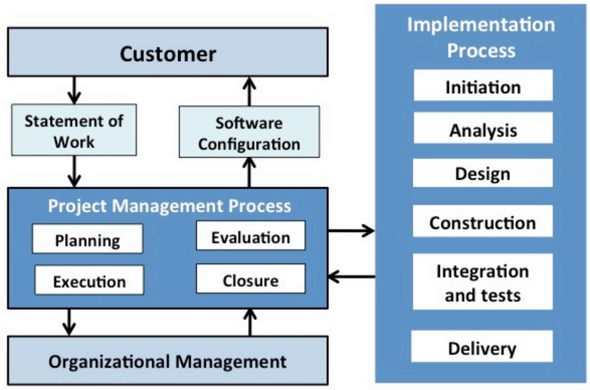



**Figure 2 Software engineering Basic profile processes and activities** (Laporte and Chevalier 2015)

| Theme | Content |
|---|---|
| Introduction | Challenges faced by organizations developing products comprising software<br>Benchmarking process performances<br>Improving process performances (e.g. quality, productivity, turnaround, etc.)<br>Outsourcing and off shoring |
| Models, standards, and methods | The IDEAL improvement model from the SEI<br>The Capability Maturity Model Integration for Development<br>ISO 29110 standards and guides for very small entities (VSEs)<br>Process performance assessment methods<br>Goal-problem approach |
| Management of organizational changes | Description of the organizational context of a change project<br>Organizational culture assessment<br>Change history assessment<br>Stress-level assessment<br>Sponsorship assessment<br>Change agent's capability assessment<br>Motivational factors assessment<br>Change readiness assessment<br>Deployment/installation plan |

**Table 2 List of SPI course topics**

Laporte, Claude Y., and Rory V. O'Connor. "Software process improvement in industry in a graduate software engineering curriculum." *Software Quality Professional Journal, ASQ* 18, no. 3 (2016): 4-17.

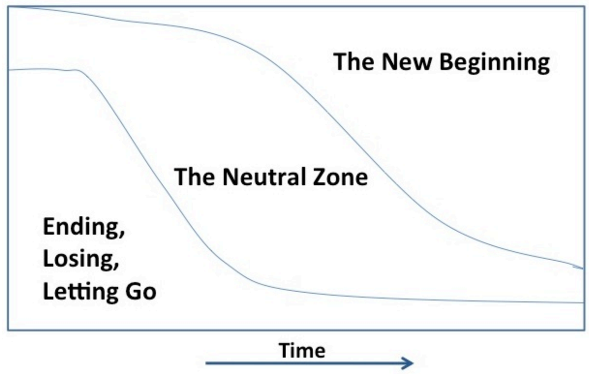



**Figure 3 Three-phase transition** (Bridges 2009)

| Title of Tool | Description |
|---|---|
| Organization's stress level | Evaluation of the priorities for resources in the organization |
| Sponsor assessment | Evaluation of the resources, reinforcement (e.g. motivation), and communications commitments made and demonstrated by the sponsor(s) of a change project |
| Change agent skills | Evaluation of the skills and motivation of those responsible for facilitating the implementation of organizational changes |
| Individual readiness | Evaluation of the reasons why people may resist an organizational change |
| Culture assessment | Assessment of the fit between the desired change and the actual organizational culture in order to identify potential barriers and to leverage actual cultural strengths |
| Implementation history | Assessment of barriers and lessons learned from previous change projects (since past problems are likely to recur, this tool allows identification of the issues that need to be managed for the change project to be successful) |

**Table 3 Elements measured with the IMA tools**

| Deliverables | Deadline |
|---|---|
| 1. Project plan and contract between team members | Lecture 2 |
| 2. Project overview<br>3. Business case<br>4. Communication plan<br>5. Organizational culture analysis | Lecture 5 |
| 6. Diagnostic of the organization<br>7. Sponsorship evaluation | Lecture 7 |

| | |
|---|---|
| 8. Contract between team members (updated) | |
| 9. Analysis of the motivational factors<br>10. Organizational stress analysis | Lecture 8 |
| 11. Change agent capability assessment<br>12. Change readiness assessment | Lecture 11 |
| 13. Process description | Lecture 12 |
| 14. Improvement/installation plan | Lecture 13 |

**Table 4 Topics of the SPI course**

| Description of organization | SPI Project Description |
|---|---|
| The company, of about 140 employees, designs and sells electric powertrain systems in the automotive field.<br><br>Its products are embedded software that controls the operation of engines in real time and embedded software that controls the interactions between the components of a vehicle. | • A compliance study was conducted to establish the difference between the processes in place and those proposed by the Entry profile of ISO 29110.<br>• An action plan was developed to organize the software process improvement activities.<br>• An analysis of differences between ISO 29110 was conducted.<br>• An economic impact assessment was conducted using the methodology developed by ISO. |
| Property management and audit of building health | • Document existing business processes, analyze them, and identify those with potential for improvement. |
| An engineering company specialized in the integration of interactive systems, communication, and security in the area of public transportation such as trains, subways and buses and railway stations, stations and bus stops. | • Start-up of four people in 2011<br>• Many customers in public transportation ask for a CMMI® level 2<br>• Implementing the CMMI® level 2 process areas was too demanding for a start-up of four people<br>• The Basic profile of ISO 29110 was used as the main reference for the development of the management and engineering processes<br>• A gap analysis between CMMI® level 2 and the ISO 29110-based processes was done. |
| Medical device R&D enterprise | • The Basic profile of ISO 29110 was used to document and implement a quality management system.<br>• ISO 13485 was used as the framework for the quality management system. |
| A project conducted at ÉTS for a unit responsible to promote activities for graduates and to raise money for the financing of the ÉTS foundation | • The software project developed a Web portal using the Basic profile of ISO 29110<br>• The portal allowed graduates to register to activities, modify their personal information |
| An enterprise specialized in industrial process control | • A department of 13 employees<br>• ISO 29110 Entry profile was used to assess practices in used<br>• The management of requirements was the focus of the project |

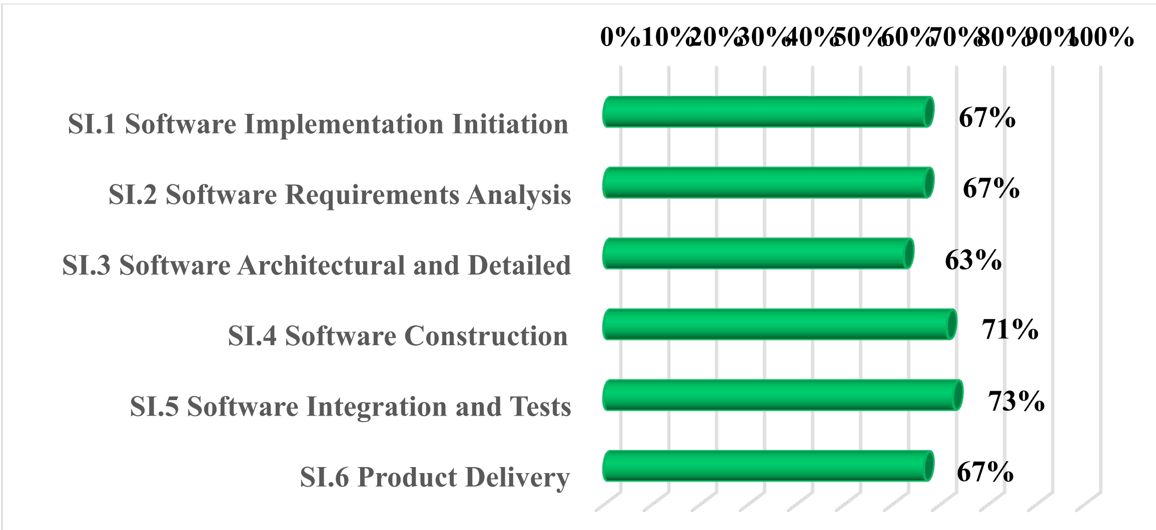
| | |
|---|---|
| An IT start-up involved in the development of Web traffic surveillance | • A start-up of four employees<br>• Documentation of the software development process using the Basic profile of ISO 29110 |
| A large civil engineering and construction firm | • A department of 15 people<br>• Responsible for the development and maintenance of software for the other units of the company<br>• After an analysis of current practices using the Entry profile of ISO 29110, the improvement implemented a change request management process |
| An IT department of a large utility provider | • A large organization with close to 2000 IT staff<br>• Twelve process areas of CMMI have been implemented<br>• A department of 11 people implemented the Basic profile of ISO 29110 adapted to a Scrum approach |
| An IT technical college | • Development of teaching material for a software engineering course<br>• The teaching material was offered to other technical colleges |

**Table 5 Examples of SPI projects conducted by graduate students**

| **Title of task** | **Prevention (hours)** | **Execution (hours)** | **Review (hours)** | **Rework (hours)** |
|---|---|---|---|---|
| Environment installation | 89 | | | |
| Project plan development | | 35 | 3 | 4 |
| Project plan execution and project assessment & control | | 47 | | |
| Specification and prototype development | | 199.5 | 7 | 18 |
| Architecture development | | 42.5 | 1.5 | 3.5 |
| Test plan development | | 12.5 | 1 | 2 |
| Code development and testing | | 361 | 47 | 96.5 |
| Develop user guide and maintenance document | | 8 | 1 | 1 |
| Website deployment | | 8.5 | | |
| Project closure | | 2 | | |

| | | | | |
|---|---|---|---|---|
| **Total (Hours)** | **89** | **716** | **60.5** | **125** |

**Table 6 Effort to execute, detect, and correct errors by the two-member team** (Laporte, Hébert, and Mineau 2014)




**Figures 5 Coverage of the initial software implementation tasks to the software Basic profile** (Translated from Plante 2015)

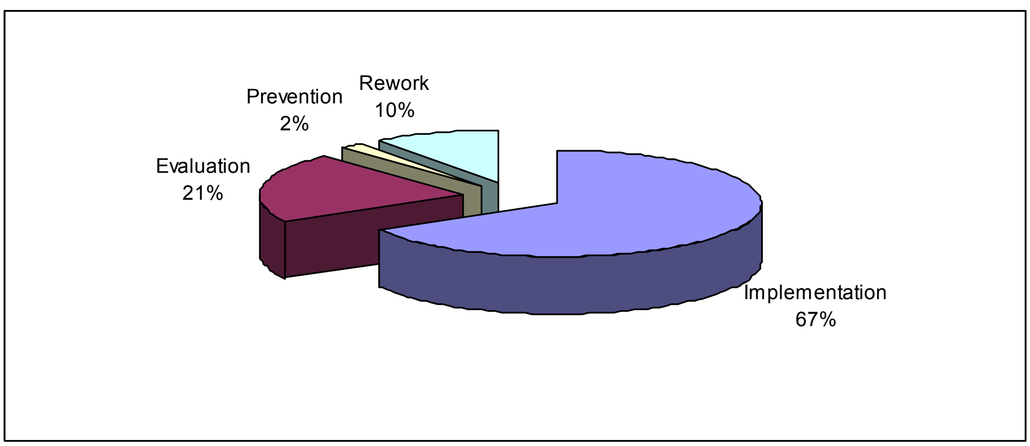



**Figure 4 Distribution of effort in the 88,000-hour project** (Laporte et al. 2012)

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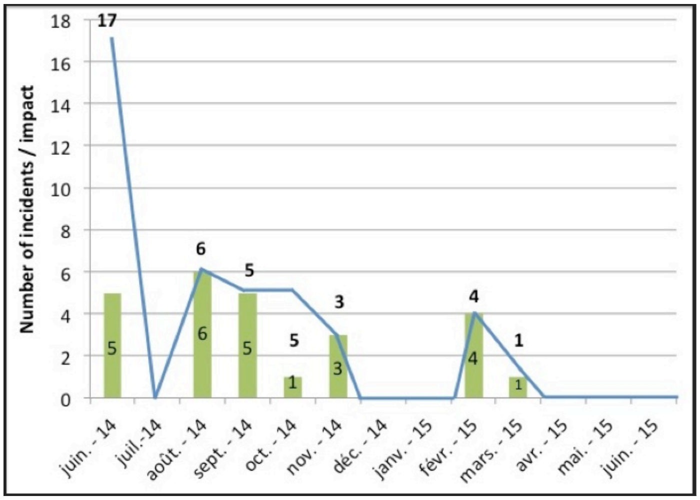


**Figure 6 Monthly number of incidents and their impact** (Translated from Plante 2015)

| | Small project | Medium project | Large project |
|---|---|---|---|
| **Duration** | < 2 months | > 2 and < 8 months | > 8 months |
| **Team size** | <= 4 people | 4-8 people | > 8 people |
| **No. engineering specialties** | 1 | >1 | Many |
| **Engineering fees** | $5,000 - $70,000 | $50,000 - $350,000 | > $350,000 |
| **Percentage of projects** | 70% | 25% | 5% |

**Table 7 Classification of projects by the engineering firm (Laporte and Chevalier 2015)**

| | Year 1 | Year 2 | Year 3 | Total |
|---|---|---|---|---|
| Cost to implement and maintain | 59,600 | 50,100 | 50,100 | 159,800 |
| Net benefits | 255,500 | 265,000 | 265,000 | 785,500 |

**Table 8 Costs (in Canadian dollars) and benefits estimations from implementing ISO/IEC 29110** (Laporte and Chevalier 2015)

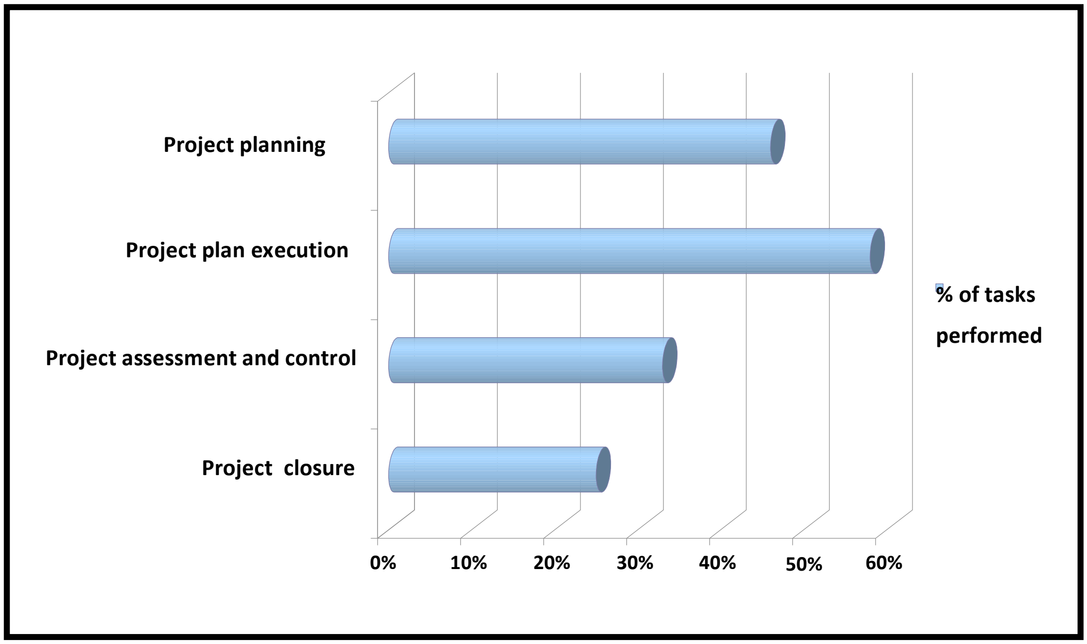


**Figure 7 Performance assessment of the Basic profile** (Laporte and Chevalier 2015)

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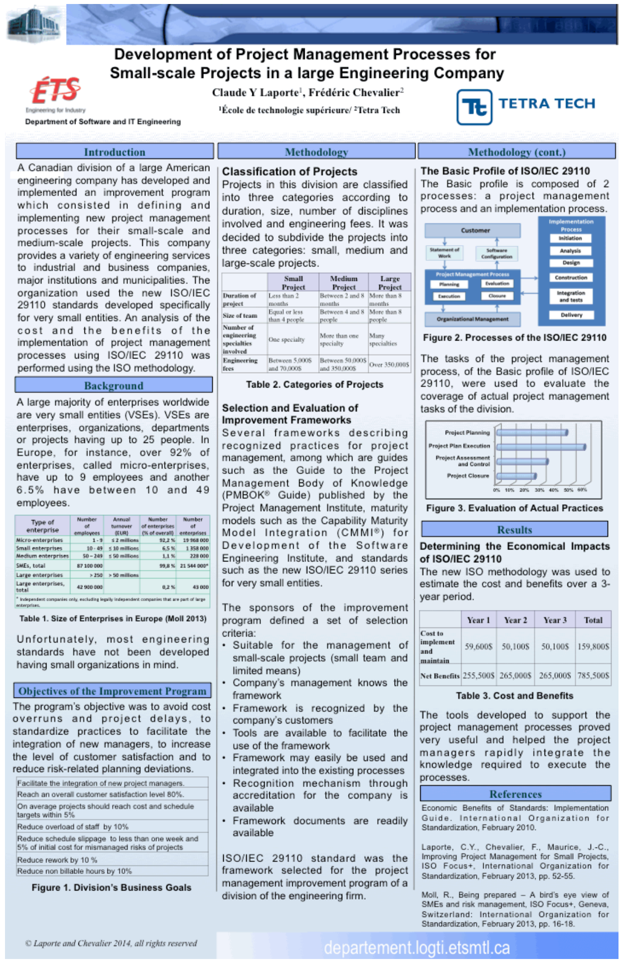


**Figure 8 The poster developed about the industrial implementation in an engineering firm** (Laporte and Chevalier 2015)

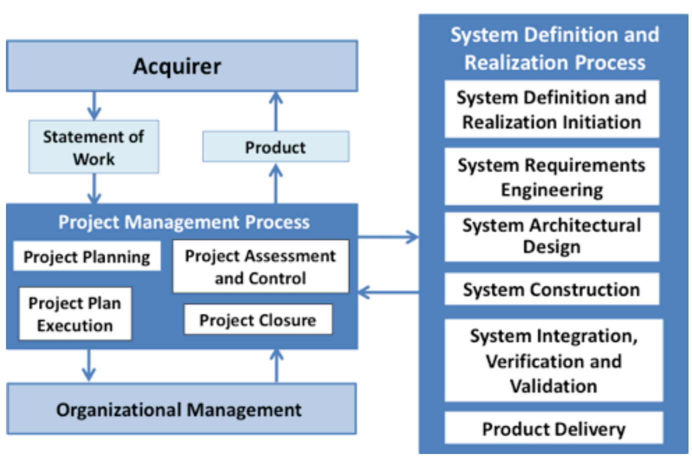

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**Figure 9 Processes and activities of the systems engineering Basic profile** (Laporte et al. 2016)

| | **Light Process** | **Standard Process** | **Full Process** |
|---|---|---|---|
| **Type of project** | Proof of concept, prototype<br><br>Product testing or product deployment at customer site<br><br>Small project | Typical project<br><br>Product deployment at customer site<br><br>Medium project | Project when CMMI level 2 is required by a customer<br><br>Product testing or product deployment at customer site<br><br>Large project |
| **Framework to be used** | ISO/IEC TR 29110-5-6-1 (Entry Profile)<br>+<br>CMMI-DEV - Supplier agreement management | ISO/IEC TR 29110-5-6-2 (Basic Profile)<br>+<br>CMMI-DEV - Supplier agreement management | CMMI-DEV (Level 2) |

**Table 9 Classification of CSiT processes** (Laporte et al. 2016)