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# Implementing systems engineering and project management processes in a Canadian company – Overview and Results Achieved

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**Abstract.** This article presents a project consisting of implementing project management and systems engineering processes at CSinTrans Inc. (CSiT), a Canadian company founded in 2011. CSiT provides multi-modal transit information systems as well as information integration to the transit industry worldwide. The Basic profile of the ISO/IEC 29110 for systems engineering has been used as the main reference for the development of these processes.

The reasons that prompted CSiT to implement the ISO/IEC 29110 are mentioned. The approach and details on how the standard has been implemented are presented. The lessons learned are described. CSiT developed three process groups to match the attributes of projects such as size and nature. The selection of tools to support the processes is discussed.

Third-party audits, conducted annually since 2016, that led CSiT to become the first systems engineering company successfully audited with ISO/IEC 29110, are presented as well as the benefits obtained.

ISO/IEC 29110 has helped raise the maturity of the organization by implementing proven practices and developing consistent work products from one project to another. ISO/IEC 29110 was a good starting point to align processes with specific practices of CMMI® Maturity Levels 2 and 3. ISO/IEC 29110 has also helped CSiT in developing light processes as well as remaining flexible and quick in its ability to respond to its customers.

To illustrate the implementation of the Basic profile of ISO/IEC 29110 in other engineering domains, this article briefly presents the implementation in the automotive, agriculture, aeronautic, nuclear and space domains in 6 enterprises of France in 2018.

## Introduction

CSiT is a Canadian company, established in 2011 in Montréal, providing multi-modal transit information systems and information integration for transport. Figure 1 illustrates an interactive in-station system developed by CSiT.


Figure 1. Interactive in-station system developed by CSiT

In transit industry, customers often require a CMMI® maturity level from companies such as CSiT (SEI 2010). An independent evaluation confirming a CMMI® level 2 increases the opportunity of winning contracts. Similarly, to ensure better work coordination and reduce risks, organizations in this industry prefer working with mature suppliers in order to get timely quality products and within the agreed budget.

## ISO/IEC 29110 Standards and Guides

As defined in ISO/IEC 29110 (ISO 29110 hereon), a Very Small Entity (VSE) is a company, an organization, a department or a project having of up to 25 people (ISO 2016). As shown in Table 1, a very large percentage of European enterprises are VSEs (Moll 2013). In Canada, nearly 98% of companies are small enterprises with fewer than 50 employees, and nearly 32% of them have fewer than 20 employees. In the US, about 57% of companies are micro-enterprises. CSiT fits to the definition of VSE.

Table 1: Size of enterprises in Europe (Moll 2013)

| **Type of enterprise** | **Number of employees** | **Annual turnover (EURO)** | **Number of enterprises (% of overall)** | **Number of enterprises** |
|---|---|---|---|---|
| Micro-enterprises | 1 - 9 | ≤ 2 million | 92.2% | 19 968 000 |
| Small enterprises | 10 -49 | ≤ 10 million | 6.5% | 1 358 000 |
| Medium enterprises | 50 - 249 | ≤ 50 million | 1.1% | 228 000 |
| SMEs, total | 87 100 000 | | 99.8% | 21 544 000[1] |
| Large enterprises | > 250 | > 50 million | | |
| Large enterprises, total | 42 900 000 | | 0.2% | 43 000 |
| [1] Independent companies only, excluding legally independent companies that are part of large enterprises | | | | |

VSEs can play different roles in systems engineering: as suppliers, integrators, and sometimes both. Since most large organizations are structured in a way to be more manageable (e.g. project, department), VSEs are present at all stages of a product manufacturing chain.

The Systems Engineering (SE) ISO 29110 standard and guides have been developed using, as its main framework, ISO/IEC/IEEE 15288 (ISO 2015). With some exceptions, document descriptions are based on ISO/IEC/IEEE 15289 (ISO 2019a). The ISO 29110 management and engineering guides are tailored, mainly from ISO 15288 and ISO 15289, to provide a minimum set of technical and management tasks for VSEs.

A four-stage ISO 29110 roadmap has been developed for VSEs that do not develop critical systems: Entry, Basic, Intermediate, Advanced. VSEs targeted by the Entry profile are those working on small projects (e.g., at most six-person months of effort) and for start-ups (ISO 2015). The Basic profile describes the development practices of a single application by a single project team (ISO 2014). The Intermediate profile is

targeted at VSEs developing multiple projects with more than one team (ISO 2019b). The Advanced profile will be targeted at VSEs wishing to sustain and grow as independent competitive businesses.

The SE Basic profile, as illustrated in Figure 2, is composed of two processes: Project Management (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.

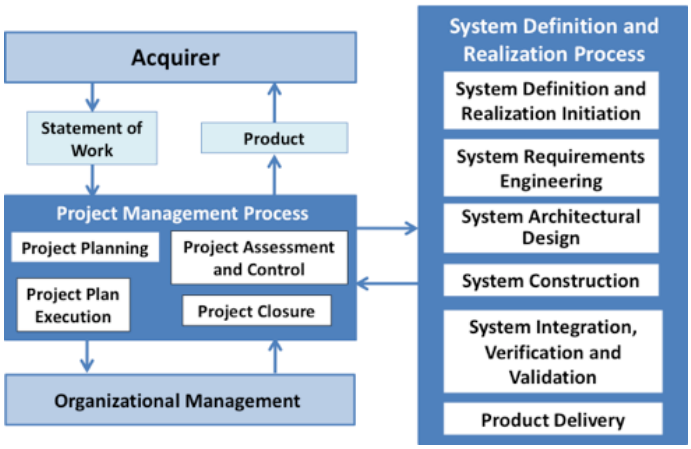


Figure 2. Processes and activities of the systems engineering Basic Profile (Laporte et al. 2017)

For illustration purposes, one task of the System Requirements Engineering activity of the SR process is listed in Table 2. On the left side of the table are listed the roles involved in a task. The Project Manager (PJM) and the Work Team (WT) are involved in this task. In the next column, the task is described. The two columns on the right list the input work product required to perform this task and the output work products of this task.

Table 2: Example of one Task of the System Requirements Engineering Activity (Laporte et al. 2017)

| **Role** | **Task list** | **Input Work Product** | **Output Work Products** |
|---|---|---|---|
| PJM | SR.2.2 Verify the Stakeholders Requirements Specifications with PJM | Stakeholders Requirements Specifications [*initiated*] | Stakeholders Requirements Specifications [*verified*] |
| WT | Obtain Work Team agreement on the Stakeholder Requirements Specifications | | Verification Report<br>Stakeholders Requirements Specifications [*published*] |

The SE ISO 29110 standard and guides are designed to work hand-in-hand with the software engineering (SW) ISO 29110 standard and guides. ISO 29110 does not impose a specific life cycle model, therefore leaving VSEs free to choose the model that best suits their needs among the cascade, iterative, incremental, evolutionary and agile models. Similarly, ISO 29110 does not impose a specific method or tool to its users.

So far, the SE Entry profile (ISO 2015a) and the SE Basic profile (ISO 2014) have been published. The SE Intermediate profile should be published in 2019 (ISO 2019b). The SE Advanced profile development should start in 2019. The SE Basic profile guide is available, at no cost from ISO, in English and French[2].

## Motivations and objectives of the implementation of ISO 29110 at CSiT

Shortly after its creation in 2011, CSiT learned that an event in Montréal would be held on the new ISO 29110 management and engineering guide for systems engineering. This standard was seen as a good starting point towards implementing CMMI level 2. Thus, CSiT has undertaken a new project to implement the ISO 29110 standard to guide the project management and system development activities. The Intermediate profile was targeted as it applies to VSEs that conduct several projects simultaneously with more than one team. However, the Basic profile was selected since the Intermediate profile was not published when the project was initiated at CSiT.

### Motivations for the implementation of project management and engineering processes

Several factors prompted CSiT to develop and document their processes. Their first projects were based on employees' experience as well as recognized practices. This approach was effective and agile, but it was not possible to produce consistent deliverables from one project to another and be able to demonstrate that the work could be done over again since these practices were not documented into company's processes. Also, since there were no templates or checklists, project management and product development activities were done rather informally. Finally, considering business and nature of projects of CSiT, customers often require proof demonstrating rigorous work and a level of maturity.

Therefore, the company considered the development and implementation of processes as a need, in other words, the situation could become problematic if no action was taken. Specifically, the lack of a CMMI maturity level or compliance with international standards, such as ISO 29110, was not an option. CSiT wanted to ensure the company's growth and show its expertise and organizational maturity to its customers.

[2] Available at no cost from ISO: http://standards.iso.org/ittf/PubliclyAvailableStandards/index.html

**Guidance for the implementation project**

To avoid making the process cumbersome and producing too many documents, participants gave themselves 2 sets of guidelines:

1. For processes, the guideline was to add tasks not described in the SE Basic profile only if they bring value to the context and projects of the company or provide an alignment with CMMI level 2.

2. For document templates, the guidelines were:

    - Group different documents into one where possible;
    - Each template's section must be relevant and applicable. If a section does not provide added value, it should not be included.

## Approach to the Implementation of the SE ISO 29110 at CSiT

The first phase of the improvement project was to determine the set of documents to be produced during a typical project and how they should be organized in the document structure of the company. The five types of documents at the foundation of the company's quality system are illustrated in Figure 3.

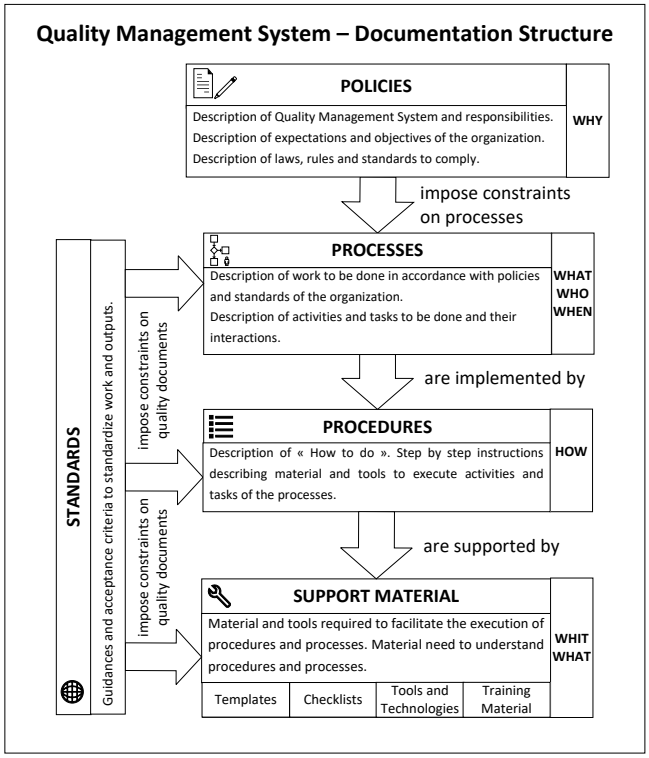


Figure 3. Identification of documents and their relationships

For the moment, CSiT decided to leave aside the creation of training material because this material can take time to develop and does not really bring value at this time. The company prefers to promote interactive training in person rather than the reading of a

document or the viewing of a presentation. Documented processes can be used as training material for new employees as necessary.

**Processes and procedures description**

To better respond to different types of projects, CSiT decided to develop three process groups (light, standard, full), each being adapted to meet the attributes of projects such as the size and nature. Table 3 shows the three process groups and the frameworks used as references.

Table 3: Classification of CSiT processes

| | **Light Process** | **Standard Process** | **Full Process** |
|---|---|---|---|
| **Type of Project** | Proof of Concept, Prototype<br><br>Concept validation or Product Deployment at Customer Site<br><br>Small Project | Typical Project<br><br>Product intended to be installed at Customer Site<br><br>Medium Project | Project when CMMI level 2 is required by a Customer<br><br>Product intended to be installed at Customer site<br><br>Large Project |
| **Framework to be used** | ISO/IEC TR 29110-5-6-1 Entry Profile<br>+<br>CMMI - Supplier Agreement Management | ISO/IEC TR 29110-5-6-2 Basic Profile<br>+<br>CMMI - Supplier Agreement Management | CMMI (Level 2) |

**Using the management and engineering guide of ISO 29110**

To document CSiT processes, the management and engineering guide of ISO 29110 SE Basic profile was used as the main reference (ISO 2014). The software engineering (SW) management and engineering guide of ISO 29110 Basic profile (ISO 2011) was also used as a reference to complement the SE guide. The SW guide was used to document processes involving the development of SW elements of a system.

**Process documentation**

For the description of processes, CSiT decided to break down processes into activities and tasks. There are two reasons for this representation. First, this representation is simple and it is commonly used in industry and literature. Second, it is consistent with ISO 29110, which is structured the same way.

**Graphical and textual documentation of processes**

It was decided that documentation of CSiT processes would consist of two parts: a graphical part and a textual part. Each of these parts has different but complementary goals. The graphical part is primarily targeted at "experts", while the textual part is targeted mainly at "beginners" (e.g. a new employee) or an intermediate user (e.g. an employee who has participated to an engineering project) (Laporte and April 2018).

The textual part is a detailed description of activities, tasks and interactions between the activities of a process. The textual part describes the tasks, i.e. what to do, and the roles associated with each task. The format used to describe the activities is the notation used in the Deployment Packages of ISO 29110 (Laporte 2019). Some adjustments were made to add a few attributes, such as measures to collect, entry and exit criteria. It now looks like the ETVX notation (i.e. Entry-Task-Verification-eXit), developed in the 80s by IBM (Radice and Roth 1985) and adopted by many organizations such as NASA given its simplicity of use. Figure 4 describes an ETVX notation enriched by adding entry and exit criteria as well as measures.

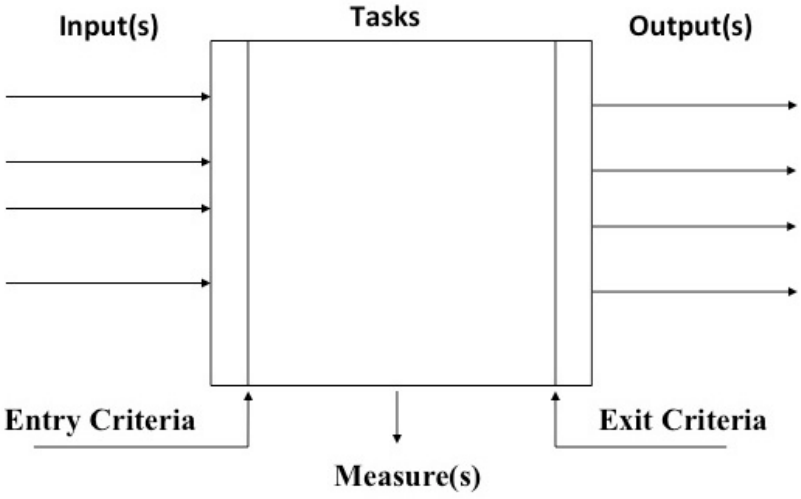


Figure 4. Enriched ETVX Notation (Laporte and April 2018)

## Techniques Used to Help Defining and Implementing ISO 29110

The Basic profile presents the project management and development processes using a waterfall lifecycle to simplify its understanding. However, the ISO 29110 guide indicates that it does not require the waterfall lifecycle, leaving VSEs to use the lifecycle that best suits their needs. Thus, CSiT decided to develop their own lifecycle models: a project lifecycle and a system development lifecycle.

The definition of these lifecycle models have facilitated the description of the processes because they provided a clear understanding of when the processes need to be executed. In addition, the lifecycles have shown the importance of some processes that are not mentioned in the standard, but that must be used during the execution of projects. For

example, it is possible that the company has to perform validation tests on the customer's site, to get the final acceptance of the system. For CSiT, this type of work is essential and was documented as a separate process.

## Definition of the Project Tree in the Configuration Management Tool

A generic project tree has been established to indicate where each work product will be stored in the configuration management tool such that projects deliverables are classified in the same way from project to project. A subset of this tree is shown in Figure 5. It shows the contents of each folder. Each acronym is defined in the nomenclature standard of the VSE.

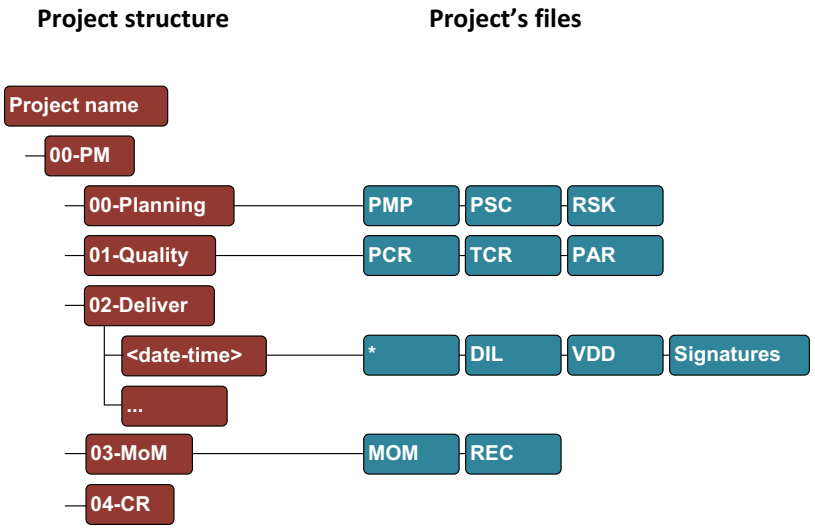


Figure 5. Subset of project tree in the configuration management tool

## Identification of verification, validation and acceptance activities applicable to work products

An important decision made during the development of CSiT processes was to determine the types of peer review to be applied to the various work products of a project. ISO 29110 states that verifications of work products must be made, but without specifying the type. This leaves freedom to organizations to decide what best verification method applies to their context. A study was therefore conducted to determine what type of reviews would be used for each work product. The first step was to draw up a list of potential deliverables in a project. Then, for each deliverable, a decision was taken for the adequacy or the need to perform at least one type of peer review. If so, the type of review was identified. Four types of reviews were identified: personal review, desk-check, walkthrough and inspection. Then, for each review, the output documents were defined. The four types of document were: a document review report (DRR - Document Review Report), an annotated document (ANN - Annotations), Minutes of Meetings (MoM - Minutes of Meeting) or a completed checklist (CHKL - Checklist).

An example of the decision made about work product reviews is presented in Table 3. The left column shows the name of deliverable or work products. Then columns 2-4 indicate for each deliverable, peer review activities to be performed. The quality control procedure (i.e. personal review, desk-check, walkthrough or inspection) has been documented in the processes. Other attributes are also defined, in the review procedure, as the person who must review the deliverables, but they are not presented in the table.

**Acceptance of deliverables**

ISO 29110 defines the roles needed to produce and review the project deliverables (documentation and product components), but it does not define the roles of the people who must approve and/or sign deliverables before they are sent to a customer, a supplier or other external stakeholders. CSiT used the same table (Table 4) to identify, for each deliverable, whether or not an internal approval is needed, whether or not it should be sent to the customer and whether or not a customer approval is required.

Table 4: Identification of verification, validation and acceptance activities of a subset of the work products

| | **VERIFICATION** | | | | | **VALIDATION** | | **ACCEPTANCE AND SIGNATURE** | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Deliverables and Internal Work Products | Peer Review | | | Tests | | Tests | | Acceptance | | |
| Description | Peer Review ? (Y=Yes, N=No) | Type of Review (P=Personal, D=Desk-Check, W=Walk-through, I=Inspection) | Output Documents ANN = Annotations RR = Review Report MoM = Minutes of Meeting CHKL = Checklist | Type of Test U = Unit I = Integration S = System | Output Document UTR = Unit Test Report ITR = Integration Test Report STR = System Test Report | Type of Test F = Factory S = On Site | Output Document FTR = Factory Test Report STR = Site Test Report | Internal Approval (signature) (Y=Yes, N=No) | Delivered to Customer? (Y=Yes, N=No) | Acceptance required form Customer? (Y=Yes, N=No) |
| Technical – System Requirement Specification | Y | D, W | RR then MoM | N/A | N/A | N/A | N/A | Y | Y | O |
| Technical – Software Requirement Specification | Y | D, W | RR then MoM | N/A | N/A | N/A | N/A | Y | Y | Y |

## Selection of measures

The management and engineering guide lists the tasks associated to the collection and use of measures (e.g. resource, cost, time). The Basic profile does not detail how to collect and analyze the measures.

The selection of measures was based on two principles: 1) a measure must meet a company's needs for information and, 2) a measure must be easy to collect and analyze. A subset of the measures selected is described in Table 5.

Table 5: Subset of process and product measures

| Measure ID | Measures | Reasons |
|---|---|---|
| MET-01 | Number of errors detected by document type and by phase of the development cycle | To know the overall quality of each work product |
| MET-02 | Number of hours worked for each phase of the system development cycle | To be able to use the performance of past projects to estimate new projects |
| MET-03 | The cost of each project | |
| MET-04 | The attributes of each project:<br>Number of change requests;<br>Level of risk;<br>Predominance hardware/software. | |
| MET-05 | Distribution of effort related to the production, review and correction of deliverables | To be able to analyze the efficiency of processes on product quality |
| MET-06 | Resources spent versus those that were planned in the project plan | To be able to analyze if the project is successful, to identify gaps and take the necessary remedial action |

An electronic time sheet has been established to record the number of hours worked on each work product of a project. The timesheet allows to classify efforts in 3 categories: efforts spent on the initial production of a work product, efforts spent on reviewing it and efforts spent on correcting identified defects. This data provides valuable information when improving a process.

**Traceability between work products**

ISO 29110 includes tasks to trace information between work products. Based on these tasks, a graphical representation was set up to show how traceability is generated between the various work products of CSiT. Only a few adjustments were made to the tasks of ISO 29110 to better reflect the context of CSiT:

- Traceability between unit tests and detailed design elements has been added.
- Traceability between the detailed design and architecture document has been defined as optional. This customization does not cause any problem for compliance with the standard since this type of traceability is not mentioned.
- Names of ISO 29110 documents have been adapted to fit documents' titles used by CSiT.

## Selection of tools to support the process

Selecting the right tools is essential to help a team carry out their tasks and meet the needs of the processes.

For systems engineering, one of the important tools selected was based on it being a complete tool and available at a reasonable cost. In addition, the team was already familiar with the tool since many of the members had used it in the past. The tool allows the team to do many systems engineering tasks such as:

- Requirements management and use cases
- Modeling, architecture and system design
- Traceability between components

In addition, the systems engineering tool was interfaced to a software development framework tool in order to have a more direct flow for traceability for the entire process.

With regard to software engineering, two main tools have been chosen. The first tool, a software development tool was selected because the programming languages were in line with the team's expertise and the business needs. The second tool, was chosen as a management tool for software development. The reasons that led to this choice are:

- Full integration between both software tools
- Allows to manage a software project with agile (that is to say it supports the notion of sprint, story, epics, features, tasks, story tests, definition of done, burn down chart)
- Manages defects
- Manages traceability between components
- Manages and control source files
- Allows the execution of code reviews
- Reasonable cost of purchase

For version control and configuration management, a common COTS tool was retained. The choice was based on the fact that this tool is a reliable configuration management tool and is used by many companies, including very large ones. Also, the tool is available for free, making it a tool of choice.

Finally, a standard office suite has been used for the production of project documents and spreadsheets. This tool is well known and mastered by the team and a lot of online resources, support and forums are available in case of problems.

## Definition of a Supplier Management Process

Since CSiT is a system integrator, the company uses suppliers for the purchase and development of components that will be used in a product. Therefore, it was imperative for CSiT to establish a supplier management process that defines how to work with them and to reduce project risks.

The SE Basic profile has only a few tasks about the 'make or buy' decisions and follow-up actions (e.g. document, review and issue a purchase order). Unfortunately, the current version of the SE Basic profile does not describe a supplier management process. This process is covered in the system and the software Intermediate profiles (ISO 2019b, ISO 2017a). The CMMI® for Development version 1.3 (SEI 2010) has been consulted, as well as ISO/IEC/IEEE 15288 (ISO 2015), the INCOSE Handbook (INCOSE 2015) and the PMBOK® Guide (PMI 2013).

The SE Intermediate profile of ISO 29110 provides a light Acquisition Management (AM) process (ISO 2019b). The purpose of the AM process is to obtain the work products and/or services that satisfy the need expressed by the VSE. This process, a conditional process, has to be executed if a VSE requires work products or services from an external supplier. If this is the case, this process is included in the scope of an audit or an assessment. Figure 6 shows the flow of information between the Acquisition Management process activities including the most relevant work products and their relationship.

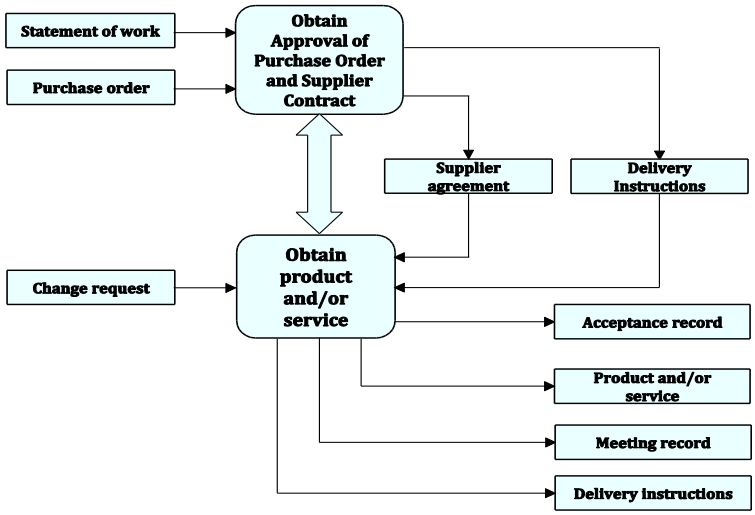


Figure 6. Acquisition Management process of ISO 29110 (ISO 2019b)

This process will probably be added, as a conditional process (i.e. process that may be mandatory under some specified conditions), in the next version of the SE Basic profile guide.

## Coverage between Frameworks

As mentioned earlier, the project goal was to implement ISO 29110 and to complement it with CMMI level 2 requirements. In order to determine the achievement of this objective,

an analysis of the coverage of CSiT processes was performed. This analysis was done in two stages. First, the correspondences between the CSiT processes with ISO 29110 have been defined. Then, connections between the processes of CSiT and those of CMMI were defined. These mappings have been represented graphically, as shown in Figure 7.

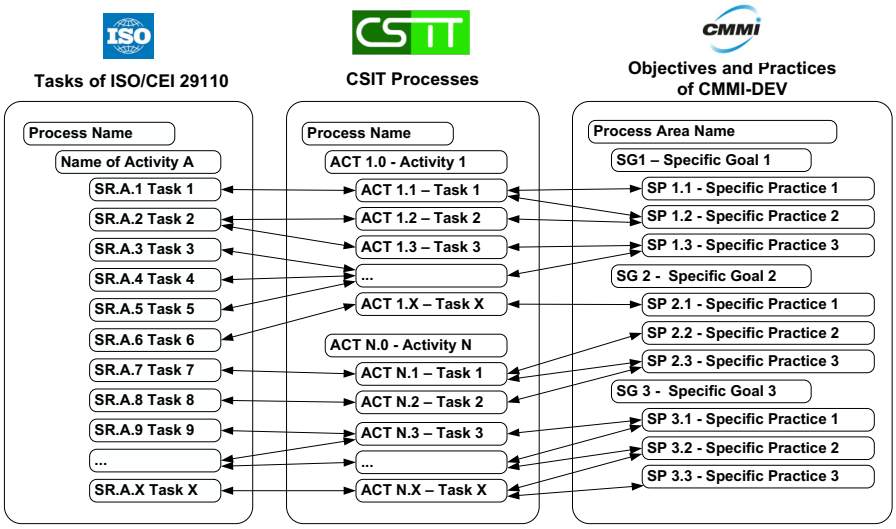


Figure 7. Mapping of CSiT processes

An analysis confirmed that the processes of CSiT fully cover the objectives and tasks of the processes defined in the Basic profile. During this analysis, mappings and tailoring have been documented. The analysis also shown that CSiT processes cover many specific practices of CMMI-DEV Maturity Levels 2 and 3 which means that the Basic Profile is a good starting point for the implementation of CMMI-DEV. CSiT is now adding the necessary practices to achieve CMMI-DEV Maturity Level 2 progressively as required by projects of customers.

Figure 8 illustrates the approximate coverage of ISO 29110 Basic profile to the CMMI® V1.3 Level 2 process areas (REQM means Requirements Management, PMC is Project Monitoring and Control, PP is Project Planning, CM is Configuration Management, PPQA is Process and Product Quality Assurance, SAM is Supplier Agreement Management and MA is Measurement and Analysis).

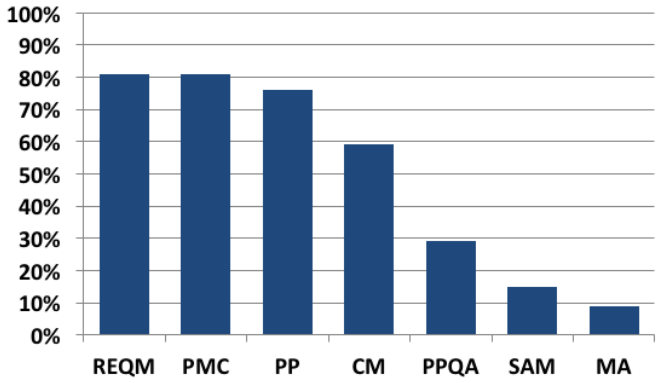


Figure 8. Approximate coverage of ISO 29110 Basic profile processes to CMMI-DEV, V 1.3 level 2 process areas

## Implementation of ISO 29110, Self-Assessment and Audit

In 2012, CSiT started the development of a product suite called 'TRANSIS'. TRANSIS is a multimodal information data integration system with interactive extensions for operators and users of public transport. This project was chosen to apply the processes and adjust them if necessary, ensuring a gradual adoption of the new work methods.

CSiT has tested the degree of implementation of its processes in its TRANSIS projects. To do this, the self-assessment score sheet of ISO 29110 (Laporte 2015c) was used. This score sheet was used to indicate the activities, tasks performed as well as the documents produced during a project and determine the level of coverage with the Basic profile.

In 2016, the systems engineering Basic Profile of the ISO 29110 was successfully audited by a third-party audit team composed of 2 independent auditors. One member of the audit team was a systems engineering domain expert. He has over 30 years of experience in government and commercial safety- and mission-critical software and systems engineering.

## Conduct of a Third-Party Audit

In 2016, CSiT was ready for a certification audit similar to ISO 9001 audits, but there was no audit scheme available for ISO 29110 in Canada. CSiT then decided to request the conduct, by external auditors, of a third-party audit. Project management and system engineering processes were within the scope.

The steps of the third-party audit are illustrated in Figure 9. Once an audit request is transmitted to an auditor, an analysis of documentation is performed to verify the readiness of the organization. Then, a written agreement is signed by both parties. This agreement describes, amongst other, the scope of the audit and the plan for the next steps (e.g. on-site audit). A confidentiality agreement is also signed by the auditor.

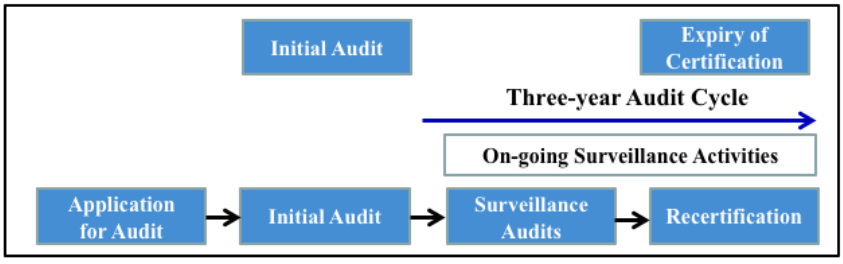


Figure 9. Third-Party Audit Cycle

**Results of audits**

The on-site audit, of 6 to 8 hours, has been conducted yearly since 2016 to review objective evidence such as processes and project specific documents (e.g. project plan, requirements specification, change request) and interview officers and employees of the VSE. Five people of CSiT participated to the interviews and provided answers and

requested evidences. Two projects were used to prove conformance to the SE Basic profile of ISO 29110. No non-conformance were identified, a few observations were noted and 5 best practices were noted by the audit team.

Among these best practices, there was the incorporation of quality gates in the project management process in order to decide whether a project is ready to continue to the next step. Also, there was the application of advanced system engineering techniques such as the development of a product line vision and the use of model-based requirements analysis techniques to develop and validate system requirements. Finally, the graphical representations of the processes was a strength because it was clear of who is doing what and at what time. Based on that, the auditors were of the opinion that the VSE demonstrated that it was well on the way to achieving the objectives of the Intermediate profile.

A letter was issued by the organization that manages the compliance program attesting the conformity based on ISO 29110 documents audited. The letter of compliance was subjected to a period of validity of one year.

Since the first audit, two other audits have taken place, one in 2017 and one in 2018. The process for these two audits were the same as for the first one. Again, CSiT successfully passed these audits, obtaining and maintaining its ISO 29110 certification. The next audit is planned for the end of 2019.

**Preparation and effort required for audits**

The preparation for the first audit lasted about 3 years. During this period, the project management and system engineering processes of ISO 29110 have been defined and adapted to the context of the company. Also, this period allowed the team to perform the activities and tasks required of both processes during projects generating the necessary evidences for the audit. Then, a self-assessment was done to ensure that the company met the requirements of the ISO 29110 standard and give the green light for the conduct of the audit. The preparation for the audit was done mainly during weekly quality meetings with key people in the process. Although the hours devoted to this work have not been officially recorded, the estimated effort for the preparation of the first audit is estimated between 800 and 1000 hours.

The effort for the second and third audits was less important than for the first audit. First, it included the time for performing the tasks and activities of the ISO 29110 standard in different projects as well as for producing the associated documents and deliverables. Second, it included the time to update and improve existing processes. This effort is estimated between 300 and 500 hours for each audit.

**Benefits of audits and ISO 29110 certification**

Holding a third-party audit each year allows CSiT to:

- Demonstrate the serious of the company's approach to its customers
- Ensure constant discipline in the way of working

- Improve the way of doing things based on the team's lessons learned as well as on the auditor's recommendations

Obtaining an ISO 29110 certification has led to many concrete benefits for CSiT. First, it has greatly helped the company to become an accredited suppliers of goods and services to one of the world's largest train operator (New York City Transit). Second, the ISO 29110 certification allowed CSiT to bid on an RFP of a European customer (Barcelona-based Transit operator) that required certification from one of the three following standards: CMMI® level 2, ISO/IEC/IEEE 15288 and ISO/IEC 29110.

In other words, the ISO 29110 certification has allowed CSiT to make market gains, have better visibility and above all, have better credibility with its customers.

## Benefits for CSiT

Standards are sources of codified knowledge. Many studies have demonstrated the benefits of standards, such as increased productivity and quality (Laporte & Chevalier 2016). As stated by Garcia « When an organization selects a standard that fits its context well, and plans the adoption thoughtfully, it's most likely to achieve the standard's advertised benefits » (Garcia 2005). Two categories of benefits observed by CSiT are listed in Table 6: observable benefits in day-to-day project activities and benefits to the VSE as a business.

Table 6: Day-to-Day Benefits and Business Benefits

| Day-to-Day Benefits | Business Benefits |
|---|---|
| - Standardized work and consistent deliverables across projects<br>- Avoids reinventing the wheel for each project<br>- Work is done in a systematic and disciplined way<br>- Better quality of deliverables and products<br>- Better project management and project monitoring<br>- Reduction of project risks<br>- Better communication within the team because the semantic of communication is standardized | - Better credibility to bid on tenders<br>- Access to markets that require certification of a quality system in line with the business practices of the company<br>- Better recognition of the quality of work done and products developed<br>- Better trust from customers and business partners<br>- An important step towards a maturity level of the CMMI®<br>  - a CMMI® level is a requirement for some customers |

## Lessons Learned

The initial approach at CSiT was to develop one process at a time, documenting it graphically and then textually. The problem is that by doing so, the interactions between processes were not considered. Therefore, when a new process was developed, the team could discover that the already described processes should be modified to better reflect this new process. At some point of the improvement project, it was decided to document

all processes in a graphical representation before documenting the textual version of each process. This approach had two advantages. First, it helped to get the big picture of the processes and their interactions. Also, it enabled the team to use and apply these processes faster in a pilot project and determine whether the activities and tasks defined in the process were relevant and if some were missing. The textual description of the process was resumed as soon as the interactions between processes were better defined and the description of activities and tasks of the process was more stable.

It was also learned that processes could be represented graphically in a simple way. Although there are many specialized tools on the market and many process modeling standards, these tools were too "heavy" for the needs of a VSE. A tool such as the Microsoft Visio tool was sufficient to document processes as a set of flowcharts.

A document standardizing the terms used should be developed and maintained. It was found that even if two terms that are similar could be considered as synonyms, it could create some confusion. For example, the terms "architecture" and "design" are similar to the extent that they represent how a system is designed or is a solution to a given problem. Some people might interchange the words, but fundamentally each of them represents a different concept. The architecture is the high-level structure of a system, its elements and their relationships while the design describes, amongst others, the detailed implementation-level physical structure, behaviour, temporal relationships of the elements of a system. A control of the terminology used in the business domain of an organization and by its customers is essential.

## Next steps

CSiT will focus on the following points in the coming year:

**1- Take additional measures to improve decision-making**

As mentioned earlier, basic measures allow the team, project manager and management to make general decisions about project execution. However, these measures could be complemented with more advanced measures for better decision-making. Work sessions are planned to identify these measures that will help making more specific decisions. The goal is to be able to generate these measures automatically, or almost, using the right tools so that the team can continue to be dedicated to their tasks and deliver results to customers.

**2- Improve business processes**

As part of the ongoing process improvement activities CSiT will continue to improve its processes based on the feedback and lessons learned gathered from completed projects as well as adapting processes and templates to better match different types of project. Also, a new tool will be evaluated in order to facilitate the access to the processes via the company’s intranet.

**3- Prepare for the next audit**

The utilization of the processes by all employees is reinforced by an organizational policy mandating an annual third-party audit. A fourth third-party surveillance audit will be conducted in 2019 with the same auditors as for the first audit.

## Implementation of ISO 29110 in 6 enterprises of France

In 2018, AFIS, the French Systems Engineering association and the French government funded a 24-month project where a team of 8 experts, members of the AFIS and INCOSE, helped 6 enterprises, located in the south of France, in implementing SE processes. The systems engineering and management processes of the Basic profile of ISO 29110 have been implemented (Galinier & Laporte 2018). The selected enterprises are operating in a wide range of domains such as automotive, space and agriculture, and their size ranges from 10 to 150 people as illustrated in Table 7.

Table 7: SMEs involved in the pilot project (Galinier & Laporte 2018)

| Domain | Size (Number of people) | Main product or service | Year established |
|---|---|---|---|
| Space | 70 | Spacecraft structural subsystems | 1994 |
| Agriculture | 10 | Farming robotics | 2016 |
| Nuclear | 150 | Electricity and ventilation engineering | 2007 |
| Aeronautics | 20 | Drone inspection services | 2015 |
| Nuclear | 10 | Nuclear dismantling simulation | 2010 |
| Automotive | 20 | Embedded electronic systems | 2003 |

The lessons learned sessions conducted with the enterprises showed how these processes helped the SMEs to understand the benefits of Systems Engineering for their business development, to embrace a bigger point of view and understand how their business environment changes.

The pilot projects will be described in more details in the English version of the French Systems Engineering book (Galinier et al. 2017) for SMEs and VSEs, titled “Systems Engineering Practices for SMEs”, that is planned to be published by John Wiley and Sons in 2019.

## Conclusion

This article has presented the development and the implementation of management and engineering processes at CSiT using mainly the ISO 29110 for systems engineering. ISO 29110 has greatly facilitated this work because it describes in detail the processes that must be documented and implemented.

It was easy for CSiT to adapt ISO 29110 to its business context. ISO 29110 helped implementing lightweight processes. This way CSiT remains a flexible organization.

ISO 29110 helped raise the organization's maturity by using industry-recognized practices that are consistent from project to project. It can be said that the standard is simple to understand and use. It is also a good starting point for a VSE that wants to cover CMMI-DEV Levels 2 and 3 practices. It enables VSEs, such as CSiT, to become more mature more rapidly by adopting systematic, disciplined and quantifiable methods of work, which are typical of engineering environments.

Finally, to illustrate the implementation of ISO 29110 in other engineering domains, we briefly presented the implementation of ISO 29110 in 6 enterprises of France.

## Additional Information

The following Web site provides more information, as well as articles by WG24 members and deployment packages for system and software engineering in English, French and Spanish:

http://profs.logti.etsmtl.ca/claporte/English/VSE/index.html

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# Biography

Nicolas Tremblay has guided the implementation of ISO/IEC 29110 at CSiT. His project management and process development skills as well as its knowledge of CMMI® and ISO environments have been important resources for the execution of the project. He holds a bachelor's degree in software engineering and a Master's degree in Project Management from the École de technologie supérieure. He has several years of experience in software and system engineering. He has worked in medical and aeronautics industry, in small and large organizations. He has contributed to the review of the management and engineering guide of ISO/IEC 29110 and the development of support tools including the deployment packages. He is a member of the professional association of engineers of the Province of Québec (*Ordre des ingénieurs du Québec*), INCOSE and of Project Management Institute (PMI).

Dr. Claude Y. Laporte has been a professor since 2000 at the École de technologie supérieure (ÉTS), a 10,000-student engineering school, where he teaches software engineering. His research interests include software process improvement in small and very small enterprises, as well as software quality assurance. He has worked in defense and transportation enterprises for over 20 years. He received a Master's degree in Physics from the Université de Montréal, a Master's degree in Applied Sciences from the École Polytechnique de Montréal and a Ph.D. from the Université de Bretagne Occidentale (France). He was awarded an honorary doctorate by the *Universidad de San Martin de Porres* of Peru in 2013. He is the Lead Editor of ISO/IEC JTC1 SC7 Working Group 24, tasked to develop ISO/IEC 29110 life cycle standards and guides for Very Small Entities. He is the Co-chair of the INCOSE Systems Engineering for Very Small Entities WG. He is a member of INCOSE, IEEE, PMI and has been a member of the professional association of engineers of the Province of Québec. He is the co-author of two French books on software quality assurance published in 2011 by Hermes Science-Lavoisier and one English textbook, on the same topic, published by John Wiley and Sons in 2018. Dr. Laporte is a co-author of a French book, published in 2017, targeted at managers of small systems engineering organizations. An English and updated version, titled 'Systems Engineering Practices for SMEs' should be published by John Wiley and Sons in 2019.

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Jamil Menaceur is technical director at CSiT, a Montreal company specializing in system integration and software design for Communications and Security systems in transit industry. He has over 30 years experience in electronic design, software and mechanics. Fifteen years ago, he seized the opportunity to combine his knowledge to become a system specialist. He worked for Wang, IBM and

ALSTOM without forgetting some start-up companies such as Dip Systemes (Paris), ParcoFlex (Montreal), Micral (Algiers) and General Engineering (Constantine). He holds a degree in engineering from the University Mentouri, Constantine.

Denis Poliquin is president at CSiT, a Montreal company specializing in system integration and software design for Communications and Security systems in transit industry. His experience includes responsibilities related to systems engineering, marketing, management of marketing, marketing on a global scale as well as general management. He spent over 25 years in the information technology industry focused on large system integration projects. He is a member of the Professional Engineers of Ontario for over 20 years.

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