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CAMPUS DE EXCELENCIA INTERNACIONAL

DOCTOR OF PHILOSOPHY (Ph.D.) THESIS

Survival analysis and classification study of software process improvement initiatives and their implications in small companies.

DOKTOREGO-TESIA

Software prozesuen hobekuntzarako ekimenen biziraupen-analisia eta sailkapen-ikasketa, eta horien ondorioak enpresa txikietan

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INDEX // AURKIBIDE

Figure Index // Irudien Aurkibidea:

Table Index // Taulen Aurkibidea:

Doktorego-tesiko argitalpenen zerrenda:

A) Tesiaren oinarria diren lau artikulu nagusiak:

A.1 ARTIKULUA:

(Q2 Computer Science, Software Engineering-Impact Factor: 1.465)

"A Mapping Study about the Standard ISO/IEC29110."

Xabier Larrucea, and Borja Fernandez-Gauna.

Computer Standards & Interfaces, April 2019. https://doi.org/10.1016/j.csi.2019.03.005.

A.2 ARTIKULUA:

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"Survival Studies Based on ISO/IEC29110: Industrial Experiences."

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Computer Standards & Interfaces 60 (November 2018): 73–79. https://doi.org/10.1016/j.csi.2018.04.006.

A.3 ARTIKULUA:

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"Correlations Study and Clustering from SPI Experiences in Small Settings."

Xabier Larrucea, and Izaskun Santamaría.

Journal of Software: Evolution and Process, September 12, 2018, e1989. https://doi.org/10.1002/smr.1989.

A.4 ARTIKULUA:

(Q3 Computer Science, Software Engineering -Impact Factor: 1.167)

"Managing Security Debt across PLC phases in a VSE context."

Xabier Larrucea, Izaskun Santamaria and Borja Fernandez-Gauna. *Journal of Software: Evolution and Process*, https://doi.org/10.1002/smr.2214

B) Aldizkarietako artikulu osagarriak

(Q1 Computer Science, Software Engineering -Impact Factor: 2,547)
Xabier Larrucea, Rory V. O'Connor, Ricardo Colomo-Palacios, and Claude Y. Laporte. "Software Process Improvement in Very Small Organizations." IEEE Software 33, no. 2 (March 2016): 85–89. https://doi.org/10.1109/MS.2016.42.

C) Konferentziako artikuluak

X. Larrucea, F. Nanclares, I. Santamaria, and R. R. Nolasco, "Approach for Enabling Security Across PLC Phases: An Industrial Use Case," in *Systems, Software and Services Process Improvement*, vol. 896, X. Larrucea, I. Santamaria, R. V. O'Connor, and R. Messnarz, Eds. Cham: Springer International Publishing, 2018, pp. 354–367.

M.-L. Sánchez-Gordón, R. Colomo-Palacios, A. Sánchez, A. de Amescua Seco, and X. Larrucea, "Towards the Integration of Security Practices in the Software Implementation Process of ISO/IEC 29110: A Mapping," in *Systems, Software and Services Process Improvement*, vol. 748, J. Stolfa, S. Stolfa, R. V. O'Connor, and R. Messnarz, Eds. Cham: Springer International Publishing, 2017, pp. 3–14.

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D) Liburuak

Larrucea, Xabier, Izaskun Santamaria, Rory V. O'Connor, and Richard Messnarz, eds. Systems, Software and Services Process Improvement: 25th European Conference, EuroSPI 2018, Bilbao, Spain, September 5-7, 2018, Proceedings. Vol. 896. Communications in Computer and Information Science. Cham: Springer International Publishing, 2018. https://doi.org/10.1007/978-3-319-97925-0.

1 Laburpena // Abstract

(BASQUE / EUSKARAZ)

Softwareak funtsezko papera dauka negozio gehienetan. Hain zuzen ere, edozein negozioren abantaila lehiakorraren gako nagusietako bat dela esan daiteke. Software hori enpresa handi, ertain edo txikiek sor dezakete. Testuinguru horretan, erakunde mota horiek prozesuak hobetzeko ekimenak martxan jartzeko hautua egiten dute, merkatuan eskaintzen dituzten zerbitzuen edo azken produktuen kalitatea hobetzeko helburuarekin. Hortaz, ohikoa izaten da enpresa handi eta ertainek azken produktuen garapen-prozesuak zehaztea, are eredugarriak diren kalitate-ereduak erabiltzea, industriatik eratorritako jardunbide egokiekin. Izan ere, hobekuntza-ekimen bat aurrera eramaten laguntzeko erreferentziazko eredu eta estandar asko daude. Hortaz, erakundeek hainbat eredutako eskakizunak bete behar izaten dituzte aldi berean. Estandar horien barruan antzekoak diren praktika edo eskakizunak egon ohi dira (bikoiztasunak), edo neurri handiko erakundeentzat pentsatuta daudenak. Erakunde txikien esparruan, bikoiztasun horiek gainkostua eragiten dute ekimen hauetan. Horren ondorioz, erreferentziazko ereduekin loturiko prozesuak zehazteko orduan, burokrazia-lana handitu egiten da. Horrez gain, eredu hauen bikoiztasunak ezabatzera eta bere prozesuak hainbat arau aldi berean aintzat hartuta berraztertzera behartzen ditu.

Egoera hori bereziki delikatua da 25 langiletik behera dituzten erakunde txikientzat, *Very Small Entities* (VSE) izenez ere ezagunak direnak. Erakunde mota hauek ahal duten modurik onenean erabiltzen dituzte haien baliabideak, eta, haien ikuspegitik, erreferentziazko eredu hauek gastu bat dira inbertsio bat baino gehiago. Hortaz, ez dute prozesuak hobetzeko ekimenik martxan jartzen. Ildo horretatik, erakunde horiei VSE-en beharretara egokituko zen eredu bat eskaintzeko sortu zen ISO/IEC 29110.

ISO/IEC 29110 arauaren lehen edizioa 2011n sortu zen eta, ordutik, zenbait ikerketa-lan eta industria-esperientzia garatu dira testuinguru horren barruan. Batetik, ez dago VSE-ekin loturik dauden nahikoa industria-esperientzia, eta, beraz, ez da erraza jakitea zein den VSE-en portaera. 2011tik, ISO/IEC29110 arauarekin zerikusia duten hainbat lan argitaratu dira, baina, orain arte, lan horien tipologia oso desberdina izan da. Horrenbestez, ezinbestekoa da lehen esperientzia hauek aztertu eta ezagutzea, egindako lehen lan horiek sailkatu ahal izateko. Bestetik, prozesuak hobetzeko ekimenek ez dute beti arrakastarik izaten, eta mota honetako ekimen baten iraupena zein izango den ere ez da gauza ziurra izaten. Hartara, ekimen hauek testuinguru hauetan daukaten biziraupen maila zein den aztertu behar da, bai eta VSE-etan prozesuak hobetzeko ekimenak garatu eta ezarri bitartean eman daitezkeen lan-ereduak identifikatzea ere. Azkenik, garatzen dituzten produktuen segurtasun-arloarekin kezka berezia izan ohi dute VSEk. Hortaz, segurtasun-alderdi nagusiak kudeatzeko mekanismoak ezarri behar izaten dituzte.

Lehenik eta behin, lan honetan, ISO/IEC 29110 arauarekin loturiko artikuluen azterketa metodiko bat egin dugu, eta ikerketa-esparru nagusiak eta egindako lan mota garrantzitsuenak jaso ditugu. Bigarrenik, VSEk prozesuak hobetzeko martxan jarritako mota honetako ekimenen biziraupena aztertzeko marko bat proposatu dugu. Hirugarrenik, haien portaeraren ezaugarriak zehazteko, ekimen hauetan ematen diren ereduak identifikatzeko ikuspegia landu dugu. Laugarrenik, VSEn softwarearen garapenaren bizi-zikloan segurtasun-arloko alderdiak gehitzeko eta zor teknikoa kudeatzeko proposamena egin dugu.

(ENGLISH / INGELESEZ)

Software plays a key role in most of the businesses. In fact, software is considered as a key factor for the competitive advantage in any business. This software is produced by

large, medium and small sized organisations. In this context, this type of organisations decides to embark on software process initiatives in order to improve the quality of their final products and services offered in a market. Therefore, medium and large organisations use to define their development processes of the final products, and even they use quality models as reference models prescribing Good practices stemming from the industry. In fact, there are a lot of reference models and standards that can be used as a reference for starting an improvement initiative, and therefore, organisations are forced to fulfil requirements from various reference models/standards at the same time. These standards include practices and requirements that are quite similar (duplicities) among them, and use to be focused on large organisations' needs.

In the context of small organisations, these duplicities imply an over cost for carrying out these initiatives. This leads an increase of bureaucracy during the definition of processes related to these reference models. In addition, they are forced to assess duplicities, and to finally re-evaluate their processes with respect to several reference models at the same time. This situation is especially critical for the so-called *Very Small Entities* (VSE) which are organisations with less than 25 workers. This type of organisations does not have enough resources to be invested on these initiatives, and they use to perceive them as a cost instead of as an investment. Therefore, they do not embark on these process improvement initiatives. In this sense, ISO/IEC29110 was created with the objective to facilitate/ease and to offer an appropriate model for VSEs' needs. The first ISO/IEC29110 release was in 2011, and since then several research works and experiences have been reported in this context.

On one hand, there are not enough industrial experiences related to VSEs, and it is hard to figure out how they behave. Since 2011, some research works related to ISO/IEC29110 have been published, but until now the type of research is diverse. On the other hand, process improvement initiatives are not always successful and there is no a clear idea of how much time this kind of initiatives will require. In this sense, it is really necessary to analyse the survivability of these initiatives in VSEs' context, and even the identification of potential patterns during the development and implementation of VSEs' process improvement initiatives. Finally, VSEs are more and more worried about security concerns and its implications to products development. Therefore, mechanisms must be set up in order to manage the related security aspects

Firstly, this thesis analyses from a systematic and methodological way the published literature related to ISO/IEC 29110 stressing the main research areas, and the main types of research carried out. Secondly, I propose a framework for analysing survivability of this process improvement initiatives carried out by VSEs. Thirdly, in order to characterise their behaviour, I propose an approach for identifying patterns. Fourthly, I propose an approach for adding security concerns while developing a software system, and for considering technical debt within the VSEs' context.

2 Sarrera eta Aurrekariak//

Introduction and Background

2.1 Tesiaren jatorria

Erakundeek, batez ere VSEk, prozesuak hobetzeko lana nola egiten duten hainbat urtez aztertu ondoren prestatu da lan hau. Azterketa horren emaitzak erakunde mota horren mugak eta aukerak identifikatzen dituen azterlan batean jaso ziren [1]. Funtsean, mota honetako erakunde batek hobekuntza-ekimenen bat martxan jartzea erabakitzen duenean, hainbat galdera datozkio burura: Zenbat denbora beharko da ekimena ezartzeko? Arrakastatsua izango da? Zeintzuk izango dira onurak? Erakunde txikien beharretara egokitutako ereduak daude? Segurtasunarekin zerikusia duten jarduerak gehitu ditzakegu, eredu horiekin bateragarriak direnak?

Hori guztia aintzat hartuta, VSE-en testuinguru berezi hau ulertzea eta mahai gainean jarritako helburuak betetzea xede duen lan bat proposatu dut. Horrez gain, ISO/IEC 29110 arauaren editore nagusiek gainbegiratu dute azterlana.

2.2 ISO/IEC29110

Gaur egun, softwarea garatzen duten erakundeek hamaika erronkari aurre egin behar diete, gero eta lehiakorragoa den merkatuan bizirauteko. Testuinguru horretan, erakunde mota horiek prozesuak hobetzeko ekimenak martxan jartzeko hautua egiten dute, merkatuan eskaintzen dituzten zerbitzuen edo produktuen kalitatea hobetzeko helburuarekin. Izan ere, hobekuntza-ekimen bat aurrera eramateko orduan, erreferentziazko eredu eta estandar asko daude. Hortaz, erakundeek hainbat eredutako eskakizunak bete behar izaten dituzte aldi berean. Gainera, arau horiek antzeko jardun edo eskakizunak jasotzen dituzte, eta, beraz, erakundeen ahaleginak biderkatu eta prozedura burokratikoak handitu egiten dira. Maiz, prozesuak hainbat arau aldi berean aintzat hartuta berriro ebaluatzeko lanak hartzen dituzte erakunde askok.

Egoera hori bereziki delikatua da 25 langiletik behera dituzten erakunde txikientzat, *Very Small Entities* (VSE) izenez ere ezagunak direnak. Erakunde mota horiek ahal duten modurik onenean erabiltzen dituzte haien baliabideak, eta, haien ikuspegitik, erreferentziazko eredu hauek gastu bat dira inbertsio bat baino gehiago. Hortaz, ez dute prozesuak hobetzeko ekimenik martxan jartzen. Erakunde horiei VSE-en beharretara egokituko zen eredu bat eskaintzeko sortu zen ISO/IEC 29110.

ISO/IEC 29110 arauaren lehen edizioa 2011n sortu zen eta, ordutik, zenbait ikerketa-lan eta industria-esperientzia garatu dira testuinguru horren barruan. Batetik, ez dago VSEtan nahikoa esperientzia industrian, hainbat erreferentziazko eredu aldi berean aintzat hartuta, ISO/IEC29110 araua barne. Hortaz, lehen esperientzia hauek azaldu beharra dago (Figure - 1 - Irudia). Bestetik, prozesuak hobetzeko ekimenek ez dute beti arrakastarik izaten, eta mota honetako ekimen baten iraupena zein izango den ere ez da gauza ziurra izaten. Kalkulu eta aurreikuspen horiek aholkularitza-enpresen iritzi subjektiboak izan ohi dira. Hartara, testuinguru berezietan, hala nola VSE-en kasuan, ekimen hauen biziraupena zein den aztertu beharra dago. VSE-etan prozesuak hobetzeko ekimenak garatu eta ezartzeko orduan sor daitezkeen ereduak identifikatzen baditugu, hainbat arlotako aurreikuspenak hobetzeko aukera izango genuke, hala nola: beharrezko baliabideak, erabili beharreko denborak edo lortutako etekinak, besteak beste.

Aurkeztutako lanak [1], hain zuzen ere, VSE-etan ISO/IEC29110 arauaren betetze-maila zein den ezagutzeko aukera ematen du. Kalitatearen bermea, arkitektura eta diseinuarekin loturiko alderdiak eta software osagaien eremua kontuan hartu beharreko alderdiak dira, eta arreta berezia jarri behar zaie.

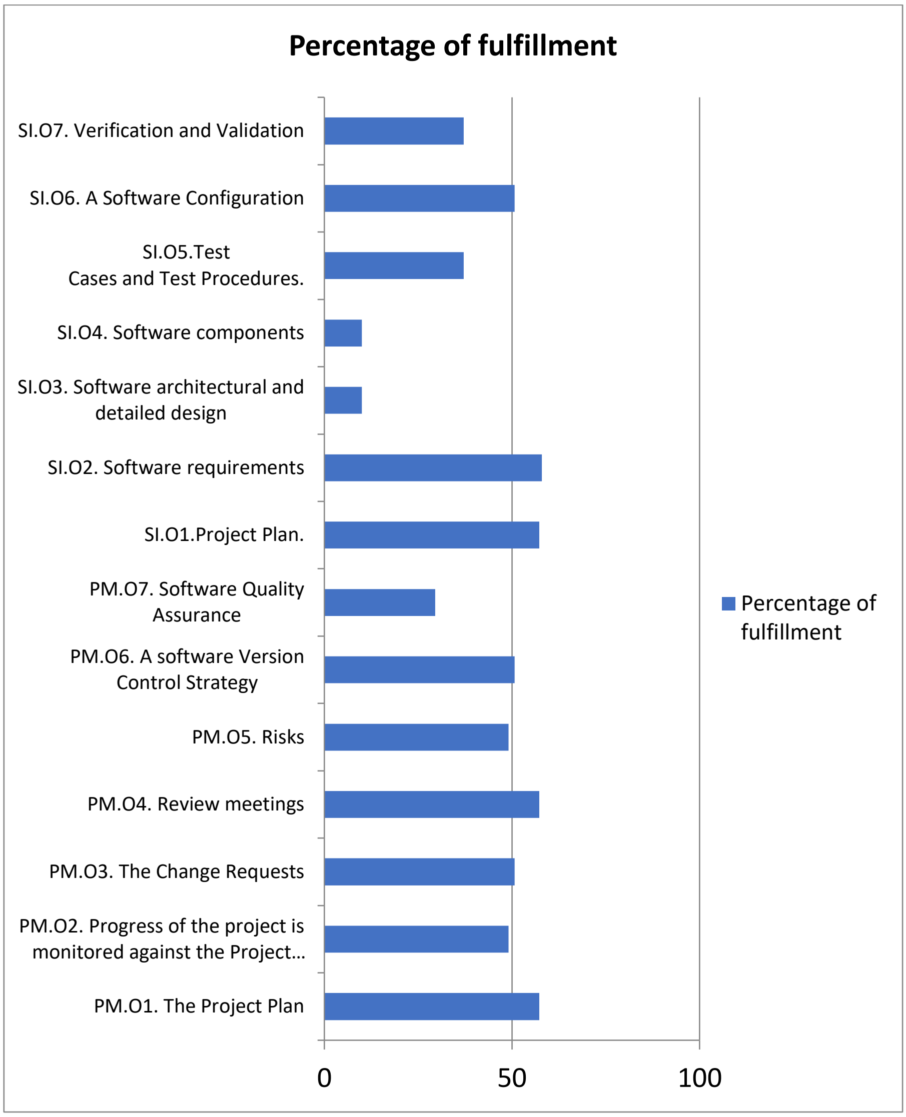

Figure - 1 - Irudia VSE-etan ISO/IEC29110 arauaren betetze-maila [1]

Testuinguru industrialean zenbait esperientziaren berri eman da [2]–[6] ISO/IEC 29110 arauaren aplikazioan [7]. Arauaren erabilera ([8], [9]) eztabaidagarria da, eta zenbait ikertzailek ekarpenak egin dituzte hainbat ikuspegitatik [10]. Proiektuen kudeaketaren ikuspegitik eta ezarpenaren ikuspegitik, erakunde mota hauek hainbat oztopo izaten dituzte [1]. Softwarearen garapenarekin, egiaztatzearekin, balioztatzearekin, probakasuekin, proben prozedurekin, softwarearen osagaiekin eta software arkitekturaren diseinu zehatzarekin zerikusia izaten dute oztopo eta ahulgune horietako batzuk [1]. Are, estandarren ezarpena ere arazo bat izan ohi da erakunde txikientzat [11]. Prozesuen hobekuntzaren testuinguruan lan ugari egin dira [12]–[15].

2.3 ISO/IEC29110 arauari buruzko atariko azterlanak

ISO/IEC29110 arauari buruz egindako lanak aztertzeko helburuz, azterlan honetan *Systematic Mapping* (SM) [16] bat garatu dugu, *Systematic Literature Reviews* (SLR) [17] lanetan egiten denaren antzekoa. Ikuspuntu horietan ezinbestekoa izaten da argitaratutako artikuluen gaineko ikuspegi metodologiko eta sistematiko bat aplikatzea. Ikuspuntu mota hauek hainbat arlotan erabili dira, esate baterako, ezagutzaren kudeaketarekin loturiko lanak berrikusteko [18], softwarearen ingeniaritzan *case based reasoning* ikuspegiak aztertzeko [19] edo are *text mining*-aren testuinguruan [20]. Horrez gain, SMa SPI (*Software Process Improvement*) testuinguruetan ere aplikatu da [21], eta hainbat ikerketa-artikulu SLRekin bat datoz ([22], [23]). Ikuspuntu horiek ezagutza-arlo edo esparruren batean gabeziak identifikatzeko erabili dira, hala nola segurtasun-arloko ingeniaritzan [16]. SM eta SLRek datu-baseetatik ateratako datuak kategorizatzeko sailkapen-eskema desberdinak erabiltzen dituzte. Esate baterako, [24] horren pareko sailkapen-eskema tradizional batek honako azterlan mota hauek identifikatzen ditu: *Validation Research, Evaluation Research, Solution Proposal, Philosophical Papers, Opinion Papers, Experience Papers*. Beste ikuspuntu batzuek sailkapen-sistema bateratu bat erabiltzen dute [25], eta [21] horren moduko beste sailkapen-sistema batzuk daude; egileek honako irizpide hauek identifikatzen dituzte bertan: Antolakuntza, Finantza-baliabideak, Giza baliabideak, prozesuak, proiektuak, ereduak eta estandarrak. Osagai horiek guztiak erakunde txikien bidean agertzen diren arazo zehatzen laburbilduma dira. Horrekin batera, osagai bakoitzeko, ezaugarrien zerrenda bat jaso da.

ISO/IEC 29110 arauaren familiaren estandarrak esanguratsuak dira lan honetan guztian, VSE-en beharretara egokitzen baitira. Lan hau idazteko orduan (2019ko maiatzaren 8an), guztira 17 arau eta berri-emate tekniko daude ISO/IEC29110 sailaren barruan, eta garapen-fasean beste 3 daude.

ISO/IEC JTC 1/SC 7 *Software and systems engineering group* izeneko batzordeak zehaztu du arau hau, eta estandarra 5 ataletan banatu du:

- ISO/IEC TR 29110-1 [26]: ISO/IEC 29110 sailen zehaztapen komunak zehazten ditu.
- ISO/IEC 29110-2 [27]: markoaren eta taxonomiaren kontzeptuak jasotzen ditu.
- ISO/IEC TR 29110-3-1 [28]: ebaluazio-gidak eta betetze-eskakizunak zehazten ditu.
- ISO/IEC 29110-4-1 [29]: *Generic Profile Group* izenekoa zehazten du profil guztietarako. Izan ere, oinarrizko profila eskaintzen du.
- ISO/IEC 29110-5-1 [30]: bitarteko profilaren kudeaketa eta ingeniaritza-gida eskaintzen du, negozioaren kudeaketa, proiektuen kudeaketa, softwarearen garapena eta eskuratze-prozesuaren arabera zehaztuta.

Arau hauekin zerikusia duten artikulu askok SM erabili edo zehazten dute [31], zer argitaratu den aztertzeko. Beste lan batzuk ISO/IEC 29110 [13] arauaren eragina modu orokorrean neurtzen dute. Ildo horretatik, orain arte SM bat [32] argitaratu da, baina ez du eskaintzen espero den analisia argitaratutako lan motei edo ekarpen motei buruz, besteak beste. Beste arlo batzuetan ohikoa den moduan, askotariko ekarpenak daude, eta arauaren alderdi osagarriak aztertzen dituzte, hala nola segurtasun-praktikak [33]. Beste ekarpen batzuen ardatz nagusiak ebaluazioarekin loturiko alderdiak dira [34], baina horien datu errealak oso eskasak dira.

Profilen sorrera arau horren ezaugarri berezi bat da, eta arlo interesgarria da, erakunde bakoitzarentzako erreferentzia-eredu zehatz bat zehazteko aukera eskaintzen baitu.

2.4 Biziraupen metodoak

Biziraupen metodoak [35] metodo estatistikoen esparruan zehazten dira, eta hainbat arlotan aplikatzen dira, hala nola osasunean [36], gaixotasun baten aurrean daukagun biziraupen denbora kalkulatzeko, edo baita ekonomian [37] ere. Normalean, gertaera jakin bat eman arte igaro beharreko denborarekin loturiko behaketen ingurukoak dira biziraupen datuak [38]. Prozesuak hobetzeko ekimenak aztertzen ditugunean, ebaluatzen erabilitako denbora aztertu nahi dugu, arauak zehazten duenarekin alderatuta. Biziraupen denbora (*survival time*) erreferentzia-ereduak zehaztutako eskakizun guztiak bete arte erakundeak erabili duen denbora da, emaitza onuragarria izan ala ez.

Ikuspuntu hau [39] horren parekoa da. Bertan, biziraupen denbora gertakari positibo bat da, eta iraupena gertakari hori gertatu bitartekoa da. Tradizioari begiratuta, metodo hauek ikuspegi parametrikoak (*lognormal, Weibull*), ez-parametrikoak (*Kaplan-Meier*) edo erdi-parametrikoak (*Cox Proportional Hazard Regression model*) barne hartzen dituzte. Lan honetan *Cox Proportional Hazard Regression* (CPHR) izeneko ikuspegi erdi-parametriko bat erabili dugu, aztertu beharreko gertakariaren banaketa ezaguna delako, eta gertakaria gauzatu arte erabilitako denbora ez delako osorik behatzen. CPHR denboraren mendeko aldagaiak datu kategorikoekin nahasten dituen eredua da, hain zuzen ere.

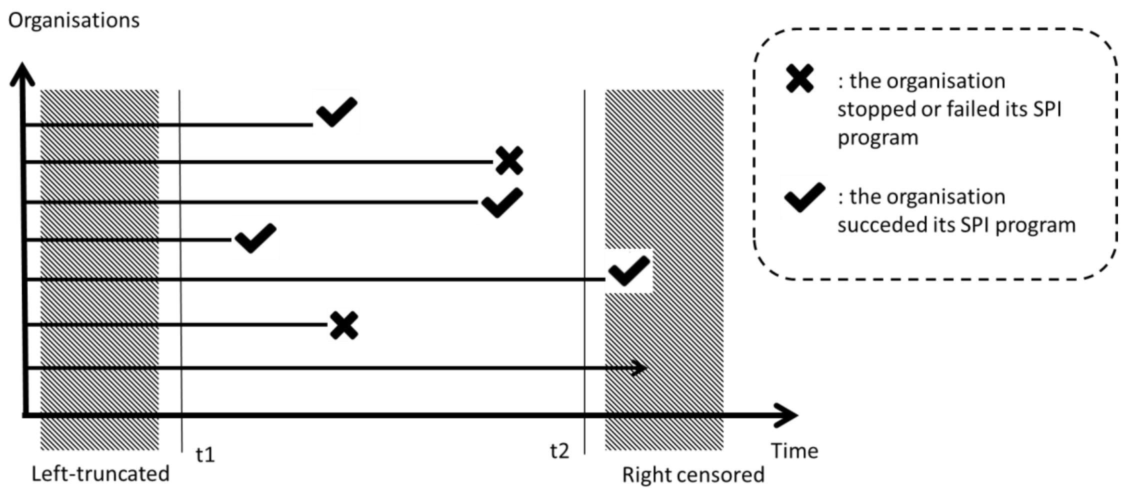

Figure - 2 - Irudia Gertaera motak

VSE-en prozesuak hobetzeko gure testuinguru honetan, ebaluazioak denbora-tarte jakin batean egiten dira. Ohikoa izaten da zenbait ekimen bertan behera uztea edo huts egitea behaketa egiten den epealdi horretan. Hortaz, azterlanaren tarteen mugetatik kanpo egongo diren *censored* datuak izango ditugu. Azterketaren epealdia baino lehen ematen diren gertakariei *left truncated data* esaten zaie, eta azterketaren epealdiaren ondoren gertatzen direnen, aldiz, *right censored data*.

Gure kasuan, ISO/IEC 29110 araua eta VSE-ek prozesuak hobetzeko ekimen bat martxan jartzeko erabilitako denbora aztertu ditugu.

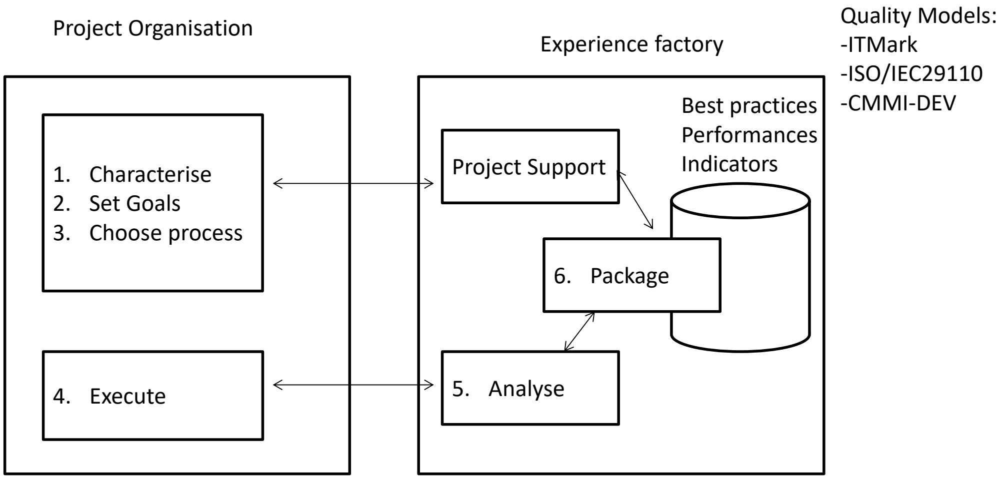

Figure - 3 - Irudia Tecnalia VSEs-en esperientzien ikerketa-metodo enpirikoa [51]

2.5 *Clustering*

Self Organising Maps (SOM) mapak Kohonen-ek erabili zituen lehenengo aldiz [40], eta geroztik, hainbat aldiz erabili izan da metodo hori [41]. SOM *feedforward* sare neuronal bat da, eta *unsupervised neural networks* sailkapenaren barruan dago.

Gainbegiratu gabeko ikaskuntza mota hau gure testuinguruaren beharretara egokitzen da, aurretik hura osatzen duten klaseak zeintzuk diren ezezaguna zaigulako. Horrek esan nahi du ez dakigula zeintzuk diren software prozesuen hobekuntzen kategoriak. NN horiek ingurune desberdinetan ereduak ateratzeko erabili izan dira, hala nola [42] horretan, non egileek SOM erabiltzen duten larrialdien sail batean oheen erabilgarritasuna planifikatzeko.

Gainbegiratu gabeko sare neuronal hauek sareak kudeatzeko [43], bidegabeko sarrerak detektatzeko [44] edo hornidura-katean elikagai galkorren tenperatura aurreikusteko [45] ere erabili izan dira.

Lan honen helburua ez da SOM algoritmo berri bat eskaintzea, baizik eta ikuspuntu hori erabiltzea, prozesuak hobetzeko testuinguruetako ereduak identifikatzeko. Hain zuzen ere, lan honetan proposatzen den ikuspuntua [46] horren antzekoa da; bertan, egileek,SOMen erabileraren bidez, akatsak aurreikusi nahi dituzte. Nire kasuan, prozesuak hobetzeko ekimenak ezagutu eta ezaugarritzeko erabiliko da SOM, batez ere arrakastatsuak diren ala ez jakiteko. Azterlan honen testuinguruan, hainbat parametro erabiliko dira gainbegiratu gabeko sareetara sartzeko. Kohonenek hemen [47] aipatzen duenez, SOM ez da beti zuzen aplikatzen, eta, gainera, SOM ez zen sortu eredu estatistikoak antzemateko. SOM batez ere *clustering*, bistaratze eta abstrakziorako erabiltzen da, eta horrela ere erabili da lan honetan. Norbaitek erabakitze eta sailkatze-prozesuak ezarri nahi baditu, *Learning Vector Quantification* (LVQ) erabili beharko du.

2.6 Software garapenaren bizi-zikloa eta zor teknikoa

Software garapenaren bizi-zikloan gertatzen dena funtsezkoa da edozein erakundetan, lortuko den produktuaren kalitatean zuzeneko eragina daukalako. Edozein erakundetan, bizi-zikloak hainbat fase ditu eta sail ugariri eragiten die aldi berean, hortaz, koordinazioa ezinbestekoa izaten da. Prozesua hobetzeko ekimen batean, eskaintzen dituzten produktu edo zerbitzuekin loturiko prozesu guztiak identifikatu eta zehazten dituzte erakundeek, eta bizi-zikloak funtsezko papera betetzen du hor. Gaur egun, ISO/IEC 12207:2008 eta bestelako marko estandarizatuak ditugu bizi-zikloa definitzeko. Hala ere, bi arazo identifikatu dira:

- Marko honen barruan jarduera gehiegi daude VSE-en testuingururako.
- Marko honen barruan segurtasun-arloko alderdiak ez daude berariaz jasota.

Hain zuzen ere, VSEk ez dituzte bizi-zikloa kudeatzeko beharrezkoak diren baliabideak, eta, zenbaitetan, prozesuak hobetzeko ekimenetan oztopo izaten dira. ISO/IEC 29110 arauari esker, VSE-en beharretara egokitutako erreferentzia-marko bat lortu daiteke. Hala ere, ziklo osoan kudeatu beharreko segurtasun-arloko alderdiak ez ditu barne hartzen. Produktuaren bizi-zikloan, produktuaren behin betiko kalitatearekin, eta, zehazki, azken produktuaren segurtasunarekin harremana duten erabaki asko hartzen dira. Erabaki tekniko horiek etorkizuneko kostu bat eragiten dute produktuaren mantentze-lanetan, eta, beraz, identifikatu eta kuantifikatu behar dira, ondoren kontsultatu eta kudeatu ahal izateko. Produktuaren bizitzaren uneren batean, bizi-zikloaren momentu batean hartutako erabaki tekniko kontzienteek, segurtasunarekin loturiko produktuaren kalitatearen gainetik jarri dutenek *time to market* aldagaia, kostu gehigarri bat eragingo dute, kalitate falta horretatik sortuko diren gorabeherak konpontzeko.

3 Helburuak // Goals

VSE-en hobekuntza ekimenak aztertzea da lan honen helburu nagusia, bide horretan egin diren ekarpen garrantzitsuenak ere aintzat hartuta, bai eta ekimen horien biziraupena analizatzea eta antzeko ereduak identifikatzea ere, arrakasta-tasak handitzeko, betiere segurtasuna-arloko alderdiak indartuz.

Horretarako, lanak honako egitura hau dauka:

1. ISO/IEC 29110 arauarekin loturiko artikuluen azterketa metodiko bat, ikerketa-esparru nagusien eta egindako lan mota garrantzitsuenen aipamenarekin.
2. Enpresa txikietako prozesuen hobekuntzaren biziraupen-analisi baten aurreikuspena eta behaketa: prozesuak hobetzeko 90 ekimen behatzea eta ekimen horien biziraupenaren analisia egitea da helburua, haien portaeraren ezaugarriak zeintzuk diren zehazteko helburuarekin.
3. Goian azaldutako hobekuntza-ekimenen barruan, *clusterren* identifikazioa (*clustering*), haien portaeraren ezaugarriak zehazteko helburuarekin.
4. VSE-etan segurtasun-arloko alderdiak gehitzea, VSE-ek bizi-ziklo osoan hartutako zor teknikoa kudeatzeko helburuarekin.

4 Hipotesia //Hypothesis

Jarraian azaltzen diren lau hipotesiek, aurrez definitu diren doktorego-tesiaren helburuek izango dituzten emaitzak aurreikusten dituzte:

1. Gaurko egunera arte, ISO/IEC 29110 arauarekin zerikusia duten hainbat ikerlan egin dira. Hala ere, lan horiek ez dira ikuspuntu zorrotz batetik aztertu. Horregatik, arau horren inguruan orain arte egindako ekarpen gehienak aztertu nahi ditugu, ekarpenen analisirako metodologia sistematiko baten laguntzarekin. Analisi honen bidez, argitaratutako lan guztiak ezagutzeaz gain, ekarpen motak, ikerketa-arlo nagusiak eta orain arte egin diren azterlan mota garrantzitsuenak ezagutu ditzakegu. Horrenbestez, arauari egin zaizkion ekarpenak eta jaso eta zabaltzen ari diren esperientziak ezagutzeko aukera izango dugu. Horrekin guztiarekin, VSE-en testuinguru orokorra azaldu eta ezagutu daiteke.
2. Prozesuen hobekuntzaren esparruan, proiektuen huts egitea azaltzeko askotariko arrazoiak daude, esate baterako: helburuak oso argiak ez izatea, oso errealistak ez diren helmugak zehaztea eta oso egokiak ez diren aurreikuspenak egitea, ekimenarekiko konpromiso eta babes falta, aldaketaren aurkako portaerak, eta beste hainbat. Ekimen horien ebaluazioa ezin da aurreikusi eta emaitzak ustekabekoak izaten dira. Ekimen horien biziraupena aztertzen badugu, prozesua hobetzeko ekimen berri baten garapena zein izan daitekeen jakitetik eta amaiera kontrolatu ahal izatetik gertuago egongo gara. 90 ekimenen analisiak bere portaeraren ezaugarriak zehazteko eta, prozesua hobetzeko

bidean, etorkizuneko ekimenei aurrea hartzeko aukera ematen du. ISO/IEC 29110 arauaren oinarrizko profilean oinarrituriko biziraupen-analisien alderaketa enpirikoari esker, arlo bakoitzeko joera zein den jakin daiteke.

3. Prozesuen hobekuntzaren barruan egindako azterketa gehigarri bat ISO/IEC 29110 arauaren oinarrizko profilaren arloen arteko korrelazioa ezagutzea da, antzekotasunak aurkitzeko helburuarekin. Horrez gain, ekimen baten portaera aurreikusteko edo ekimen horietatik ikasi ahal izateko, gainbegiratu gabeko ikaskuntza gehitu beharko dugu. Prozesuak hobetzeko ekimenen barruan, *self-organizing maps* (SOM) mapen bidez, *cluster* (*clustering*) edo taldekatzeak identifikatzearen moduko ikaskuntza ez-gainbegiratua egokia da azaldutako testuinguruan.
4. VSE baten bizi-zikloan segurtasun-arloko alderdiak gehitzen badira, azken produktuaren gaineko erabaki teknikoak hartu beharko dira. Erabaki hartze horrek zor tekniko bat eragingo du (*technical debt*), VSE-ek bere egin eta kudeatu beharko dutena bizi-ziklo osoan. Produktu bat bizi-ziklo osoan kudeatzeko askotariko jarduerak egin beharko dira, produktuaren garapenari berari dagozkionak edo hornitzaile eta bezeroekin izan beharreko hartu-emanak. Bizi-zikloa kudeatzeko hainbat marko daude, esate baterako, ISO/IEC 12207:2008, *Systems and software engineering – Software life cycle processes*. Segurtasunaren barruan, duela gutxi, National Institute of Standards and Technology eta NASAk bide horretan doazen arauak argitaratu dituzte Amerikako Estatu Batuetan. Marko horietan ez da kontuan hartzen sistema baten diseinuan eta garapenean hartutako zor teknikoa. Horregatik proposatzen dugu produktu baten bizi-zikloan segurtasuna barne hartuko duen ikuspuntu bat VSE-en testuinguruan.

5 Metodologia // Methodology

Lau metodologia nagusi erabili dira doktorego-tesi honetan: systematic mapping bidezko analisia, kasu azterketa bidezko analisia eta SOM bidezko analisia.

5.1 Systematic mapping bidezko analisia

ISO/IEC 29110 arauari buruz argitaratutako lanen azterketa egiteko proposatutako metodologia *Systemic Mapping* (SM) baten bidez gauzatuko da. Metodologia irudian azalduta dago (Figure - 4 - Irudia) eta hainbat urrats ditu. Lehenik eta behin, bilatu beharreko esaldia zehaztu zen; kasu honetan, “ISO/IEC 29110” arauarekin zerikusia daukan guztia izan zen. Bilaketa sistematiko hori datu-base garrantzitsu eta ezagunenetan egin zen. Hasiera batean, 322 lan identifikatu ziren, ondoren aztertu eta iragazi egin zirenak. Iragazteko prozesuan, artikulu bakoitza aztertu egin zen eta errepikatuta edo bikoiztuta zeuden horiek baztertu egin ziren. Iragazki horri esker, 183 artikulu geratu ziren, eta, kalitate-ebaluazio baten ondoren, behin betiko emaitza 179 artikulutara murriztu zen.

5.1.1 Azterketaren plangintza

Gaikako sailkapen eta analisi bat eskaintzea da helburua, ISO/IEC 29110 arauari buruz argitaratu dena oinarri hartuta. [11] horren arabera, mapaketan oinarritutako azterketak egokienak dira helburu mota hauetarako. Hain zuzen ere, hurrengo atalean, ikerketarako galderen multzo zabal bat zehaztu da, oraindik gehiegi jorratu ez den azterketa-esparru bati dagozkionak. Horrenbestez, atal honetan erabilitako metodologiak mapaketa sistematiko (*systematic mapping*) baten ikuspuntua aplikatzeko gidalerroak ditu ardatz [29]. Jarraian dagoen irudian (Figure - 4 - Irudia), burutu diren mapaketaren faseak agertzen dira. Fase bakoitzean eskuratutako bitarteko datuak ikus daitezke irudian. Esate baterako, lehenengo bilaketan, 322 artikulu lortu ziren, bikoiztasunak egoteko aukerarekin. Iragazketa baten ondoren, bikoiztasunak ezabatu eta 183 artikulu geratu ziren. Azkenik, kalitate-ebaluazio bat egin zen, eta 179 artikulu identifikatu ziren.

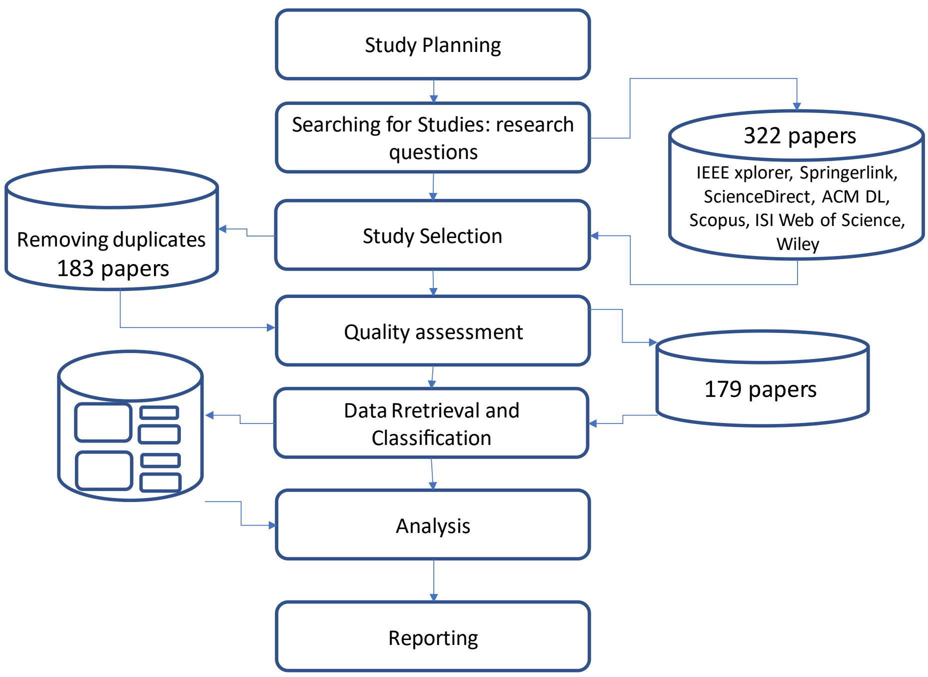

Figure - 4 - Irudia Mapaketa sistematikoaren faseak

5.1.2 Galderak

Galderek izaera zabala dute, eta ISO/IEC 29110 segidaren analisia eskaintzea dute ardatz.

Hona hemen galderak:

R1. Zeintzuk dira arlo honetako ikerlaririk garrantzitsuenak?

R2. Zenbat ekoizpen zientifiko argitaratu dira ISO/IEC 29110 arauarekin zerikusia daukatenak?

R3. Zein motatako lanak egin dira ISO/IEC 29110 arauari buruz?

R4. Zeintzuk dira gai nagusiak?

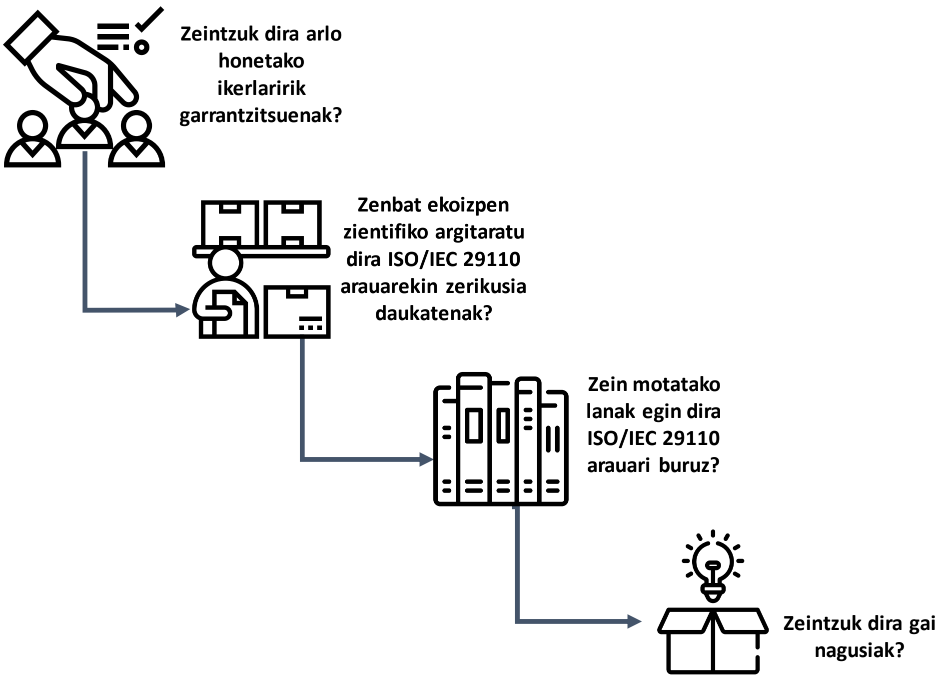

Figure - 5 - Irudia Mapaketa sistematikoaren galderak, eta ikerketa eskema

5.1.3 Bilaketaren estrategia

Bilaketaren estrategiaren ardatz nagusia "ISO/IEC 29110" terminoa izan da. Horixe da honako datu-base hauetan bilatu den hitz bakarra: ScienceDirect, SpringerLink, ISI Web of Science, IEEE Explore, ACM Digital Library, Wiley Online Library, Scopus.

5.1.4 Hautaketa

Hautaketa egiteko metodoa 5.1.1. atalean emandako azalpenean oinarritzen da. Funtsean, lehenengo bilaketaren emaitza 322 artikulu izan ziren. Hala ere, datu-base hauek elementu bera jaso dezaketenez, bikoiztutako emaitzak eman daitezke. Hain zuzen ere, 126 emaitza ezabatu ziren, eta balio errealik gabeko 12 hitzaldiren berrikuspenak baztertu ziren, dagoeneko kontuan hartutako artikuluen laburpenak baitziren.

Lehenengo analisi horren ondoren, 138 elementu utzi ziren kanpoan, hau da, kopuru osoaren % 42,9. Horrenbestez, zehaztasunez aztertzeko 184 emaitza ditugu. Emaitzak onartzeko eta baztertzeko prozesua zehazteko, honako irizpide hauek erabili ditugu [31]:

- Onartzeko irizpidea: artikulua azterketa enpiriko bati, VSE-en inguruko azterlan bati edo ISO/IEC29110 arauarekin zerikusia duen lan bati buruzkoa bada, orduan, kontuan hartu da.
- Baztertzeko irizpidea: izenburua, laburpena eta testua aztertu ondoren, helburua ez bada ISO/IEC 29110 araua edo VSE-ekin loturik ez badago, orduan, baztertu egin da. Horrez gain, ingelesez ez dauden azterketak baztertu egin dira

5.1.5 Kalitate-ebaluazioa

Egile bakoitzak honako galdera hauek egin eta ebaluatzen ditu [22]:

- Mapaketa sistematikoa argi eta garbi oinarritu da?
- Mapaketa sistematikoa argi eta garbi definitu da? (azterketaren azalpena, datuak eskuratzeko prozesua, sailkapen-eskema)
- *Mapping* prozesurako ebidentzia enpirikoren bat dago? Galdera horrek lotura dauka *mapping* prozesuaren emaitzen eskuragarritasunarekin.

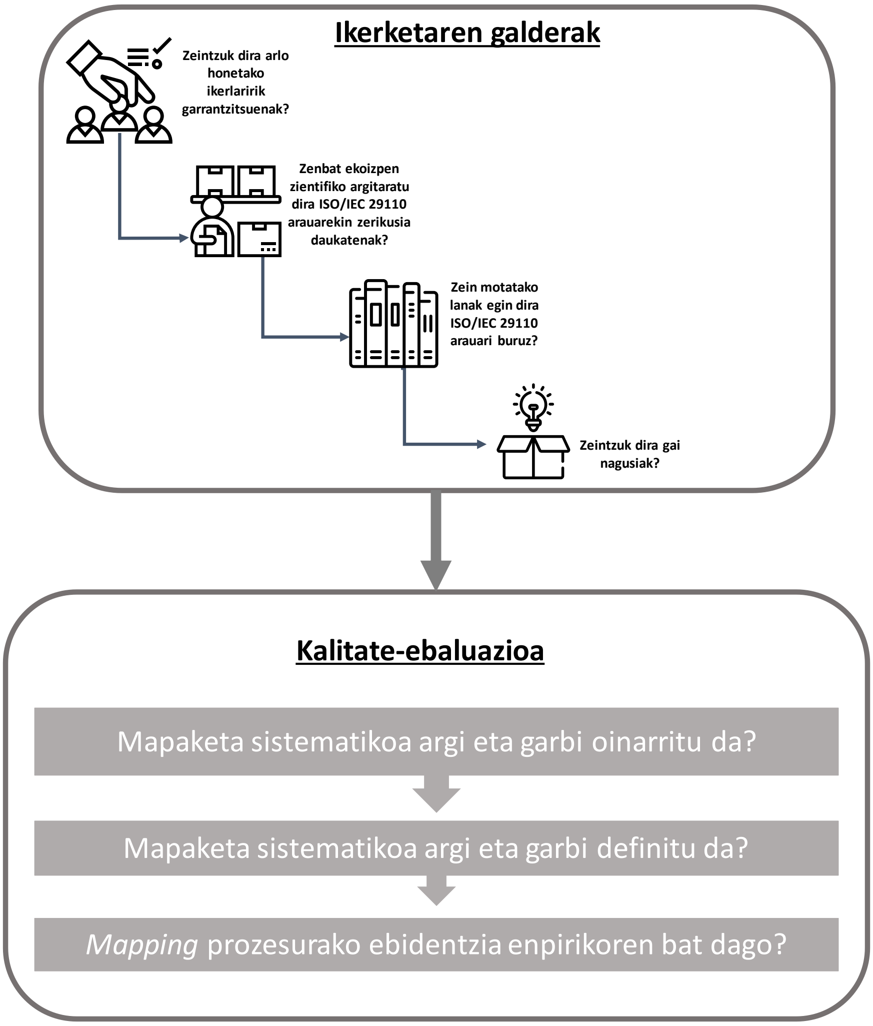

Figure - 6 - Irudia Kalitate-ebaluazioaren faseak

Egileak galdera horiek egiaztatu ondoren, bigarren egileak emaitzak egiaztatuko ditu. Kalitatea ebaluatzeko prozesua [22] 183 artikuluei aplikatu zaie. Prozesu honen ondorioz, 4 artikulu azterlanetik kanpo geratu dira, ingelesez idatzita ez daudelako edo iritzi-artikuluak direlako. Horrenbestez, 179 artikuluk osatzen dute azterlana.

5.1.6 Datuak eskuratu eta sailkatzeko prozesua

Datu guztien jatorria lehen mailako ikerketak dira (*primary studies*), teoria oinarritu bat (*grounded theory*) garatzeko teknikak eta prozedurak ardatz hartuta egin direnak [59].

Hainbat sailkapen-eskema erabili dira, dagoen literatura guztiaren ezaugarriak zehaztu eta ulertzeko helburuarekin. Horrela, ekarpenez gain, argitaratu diren esperientziak ere ezagutzeko aukera daukagu.

Lehen sailkapen-eskema Wieringa-k eta beste batzuk [24] zehaztutako eskema tradizional bat da, azterketa honetarako egokitu duguna. Hona hemen sailkapen-eskemaren azalpena:

Table - 1 - Taula Sailkapen-eskemak kategoriak identifikatzen ohi zituen

Kategoria	Deskribapena
Validation Research	Teknika berri bat ikertu da, baina ez da praktikara eraman
Evaluation Research	Teknika berri bat praktikara eraman da, eta ikuspegi praktiko batetik ebaluatu da.
Solution Proposal	Arazo baten konponbide bat xehetasun osoz zehaztu eta azaldu da. Beharrezkoak dira onuren azalpen bat eta bere aplikagarritasunaren analisi bat.
Philosophical Papers	Ikuspegi berri bat zehaztu da. Ikuspegi hori eztabaidagarria izan daiteke.
Opinion Papers	Ikerketa mota hauen ekarpen nagusiak iritzi pertsonalak dira. Artikulu hauetan, emaitzen atzean ez dago ikuspegi zientifikorik
Experience Papers	Artikulu hauetan, zer eta nola burutu den azaltzen da. Normalean, egileen beraien esperientziak jasotzen dira

5.2 Esperientzia enpirikoan oinarrituriko analisia

Bigarren helburu eta hipotesirako software ingeniaritza enpirikoan oinarritutako metodologia bat zehaztu da [51]. Funtsean, prozesuen hobekuntzarekin zerikusia duten 90 esperientzia industrialen azterketan oinarritu da erabilitako ikuspuntua. Esperientzien ezaugarritzea, helburuen zehaztapena eta emaitzak eskuratzeko modua zorroztasun osoz egiten da ikuspuntu honekin. Ekimen guztiek hasiera eta amaiera erregistratuta daukate, eta erabilitako erreferentzia-ereduak eta ebaluazioen emaitzak ere eskura ditugu. “Biziraupen-denbora” terminoarekin zera esan nahi dugu, erakunde batek erreferentzia-eredu batek zehaztutako eskakizunen multzoa betetzen duen arte iragan den denbora. Hortaz, gertakari positibo bat ematea da behaketaren oinarria. Oro har, biziraupen-metodoak gertakari negatiboei aplikatzen zaizkie, hala nola heriotzari, gaixotasunen garapenari eta abar. Esate baterako, osasunaren sektorean, pertsona multzo batek gaixotasun baten aurrean daukan biziraupen-denbora aztertzeko erabiltzen dira. Ekonomian ere erabili dira, finantza-merkatuak aztertzeko. Biziraupenaren inguruko datuak erlazionatutako behaketekin eta gertakari bat ematen den arte iragaten den denborarekin loturik daude. Metodo parametrikoak, erdi-parametrikoak edo ez-parametrikoak erabili ohi dira. Gure kasuan, *Cox Proportional Hazard Regression* (CPHR) eredua erabili dugu, banaketa ezezaguna delako eta gertakarira arteko denbora ez baita osorik behatzen. Prozesuak hobetzeko ebaluazioak denbora-tarte batez egin ohi dira. Gainera, zenbait ekimen arrakastatsuak dira, beste batzuk bertan behera uzten dira, eta beste batzuk behaketa-denboran huts egiten dute. Hortaz, azterketaren mugetatik kanpo geratzen diren datuak agertzen dira, baina metodologia honek ez ditu aintzat hartzen. Epealdia baino lehen ematen diren gertakariei *left truncated data* esaten zaie, eta azterketaren epealdiaren ondoren gertatzen direnei, aldiz, *right censored data*.

5.3 *Clustering* bidezko analisia

Prozesuak hobetzeko esperientzien datu-basean oinarrituta, emaitzak aztertu ditugu ISO/IEC 29110 arauaren oinarrizko profilaren arabera, eta, emaitza horietan, korrelazioaren analisi bat egin eta ereduak identifikatu ditugu. Horretarako, emaitza horien gainean SOM bat egiteko urrats batzuk zehaztu dira. Metodoaren azalpena artikuluan bertan jasota dago (Figure - 7 - Irudia). Analisi honen bidez, ISO/IEC 29110 arauaren oinarrizko profilaren arloen arteko harremanak aurkitu nahi dira.

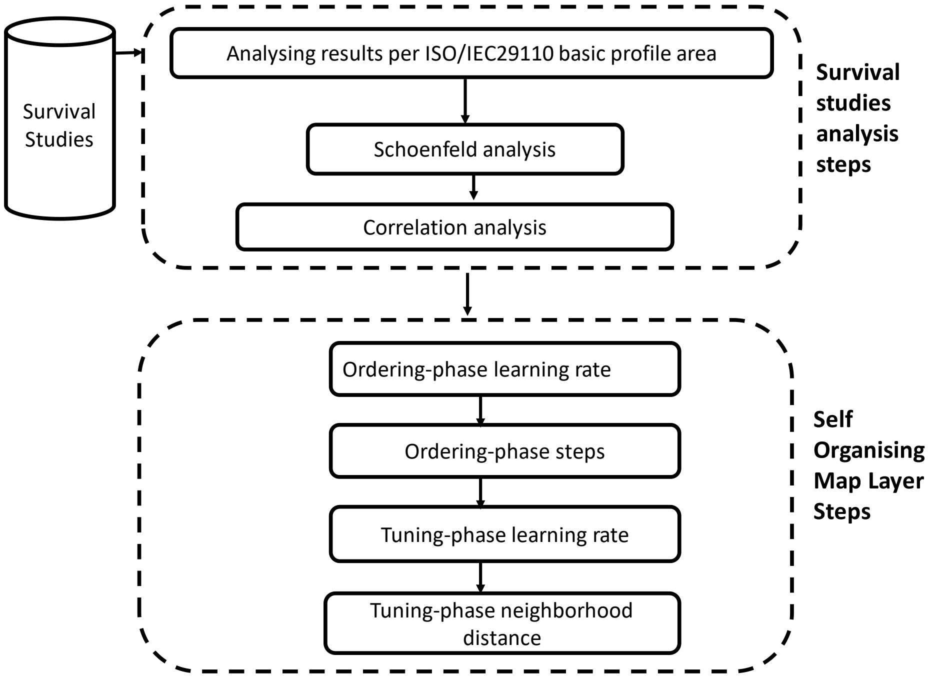

Figure - 7 - Irudia Taldekatu aztertu SPI-ikasketetarako SOM-ean oinarritutako metodoa

5.4 Kasu-azterketa baten bidezko analisia

Azterketa-kasu batean (*case study*) fenomeno bat aztertzen da bere testuinguruan, batez ere fenomenoaren eta bere testuinguruaren arteko muga oso argi ez dagoenean [55]. Definizio horrek zuzenean eragiten du jarraitu beharreko ikerketa-metodoan. Desadostasunak daude kontuan hartzean zer den eta zer ikerketaren kasu bat ez den [56]. Hartara, *assurance cases* [57] kasuen ikuspuntutik sortutako protokolo bat zehaztu da, halakoetan segurtasun-arloko alderdiak kontuan hartu eta txertatzen baitira. Zor teknikoa produktuaren bizi-ziklo osoan kudeatu beharrak horri aurre egiteko metodologia eta tresna batzuk zehaztera bultzatzen gaitu. Hain zuzen ere, PLCaren fase guztietan zor teknikoa eta segurtasun-arloko alderdiak zehazten laguntzeko metodologia bat zehaztu dugu. Azterketa-kasua azaltzeko, medikuntza sektoreko VSE baten kasua erabili dugu. Kasu horretan, behatzailearen eta eszenatokiaren arteko interakzioa oso txikia da. Atal honetan zehaztutako zor teknikoa ikuspuntuaren abiaburua da. Horrek ikerketa-lerro ireki bat eskaintzen digu.

6 1_ARTIKULUA / PAPER_1

6.1 Analysis

At this point, we need to identify which tools are going to be used for the analysis of the data. Basically, we are counting and identifying distributions over a specific period for a target population. This approach is widely used by systematic mappings. In addition, we disaggregate the authorships into different subsets in order to identify the relevance of the author on each publication. This approach is basically used for research questions 1 and 2.

One of the aspects when we are looking at the types of studies (research question 3) and the main research topics (research question 4), is the outliers over the time, because they are observations that lie outside the overall pattern of a distribution [60]. This means there is an evident distance between this observation and from the rest of values from a population. From a mathematical point of view, we are considering an outlier the observation which value falls outside the range defined by the mean +/- its confidence interval. Therefore, we consider the following formulae for calculating the mean value of the distribution:

$$\bar{x} = \frac{\sum_{i=1}^{n} x}{\mathrm{n}} \qquad (1)$$

For standard deviation:

$$\sigma = \sqrt{\frac{\sum (x-\bar{x})^2}{n}} \qquad (2)$$

For confidence interval we will use the t student distribution formula because the sample size is small and we do not know the real standard deviation. Therefore, we use:

$$\mathrm{T} = \frac{\bar{X}_n - \mu}{S_n/\sqrt{n}} \qquad (3)$$

In addition, in order to find the central position within a subset, we use the median formulae which is defined by (4)

$$\begin{cases} M_e = x_{(n+1)/2} & n \text{ is even} \\ M_e = (x_{n/2} + x_{\frac{n}{2}+1})/2 & n \text{ is odd} \end{cases} \qquad (4)$$

Next sections are dealing with these distributions and they present the results from our study.

6.2 Results

The results are analyzed according to the research questions. This paper deals with four research questions which are stated at the beginning of this paper.

6.2.1 Which researchers are the most relevant in this field?

From the primary dataset, we extracted the authors from each database entry. We consider that the position an author is signing a paper or an article is relevant for the study. Therefore, we identified the main authors for all papers. We identified 93 authors signing publications as the first author. Table - 2 - Taula summarizes for each author how many papers or articles has signed as first author. This table just represents a small subset of authors (8 out of 93 authors); those with highest number of publications. Claude Laporte and Rory V. O'Connor are the major contributors. In fact, they are the promoters of this standard and therefore they have published a large number of papers.

Table - 2 - Taula Authors as first author

Author name	Counts
Laporte, C. Y.	25
O'Connor, Rory V.	11
Sanchez-Gordon, M.-L.	8
Calderon, Alejandro	6
Larrucea, X.	6
Eito-Brun, R.	5
Ribaud, V.	5
Biró, Miklós	4

Table - 3 - Taula represents the authors signing as second author, and it just includes the authors with the highest number of authorships (contributions) as second author. In this case, 87 authors are signing as second author.

Table - 3 - Taula Authors as second author

Author name	Counts
O'Connor, R.V.	20
Laporte, C.Y.	8
Santamaría, Izaskun	5
Wen, Lian	5
Colomo-Palacios, R.	4
Messnarz, Richard	4
Ruiz, Mercedes	4
Saliou, P.	4

Table - 4 - Taula considers all papers for each author without taking into account its position within each paper or article. Claude Laporte is the project editor of ISO/IEC 29110 set of Systems And Software Engineering Standards and Technical Reports. Rory V. O'Connor is Ireland's Head of Delegation to the International Organization for Standardization (ISO) for Software & Systems Engineering (ISO/IEC JCT1/SC7).

Table - 4 - Taula Number of papers published by authors

Author name	Counts
O'Connor, Rory V.	48
Laporte, C. Y.	37
Colomo-Palacios, R.	17
Sanchez-Gordon, M.-L.	11
Larrucea, X.	9
Davila, A.	8
Piattini, M.	7
Calderon, Alejandro	6
Melendez, K.	6
Munoz, M.	6
Ruiz, Mercedes	6
Wen, Lian	6

6.2.2 How much activity has been done related to ISO/IEC 29110?

Table - 5 - Taula summarizes the number of search results per database, and the figure represents graphically these results from 2009 to 2019. These data have been extracted at the time of writing this article (end of 2018). From this Table - 5 - Taula, we can conclude that there is an increasing interest about this standard. ISI Web Of Knowledge and Scopus are the two databases containing the majority of primary studies. Some papers are included in more than one database. Therefore, we analyzed all of them, and we removed duplicate entries. The last row of Table - 5 - Taula represents all the papers without duplicates.

Table - 5 - Taula Number of search results per database

Source	Total	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
ScienceDirect	21		1			2	1	4	1	4	8	
SpringerLink	85	1	6	4	8	4	7	5	19	11	16	4
ISI Web of Science	60		4	2	3	2	3	8	17	21		
IEEE Explore	23	3	2			1	1	3	6	5	2	
ACM Digital Library	4		2								2	
Wiley online library	26				3	1	6	3	7	3	3	
Scopus	103		9	4	5	7	10	12	18	24	11	3
Total without duplicates	**184**	**2**	**11**	**5**	**13**	**10**	**18**	**17**	**37**	**33**	**34**	**4**

6.2.3 What types of studies have been carried out about the ISO/IEC 29110?

Once we have eliminated the duplicated entries, we classified all the papers according to the classification schema defined by Wieringa [24] and adapted to our study in Figure - 4 - Irudia. As a result, we obtained Table - 6 - Taula where solution proposals (59) and experience reports (54) are the two types with highest scores. As this is a standard focused on VSEs, it is worthy to note the set of industrial experiences and how they have carried out SPIs. Concerning *solution proposal* research works, we identify several approaches inside this item because sometimes the solution is focused on the assessment side and other times the solution is focused on the definition of a specific profile.

Table - 6 - Taula Classification types and how many papers for each type

Types	Counts
Evaluation Research	43
Solution Proposal	59
Experience Paper	54
Opinion Paper	6
Validation Research	14
Philosophical Paper	3

The ISO/IEC 29110 related topics are usually published in journals as it is described in Table - 7 - Taula.

Table - 7 - Taula Types of paper depending on the source

Type of paper	Counts
Conference Paper	35
Journal	86
Book Section	58

The type of study performed over the years (Table - 8 - Taula) is relevant in order to identify which studies are being carried out during these last ten years. This table provides a distribution over the years which is interesting to identify the trends of each classification type.

Table - 8 - Taula Classification types over the years

Classification Types	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Evaluation Research		2	1		4	2	5	11	4	14
Solution Proposal	2	6	1	8	2	6	4	8	12	8
Experience Paper		2	3	2	1	7	7	14	10	8
Opinion Paper				1	1	2			2	
Validation Research		1						4	3	4
Philosophical Paper				2		1				

Total	**2**	**11**	**5**	**13**	**8**	**18**	**16**	**37**	**31**	**34**

The following Table - 9 - Taula describes the standard deviation, the confidence interval and the median of these classification types. These values help us to identify which years are suffering increases over the upper limits of their confidence intervals. This means that there is a huge number of papers. These values are the outliers and for each classification type we have the following:

- For evaluation research: years 2016 and 2018
- For solution proposal: years 2017
- For experience paper: year 2016 over the upper limit, and from 2010 to 2013 where there are too few items
- For opinion paper: no outliers
- For validation research: no outliers
- For philosophical paper: no outliers

Table - 9 - Taula Confidence interval, standard deviation and Median of classification types

Types	Standard Deviation	Confidence Interval	Median
Evaluation Research	4.657942526	3.332091353	4.0
Solution Proposal	3.465704995	2.479216002	6.0
Experience Paper	4.358898944	3.118168462	7.0
Opinion Paper	0.577350269	0.413011502	1.5
Validation Research	1.414213562	1.011667438	3.5
Philosophical Paper	0.707106781	0.505833719	1.5

6.2.4 What are the main research topics?

The research methods used within these papers are not always consistent. Sometimes, they are reported as case studies and field experiments. The research method used on each item varies from a wide range of options. Literature uses different approaches for classifying the research methods such as [25], where there are 19 research methods. However, as this standard is quite new, these complex classification schemas are not too appropriate if we want to learn from these experiences. Therefore, we have defined the following research topics:

- Education: this criterion is used for tagging papers which are focused on learning and teaching about the ISO/IEC 29110. This item includes systematic mappings, bridges between one model and this standard, and so forth.
- SPI factors: this includes cultural factors, the study of the environment where the experience is reported, and so on.
- Case study: this item identifies real experiences.
- Project Management: there are many factors surrounding project management area because it represents a cornerstone for the basic profile.
- Assessment method: traditionally, the assessment method requires a quite huge amount of effort. Therefore, there are some papers focused on the assessment side of this standard.

We have analyzed the primary studies (179 papers), and we have identified and summarized in Table - 10 - Taula the research topics and its frequency within the primary studies. SPI factors such as culture are some of the research topics related to this standard. It seems reasonable to learn and investigate which factors are influencing a SPI initiative, especially those carried out by VSEs.

Education is the second most popular research topic. There are many studies related on how to teach ISO/IEC 29110, or its application in education. There are other aspects such as systematic mappings which are included within this type.

Case studies are also prominent, and 40 publications are related to the experiences carried out by industry. There are no guidelines on how to report this kind of case studies because VSEs are not going to fill in many templates due to time requirements. From these case studies, we are interested in not only positive experiences, but also in the negative experiences. From this set of primary studies, we can just identify positive ones. However, there are four research works related to survival studies, which include experiences where VSEs failed.

Project management gathers 35 publications and they include the study of different methodologies. In fact, the ISO/IEC 29110-5-1 deals with management and engineering guides including business management, project management, software implementation and acquisition processes.

Finally, assessment methods are also of interest, and the ISO/IEC TR 29110-3-1 is focused on process assessment guidelines and compliance requirements. In this sense, 12 papers are related directly to this aspect.

Table - 10 - Taula Classification of research topics

Research topics types	**Counts**
Education	44
SPI factors	48
Case study	40
Project Management	35
Assesment method	12

As there is a strong relationship between the different parts of the ISO/IEC 29110 and the research topics stemming from the primary studies, we performed a search of every part of the ISO/IEC 29110, namely ISO/IEC 29110-1, ISO/IEC 29110-2, ISO/IEC 29110-3, ISO/IEC 29110-4, and ISO/IEC 29110-5 in order to know whether the authors made a reference to a specific part of this standard or not. This research reveals that 15 over 179 refer properly the ISO/IEC 29110-1 standard, and 7 over 179 refer the ISO/IEC 29110-2 standard.

Table - 11 - Taula Research topics types over the years

Research Topics	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Education	1	1	1	5	2	5	2	4	9	13
SPI factors	1	3	1	3	2	3	6	11	11	7
Case study		3	2	1	2	4	4	13	5	6
Project Management		1	1	3	2	3	3	7	5	7
Assesment method		3		1		3	1	2	1	1
Total	**2**	**11**	**5**	**13**	**8**	**18**	**16**	**37**	**31**	**34**

The following Table - 12 - Taula describes the standard deviation, the confidence interval and the median of these research topics. These values help us to identify which years are above the upper limits of their confidence intervals. These values are the outliers and for each research topic we have the following:

- For Education: years 2017 and 2018

- For SPI factors: years 2016, 2017 and 2018
- For Case study: year 2016 over the upper limit
- For Project Management: years 2016, 2017 and 2018
- For Assessment Method: years 2010 and 2014

From these data, we can conclude that since 2016 there is an evident increase of research works related to SPI factors, case studies and project management because they are located above the upper limits of the confidence interval. This is due to the fact that case studies, SPI factors and project management research topics require some time for performing their research and for publishing their results. Topics related to education are being increasingly studied, and there is a huge increment since 2017. This fact can be partially explained because after the introduction of a new innovation there is a diffusion process [61] requiring time. In addition, it seems that Assessment Methods were mainly studied during the first years after the ISO/IEC 29110 release.

Table - 12 - Taula Confidence interval, standard deviation and median of research topics over the years

Types	Standard Deviation	Confidence Interval	Median
Education	3.973523485	2.842487466	3.0
SPI factors	3.794733192	2.714588595	3.0
Case study	3.574601765	2.557116059	4.0
Project Management	2.297341459	1.643419078	3.0
Assesment method	0.951189731	0.680440143	1.0

6.3 Contribution details

(Q2 Computer Science, Software Engineering-Impact Factor: 1.465)

<u>Xabier Larrucea</u>, and Borja Fernandez-Gauna. "A Mapping Study about the Standard ISO/IEC29110." *Computer Standards & Interfaces*, April 2019. https://doi.org/10.1016/j.csi.2019.03.005.

7 2_ARTIKULUA / PAPER_2

7.1 Survival analysis

There is a wide set of survival methods for analyzing “time to event” approaches. This section provides an overview of the non-parametric models and a semi-parametric model such as the Cox Proportional Hazards Regression (CPHR) model [35]. As stated before we are going to use CPHR because SPI assessments rely on time dependent variables and categorical data. The first step is to introduce the non-parametric models. Afterwards we need to interpret and adapt the Cox Proportional Hazard Regression model to our study. Third we analyse the scenario, and we need to specify which SPI initiatives are taken into account or not.

7.1.1 Non parametric models

Kaplan-Meier [85] and Nelson-Aalen estimators are some of the most well-known non-parametric models. Kaplan-Meier defined a product-limit estimator (PLE) (formula 1) which is based on a product of the conditional survival probabilities. Based on a set of items called *r* we have an associated $t_r^{'}$ $\mathrm{t}_\mathrm{r}^{'}$ which can be a positive or a negative event. After *N* observations $0 \leq t_1' \leq t_2' \leq t_3' \leq \cdots t_N'$ we have the following PLE:

$$\hat{P}(t) = \prod_{r=t_r'}^{t_r} [(N-r)/(N-r+1)] \text{..........(1)}$$

Nelson-Aalen (formula 2) is used when we consider estimating the cumulative hazard of the survival functions:

$$\widehat{\mathrm{A}}(t_i) = \sum_{j=1}^{i} \frac{d_j}{r_j} \text{............(2)}$$

Where d_j is the number of individuals who experience an event at t_i, and r_j is the number of individuals at risk before t_i. This function accumulates (sum) the hazard from time = 1 to time=i at it increments $\frac{d_j}{r_j}$ during the time observed.

Both functions are used in our study for comparing survivability of SPI initiatives.

7.1.2 Semi-parametric model: Cox Proportional Hazard Regression model

The Cox Proportional hazard model [35] is a semi–parametric proportional hazard regression model which is an extension of the Kaplan-Meier estimator. This model uses numerical variables, and it assumes that the complete distribution over the time is not known. Its formula is:

$$h_i\ (t) = h_0\ (t) * \exp(\beta * \mathrm{X(t)}) \qquad (3)$$

where $h_i\ (t)$ is a hazard rate for a subject *i*, $h_0\ (t)$ depends on time (not on the covariates) with an unspecified baseline hazard function that describes the instantaneous risk of experiencing an event at some time, t, when the values of all covariates are zero. $\exp(\beta * \mathrm{X(t)})$ depends on the covariates (not the time). X(t) is a vector of possibly time-independent covariates that are collected at each event occurrence that may or may not have predictive power over the time to the event. In our SPI initiatives context this vector is composed by several parameters which are common in several reference models such as the ISO/IEC 29110 basic profile elements. β is a vector of regression coefficients (i.e., one coefficient for each covariate). Our purpose is to analyze their survival rates and to compare different initiatives. The main difference between 2 subjects under study (two SPI initiatives) only depends on their covariate values. This difference is calculated as described in formula 4.

$$\frac{h_i\ (t)}{h_j\ (t)} = \frac{h_0\ (t)*\exp\left(\beta * X_i\ (\mathrm{t})\right)}{h_0\ (t)*\exp\left(\beta * X_j\ (\mathrm{t})\right)} = \exp\left(\beta * (X_i\ (\mathrm{t}) - X_j\ (\mathrm{t}))\right) \qquad (4)$$

For representing the results we used the R studio [86] and the Cox's model implementation in the R survival package [87].

7.2 Survival study in small settings

7.2.1 Research method

Recent research works such as [48] where authors outline a research agenda, or [49] where authors provide an approach for predicting delays of issues with due dates, are suggesting that there is an evident need for setting a grounded theory[50] in this sense. As stated before we have analyzed 90 improvement initiatives stemming from our experience factory [51] which has been published in Tecnalia's website (https://tinyurl.com/larnc8q). In fact, the aforementioned webpage contains further experiences but they are not taken into account because they are not small companies and/or we do not have enough information regarding the assessments and the time used for each initiative. Therefore, we analyzed a wide set of process improvement projects related to VSEs. There are some companies which are small-medium entities but they are not VSEs, and we focused on those organizations achieving a set of reference models such as CMMI-DEV. During this research method, we packaged these experiences in a database (Figure - 3 - Irudia) containing the reference model used, the time required/invested, and best practices.

7.2.2 Data collection

We collected the data from this experience factory, and we identified different types of events (c):

1) Starting event –an SPI initiative has started.

2) Succeeded/Failed event- this event is positive or negative depending on whether the improvement initiative succeeded or not.

3) Censoring event – an event that is falling outside the interval of study. This event can be left-truncated data or right censored data. Left truncated data is not considered on this study because we do not know whether the organizations started or not an improvement initiative before the time t1 (Figure - 2 - Irudia). T1 is basically the first observation of our study. Right censored data is the data falling behind t2, and it is not relevant whether this organization obtained or failed on their SPI initiatives.

All these experiences are gathered in a set of excel sheets, and the following table represents an excerpt of the data we are managing. For example, we include the duration required for the event. In fact, the event is Boolean (1 or 0) for representing whether this organization achieved its goals. In addition, we are gathering other aspects such as the reference model used (CMMI-DEV or ITMark). Pm1 to pm4 and si1 to si7 are activities defined by the ISO/IEC 29110 basic profile.

Table - 13 - Taula An excerpt of the experience database

duration	event	pm1	pm2	pm3	pm4
13	1	40.32	45.13	54.52	62.67
19	1	56.83	45.68	64.38	50.96
17	1	49.92	33.00	61.90	58.77
21	1	57.42	52.72	57.66	45.76
17	1	57.70	54.94	46.42	56.60
19	1	51.59	34.90	62.90	59.70
17	1	47.28	45.77	60.00	52.81
22	1	64.28	47.88	46.70	58.13
19	1	57.98	53.97	66.88	44.41
22	1	52.45	72.74	56.29	47.86
15	1	64.71	40.21	80.64	47.69
19	1	46.20	45.09	26.19	55.85
24	1	65.44	63.14	33.77	59.75
…	…	…	…	…	…

7.2.3 Survival results

In our study we are considering 90 SPI initiatives which include VSE and non-VSEs. Table - 14 - Taula provides the survival probability based on Kaplan-Meier (KM) model for this dataset. This figure is the final results of applying KM to all VSEs. Those initiatives requiring more than 11 months, their probabilities of success decrease. It is worth mentioning that in this case we do not discriminate by the reference model used, and we are considering all SPI initiatives.

Table - 14 - Taula Kaplan-Meier survival table snapshot

Id	Time	Risk	Event	Censor	Surv	Upper	Lower
1	3	24	0	1	1.0000000	1.0000000	1.0000000
2	12	23	0	1	1.0000000	1.0000000	1.0000000
3	13	22	1	0	0.9545455	1.0000000	0.8713550
4	14	21	1	0	0.9090909	1.0000000	0.7965615
5	15	20	4	0	0.7272727	0.9393527	0.5630746
6	16	16	1	1	0.6818182	0.9070700	0.5125029

Table - 14 - Taula is a snapshot of the KM survival data where:

- Id: is the reference id number.
- Time: the time points on the curve.
- Risk: the number of subjects at risk at time t
- Event: the number of events that occurred at time t.
- Censor: the number of subjects that are censored at time t.
- Surv: probability of success (survive)
- Lower, Upper: lower and upper confidence limits for the curve

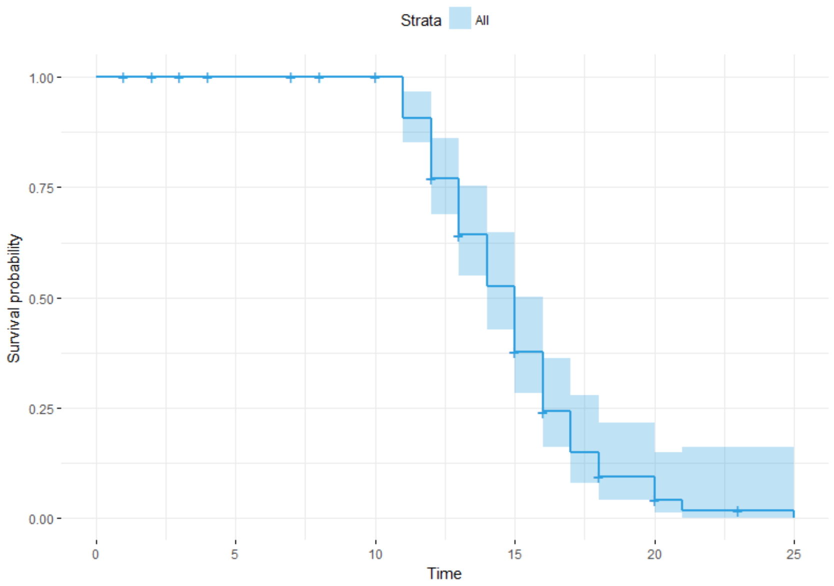

Figure - 8 - Irudia KM for VSEs

From our working dataset we have information based on the ISO/IEC 29110 basic profile which is based on two groups: project management (PM) and software implementation activities (SI). Table - 15 - Taula and Table - 16 - Taula show the survival objects for each group. Table - 15 - Taula is related to project management activities covariates and Table - 16 - Taula is related to software implementation activities covariates. *z* column provides the Wald statistics and it indicates that PM1, PM2 ,PM3 and SI5 are statistically significant coefficients. We need to highlight also the sign of the coefficients (*coef*) for PM4 and SI1 and SI2 which imply they are less relevant with respect to the success of an SPI initiative. Hazard ratios are represented in the *exp(coef)* column. *p* values are also relevant for PM3·and SI5 which are too small.

Table - 15 - Taula The CPHR survival object of project management variables

variable	coef	exp(coef)	se(coef)	z	p
PM1	0.01417	1.01427	0.01134	1.25	0.2115
PM2	0.02243	1.02268	0.01244	1.80	0.0715
PM3	0.02956	1.03000	0.01128	2.62	0.0088
PM4	-0.00228	0.99773	0.01088	-0.21	0.8344

Table - 16 - Taula The CPHR survival object of software implementation variables

variable	coef	exp(coef)	se(coef)	z	p
SI1	-0.01472	0.98539	0.01941	-0.76	0.448
SI2	-0.00887	0.99117	0.01300	-0.68	0.495
SI3	0.02530	1.02562	0.03932	0.64	0.520
SI4	0.00822	1.00826	0.03290	0.25	0.803
SI5	0.07136	1.07397	0.03265	2.19	0.029
SI6	0.02437	1.02467	0.02526	0.96	0.335
SI7	0.01542	1.01554	0.03055	0.50	0.614

Graphically,Figure - 19 - Irudia and Figure - 20 - Irudia represent a set of graphs describing survival curves for our dataset taken into account project management practices (Figure - 19 - Irudia) or software implementation practices (Figure - 20 - Irudia) as covariates. Figure - 21 - Irudia overlaps both groups. There is less variance in software implementation practices, and their survival curve is shorter than project management practices.

7.3 Contribution details

(Q2 Computer Science, Software Engineering-Impact Factor: 1.465)

Xabier Larrucea, and Izaskun Santamaria. “Survival Studies Based on ISO/IEC29110: Industrial Experiences.” *Computer Standards & Interfaces* 60 (November 2018): 73–79. https://doi.org/10.1016/j.csi.2018.04.006

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8 3_ARTIKULUA / PAPER_3

8.1 Correlations and Clustering

This section presents the method used for clustering the SPI studies. This method uses as input the SPI studies resulting from previous studies [52], [53] and [54]. This method is split into two main phases. The first phase is related to SPI studies analysis steps where we analyse the SPI studies results: the summary of the ISO/IEC 29110 basic profile areas, SPI independence testing and their correlations. The second phase is related to the application of SOM as outlined by Figure - 7 - Irudia.

8.1.1 SPI studies analysis- time and correlation

This first phase takes as input the SPI studies carried out previously, and it summarizes them based on the ISO/IEC 29110 basic profile areas. As these studies are based on the proportional Hazard assumption in Cox Model we need to analyse the independence between residuals and time because it is a factor which was not calculated in previous works. This aspect is interesting because we want to know whether the time has an impact onto the expected results. In fact, we use the Schoenfeld Residuals test[97] which formula is:

$$r_k(\beta) = Z_{(k)} - M(\beta, t_k)......(1)$$

Where $Z_{(k)}$ is the covariate vector of the subject, β is a vector of regression parameters, and M is a weighted mean as described in [97]. Note that in this formula we use k for indexing times.

Finally, we study the linear dependence among the ISO/IEC 29110 basic profile areas. Basically, we use the Pearson correlation (r) for measuring this linear independence between two variables (x and y):

$$r = \frac{\sum_{i=1}^{n}(x_i-\bar{x})(y_i-\bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i-\bar{x})^2}\sqrt{\sum_{i=1}^{n}(y_i-\bar{y})^2}} \text{.............(2)}$$

Where n is the sample size, $\bar{x}$ and $\bar{y}$ are the mean of the variables x and y respectively. In fact, this Pearson value is the division of the covariance between x and y by their standard deviations. In our context, this Pearson correlation factor is calculated for every tuple from the ISO/IEC 29110 basic profile areas.

8.1.2 Self Organising Map Layer

This unsupervised neural network is based on a competitive learning approach and it does not require the human intervention during the learning phase. For defining a SOM we need to identify the data, represented as a vector, and its weights. The data used stem from the ISO/IEC 29110 basic profile elements, and we want to identify features and patterns from these experiences. The SOM algorithm helps us to identify these features, and it is usually represented as a two-dimensional grid of neurons (Figure - 9 - Irudia) where each neuron is competing against the others.

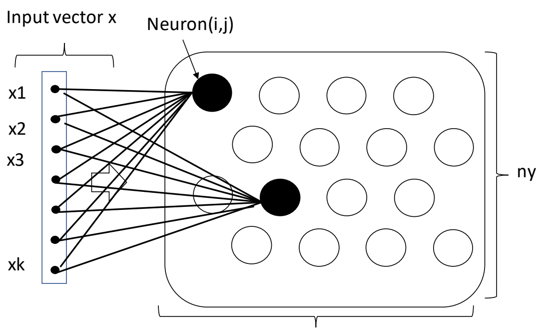

Figure - 9 - Irudia SOM representation

Based on Kohonen [47], we consider a set of input variables $\{\varepsilon_j\}$. *j=1, .. ,n* and a real vector such as $x = [\varepsilon_1, \varepsilon_2, \varepsilon_3, \ldots, \varepsilon_n]^T \in \mathbb{R}^n$. Each element in the SOM array is associated to a parametric real vector $m_i = [\mu_{i1}, \mu_{i2}, \mu_{i3}, \ldots, \mu_{in}]^T \in \mathbb{R}^n$ which represents a model. The general distance between vectors is calculated by the Euclidean distance following the best matching unit (BMU):

$$\|x - m_c\| = \min_j\{\|x - m_j\|\} \quad (3)$$

The SOM algorithm is based on the neighbourhood function which means that a neuron is competing against its neighbours, and during the learning process the algorithm aims to maintain the neighbourhood relationships existing within the input data. In fact, a neuron wins based on a competitive process. The used SOM algorithm is based on the following steps:

1. Construct the data set: this dataset is based on the ISO/IEC 29110 basic profile areas. This dataset is described in recent SPI analysis studies ([52], [53] and [54]).
2. Normalize the model and the values of the input is normalized.
3. Train the map: this process will generate a model containing the codebooks [47].
4. Visualize map in a two-dimensional grid
5. Analyse results based on the patterns extracted from the U-Matrix which is a matrix to illustrate the clustering of codebook vectors

8.2 Results analysis

8.2.1 SPI studies analysis

The data we are using stem from the previous studies [52], [53] and [54]. We have a broad set of SPI initiatives and we analysed and observed organisations implementing a SPI initiative. For each organisation, we have gathered and collected the following data: duration (the time taken by each organisation to succeed or to fail), event (three types of events), censor (whether it is censored or not), and the ISO/IEC 29110 basic profile elements among others. More detailed information is included in the aforementioned studies.

Firstly, we want to summarise the data from our repository. The values related to ISO/IEC 29110 basic profile areas reflect the percentage of fulfilment of the identified profile elements [90]. The following Figure - 10 - Irudia represents the boxplot of the data set. “SI3: Software Architectural and Detailed Design” and “SI4: Software Construction” are the ISO/IEC 29110 basic profile elements with the worst results.

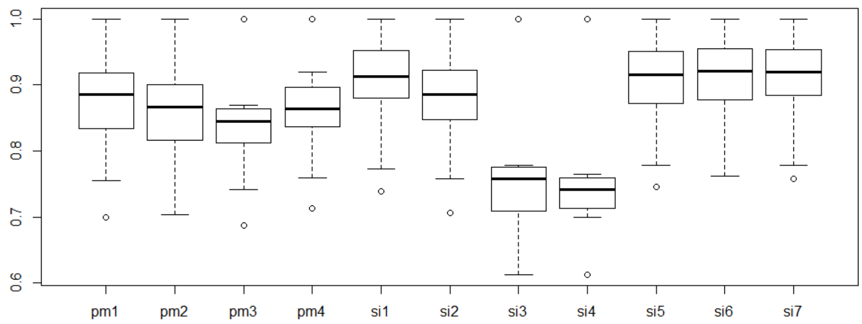

Figure - 10 - Irudia Boxplot of ISO/IEC 29110 basic profile elements

Secondly, we want to analyse whether these SPI studies are time dependent or not, and therefore we apply the Schoenfeld residuals test for each covariate. Figure - 11 - Irudia represents the residuals for VSEs.

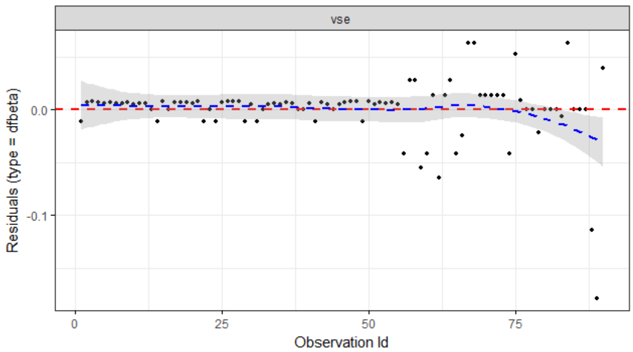

Figure - 11 - Irudia Residuals using “dfbeta” type analysis

Figure - 12 - Irudia provides the Schoenfeld individual test for checking the proportionality assumption against the transformed time. The result shows a very small *p* value (0.0202) indicating that there are time dependent coefficients, and therefore SPI initiatives have a strong time relationship.

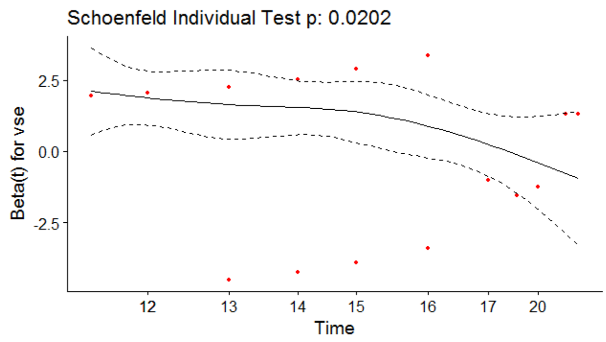

Figure - 12 - Irudia Schoenfeld individual test p:0.0202

Finally, we have performed a correlation analysis (table1) among the ISO/IEC 29110 basic profile elements. The following Figure - 13 - Irudia represents graphically these correlations. The Y-axis from top to the bottom is pm1, pm2, pm3, pm4, si1, si2, si3, si4, si5, si6, si7, and X-axis from left to right is pm1, pm2, pm3, pm4, si1, si2, si3, si4, si5, si6, and si7.

It is relevant to highlight the strong relationship between them. All of them are above 0.6. Most of them are close to 1 which implies a strong correlation.

The “weakest” relationship is between two software implementation areas: “si3 software architecture” and “si4 software construction” with a p-value of 0.612378. Graphically, it is shown as a disperse graph.

The “strongest” relationship is also between two software implementation areas: “si6 Software Integration and Tests” and “si7 Verification and Validation”.

Graphically (Figure - 13 - Irudia), we can identify some interesting relationships among ISO/IEC 29110 basic profile elements such as project management practices (pm1 to pm4) and software implementation practices (si7). Project management practices are tightly related among them. These four areas are considered the basic elements to be carried out during the management of projects. Something similar occurs among software implementation practices. However, the relationship among software implementation and project management areas is not always evident, and the results are graphically disperse.

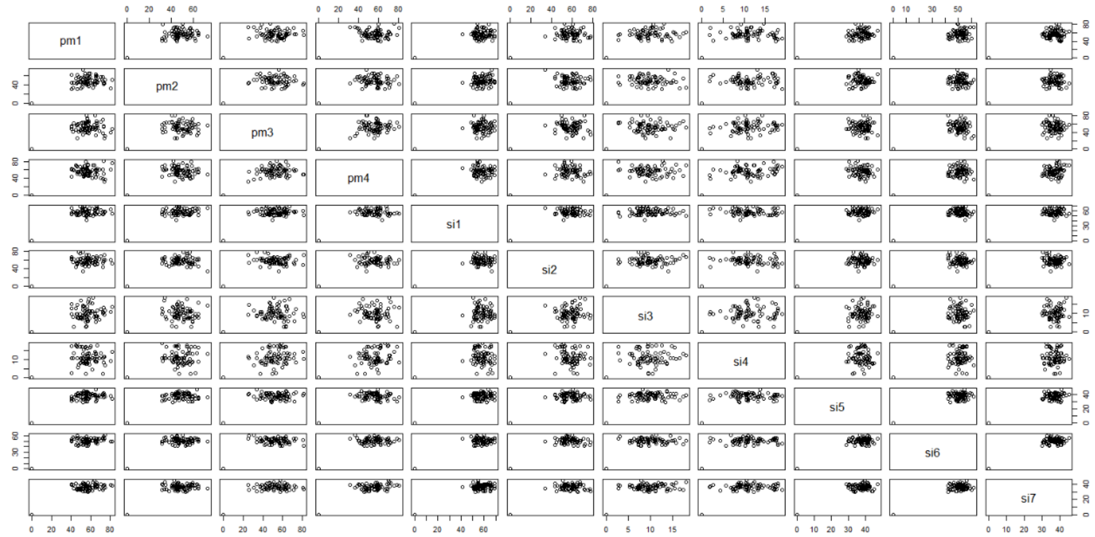

Figure - 13 - Irudia ISO/IEC 29110 basic profile areas (pm1, pm2, pm3, pm4, si1, si2, si3, si4, si5, si6, si7) correlations

8.2.2 Self Organising Map Results

The SOM algorithm generates a map for each variable and the U-Matrix representing the distance between the neurons (Figure - 22 - Irudia).

Traditionally, if the grey scale is used, a dark colour between the neurons (codebook vectors) corresponds to a large distance, and vice versa. Therefore, light areas can be considered as clusters and dark areas as cluster separators. In this case, the SOM is coloured by the values of U-matrix elements. The number denotes the values of u-matrix elements and that of the distances between neighbouring neurons.

By looking at the U -Matrix (Figure - 22 - Irudia upper left corner) we can identify some blue areas which represent clusters. In our context, this is relevant for the following areas which can be considered as clusters:

- pm2: progress of the project monitored against the project plan and recorded in the progress status record.
- si6: Software Configuration is a cluster to be considered.
- si1 to si3 “software implementation”, “requirements analysis”, and “software architectural and design” should be considered as a cluster and especial attention must be devoted to their relationships.

Each ISO/IEC 29110 basic profile area is considered as a SOM variable. Figure - 22 - Irudia represents, apart from the U Matrix, the component planes of the variables. These component planes help us to analyse them separately, and to identify which components are the most significant for the classification. Their behaviours are completely different. Note that the results have been normalized in order to compare them. The results are not as clear as other domains, but we can even identify small clusters, and the most relevant variables for the classification. In this sense, pm2 related to project plan execution and assessments area, and "software implementation", "software construction" and "software integration" are the variables which behaviours have a higher impact onto the classification.

8.3 Contribution details

(Q3 Computer Science, Software Engineering -Impact Factor: 1.167)

Xabier Larrucea, and Izaskun Santamaría. "Correlations Study and Clustering from SPI Experiences in Small Settings." *Journal of Software: Evolution and Process*, September 12, 2018, e1989. https://doi.org/10.1002/smr.1989.

9 4_ARTIKULUA / PAPER_4

9.1 Safety and Security life-cycle approach

9.1.1 Methodology

The proposed methodology considers assurance cases (safety cases) as enablers for gathering safety requirements, security requirements and its associated technical debt in a common place where these aspects are discussed along PLC. Therefore, we consider assurance cases (safety cases) as a cornerstone element of the PLC phases. Our methodological approach (Figure - 14 - Irudia) is a blend approach considering the ISO/IEC/IEEE 15288, NIST cybersecurity framework and the NIST guidance[124]. In addition, we add technical debt related information to each decision point by adding specific milestones to be reached during each stage of the life cycle. These milestones are essential because they force to meet and agree upon safety, security aspects, and to explicitly represent the technical debt. On the one hand, the ISO/IEC/IEEE15288 does not include specific practices for security aspects, but it is a framework for system life cycle. On the other hand, the IEC61508 does not prescribe any specific practice for security assurance. In addition, we have linked each phase of the ISO/IEC/IEEE15288 with one of the phases of the IEC61508. Moreover, none of these standards are related to technical debt management. Therefore, our approach deals with these three aspects: security, safety and technical debt. In fact, we align them in a common framework which is domain agnostic and considering the IEC61508 as a generic approach for all safety lifecycle activities[145]. During the design of the system, we introduce security practices within each phase, and thus, security and safety practices can coexist. These interactions between these two worlds are represented by milestones where both types of requirements are discussed in order to identify constraints and dependencies among others. In addition, these milestones must consider the related technical debt. Therefore, for representing a TD item we have identified the following attributes:

- Name: name of the debt identified
- Date: date on which a debt is identified
- Location: where the debt has an impact.
- Description: general description of this item.
- Estimated Principal: the cost of eliminating a TD immediately
- Interest Amount: how much more effort will be needed for solving the issue
- Probability: how likely is it that a security or safety issue will occur

A recent systematic literature review about TD [146] provides an overview of the main financial approaches. Based on these different approaches, the principal and the interests are based on estimations, and we are going to adopt this technique for assigning values to these attributes.

In the safety and cybersecurity environments, NASA and NIST approaches are considering milestones such as Key Decision Points (KDP) by NASA, and check points by NIST. These milestones represent temporal events where stakeholders must take a decision. Our proposal considers not only security and safety, but also technical debt decisions.

From a VSE perspective, we need to avoid having a huge number of milestones. However, we need to deal with safety, security and technical debt aspects at the same time. VSEs cannot invest too many resources for dealing with them because each element is time consuming. For an appropriate management of these elements, we need to trace what, when and where these aspects have been tackled. At the end of the system life cycle stage (e.g. Concept) we need to have fulfilled 5 internal milestones. For each stage, we include the activities stemming from NIST cybersecurity framework, and each activity is enhanced with technical debt considerations:

- Identify (ID): security requirements are considered and added to the resulting assurance case. All these security requirements can be related to safety requirements. A first trade off process between them is considered. Each relationship shall be included as a risk, and a technical debt item must be identified.

- Protect (PR): for each requirement we identify a set of protection mechanisms. From a technical debt perspective, we estimate the principal and interests.
- Detect (DE): based on potential scenarios there is a detection of potential threats. We confirm the estimated probability for the TD item.
- Respond (RS): the resulting assurance case contains measures on how respond to each potential threat. This is part of the risk management process.
- Recover (RC): the assurance case should contain how to recover the system from an unforeseen event. Traditionally this aspect is not included as part of the assurance cases. We resume the TD item.

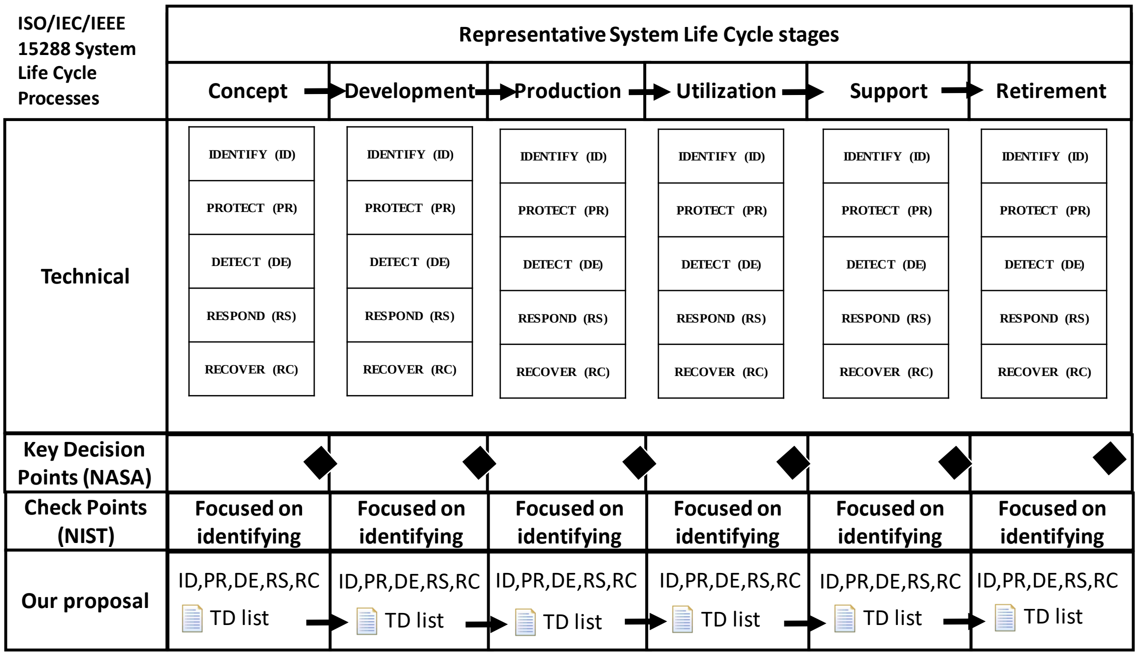

Figure - 14 - Irudia Methodological approach for safety and security using assurance cases

Table - 17 - Taula represents an excerpt of cybersecurity activities to be carried out during the system analysis process. All of them are considered as requirements in every system, so they should be considered when analyzing a system. For example, the first activity described in Table - 17 - Taula as *"Identify the security aspects of the problem or question that requires system analysis*" is an activity which requires as an evidence the identification of the problem. Assurance cases must include the scenarios and the scope for a specific component. In addition, a technical debt is integrated with the assurance cases development. This is not the sole activity with a technical debt consideration. In fact, every activity considers the TD list which is used on each phase. For example, "*Apply* *the selected security analysis methods to perform the security aspects of required system analysis*" activity requires a tool support for analysing source code vulnerabilities, and in our case we used a tool chain.

Table - 17 - Taula Security activities during the system analysis process

Prepare For The Security Aspects Of System Analysis	Identify the security aspects of the problem or question that requires system analysis
	Identify the stakeholders of the security aspects of system analysis
	Define the objectives, scope, level of fidelity, and level of assurance of the security aspects of system analysis.
	Select the methods associated with the security aspects of system analysis.
	Define the security aspects of the system analysis strategy.
	Identify, plan for, and obtain access to enabling systems or services to support the security aspects of the system analysis process.
	Collect the data and inputs needed for the security aspects of system analysis
Perform the security aspects of system analysis	Identify and validate the assumptions associated with the security aspects of system analysis
	Apply the selected security analysis methods to perform the security aspects of required system analysis
	Review the security aspects of the system analysis results for quality and validity
	Establish conclusions, recommendations, and rationale based on the results of the security aspects of system analysis.
	Record the results of the security aspects of system analysis.
Manage the security aspects of system analysis	Maintain traceability of the security aspects of the system analysis results
	Provide security-relevant system analysis information items that have been selected for baselines

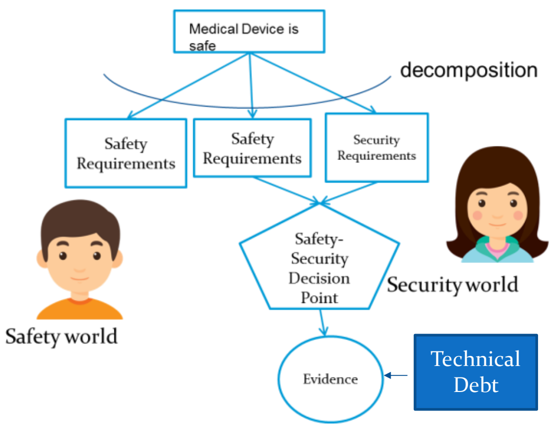

Figure - 15 - Irudia Assurance cases schema and how objectives are decomposed until evidence

Figure - 15 - Irudia introduces a decision point ("Safety Security decision point") which is a new concept in assurance cases. This decision point represents a decision between safety and security aspects, and it includes the associated technical debt item. This TD item is added to a TD list which is used along the PLC. This decision point is used during the trade-off process between safety and security aspects, and it should be analysed and balanced. NASA and NIST include a similar concept, but their approaches do not include an exhaustive set of cybersecurity related activities, and they do not include the technical debt concept. The main difference between exiting approaches and our contribution:

- Key Decision Point (NASA handbook version 2):The event at which the Decision Authority determines the readiness of a program/project to progress to the next phase of the life cycle (or to the next KDP).
- Checkpoint (NIST) Identify any unspecified emergent behavior that occurs, regardless of if that behavior is desirable or undesirable.
- Safety-Security Decision Point enhanced with TD list (our contribution); The event at which a Decision Authority identifies, protects, detects, responds and recovers safety and security events. It includes a set of TD items which are related to the assurance case.

9.1.2 Tool chain

Our methodology is supported with a tool chain where assurance cases are the key elements. As stated before assurance cases must include system design related arguments and the evidences supporting the arguments. In addition, we have included decisions points to be included with the assurance cases. In fact, we represent on each decision point not only safety aspects but also security and technical debt concepts. Each decision must be registered in order to trace technical decisions and their impact onto the system. Our toolchain is based on Opencert tool [127] which has been used in safety critical environments for representing assurance cases. These cases are used, enhanced and modified along the whole PLC. Therefore, we need a supporting tool for modelling all the arguments to be described during the lifecycle. In this sense, security and safety constraints stemming from ID, PR, DE, RS, RC are taken into account, and a TD list is maintained along the PLC.

Figure - 16 - Irudia outlines the schema of the toolchain (on the left) and the running tools (on the right). Firstly, the Opencert tool is used for creating and maintaining the assurance cases. As result, we have a set of evidences. Secondly, we link our assurance cases tool to a source code analyzer based on Sonarqube. This tool is essential for demonstrating the evidence related to source code analysis, especially those related to security aspects.

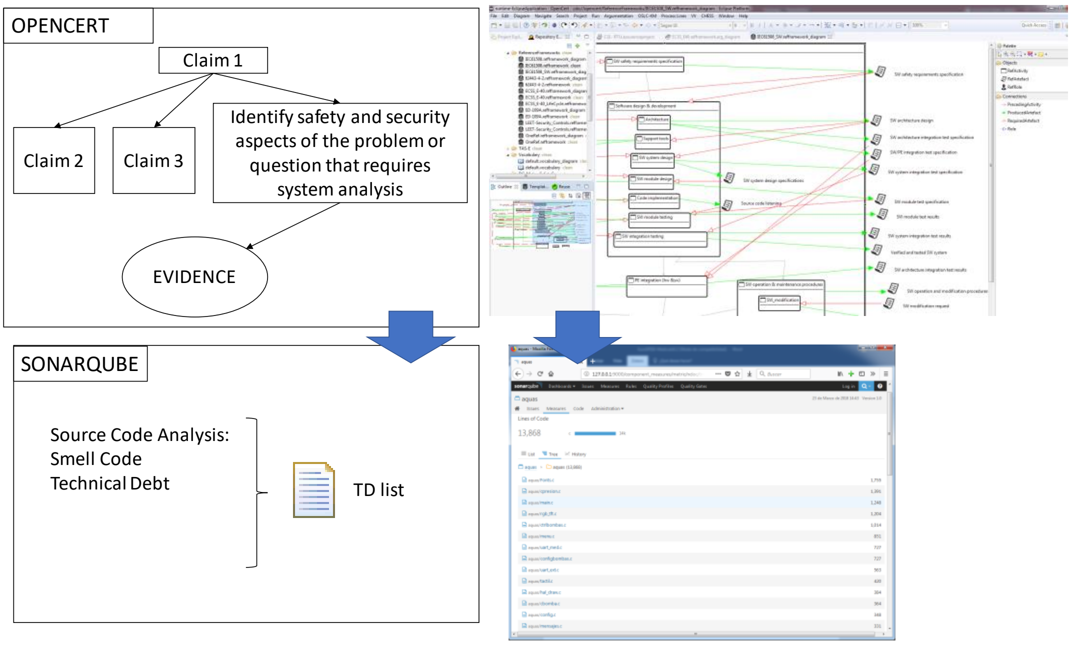

Figure - 16 - Irudia Toolchain based on Eclipse/polarsys Opencert and Sonarqube instance

9.2 Contribution details

(Q3 Computer Science, Software Engineering -Impact Factor: 1.167)

Xabier Larrucea, Izaskun Santamaria and Borja Fernandez-Gauna. Managing Security Debt across PLC phases in a VSE context. *Journal of Software: Evolution and Process*,

10 Emaitzak // Results

Ekarpen bakoitzeko emaitzak argi eta garbi identifikatzeko helburuarekin, hurrengo ataletan, lan bakoitzari dagozkion ekarpenak elkartu dira.

10.1 *Mapping* ISO/IEC 29110

ISO/IEC 29110 estandarra bera ikerketagai bihurtzen ari da (Figure - 17 - Irudia). 2011tik, estandarra argitaratu zen urtetik, hainbat arlo landu dira, baina oraindik ezezaguna zen zeintzuk ziren ekarpen garrantzitsuenak egin dituztenak eta zer jarduera mota egiten ari diren.

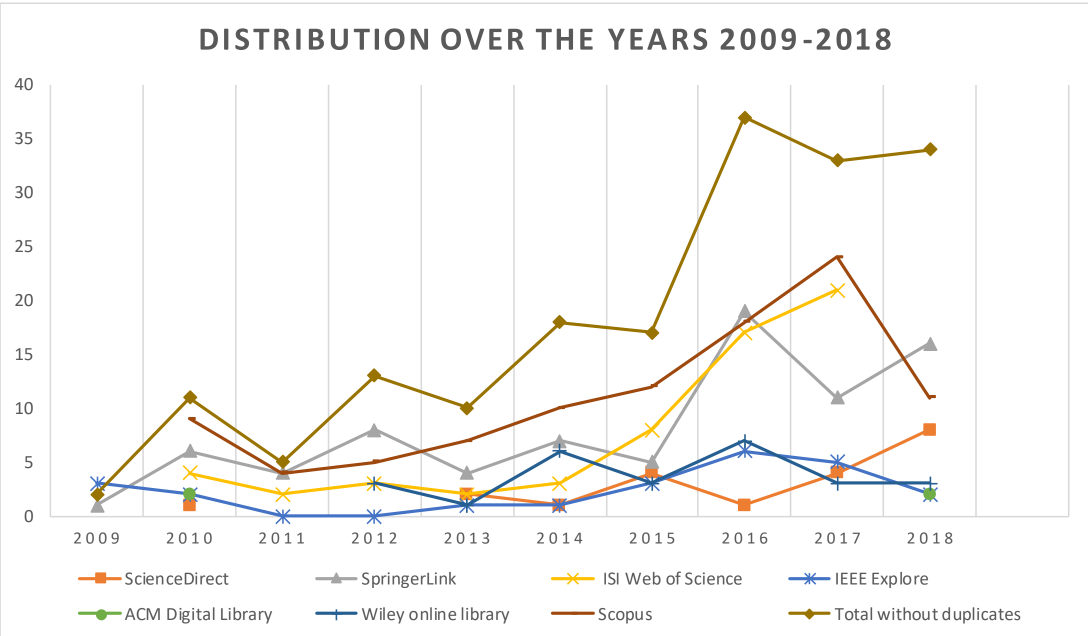

Figure - 17 - Irudia Distribution of papers over the years 2009-2018

Prozesuak hobetzeko orduan, estandarrak beharrezkoak diren jarduera asko errazten baditu ere, bere egitura ez da hasieratik erraz ulertzen den horietakoa, eta ekarpenak konplexuak dira. Hortaz, atzera begiratzeko unea iritsi da, argitaratu diren lanak laburbiltzeko eta landuko dugun eremua bere testuinguruan kokatu ahal izateko.

Lehen atal honetan, honako erantzun hauek lortu dira galdera bakoitzeko:

- **Zeintzuk dira arlo honetako ikerlaririk garrantzitsuenak?** Lanak lehenengo egile moduan sinatu dituzten 93 egile daude. Claude Laporte (25) eta Rory V. O'Connor (11) dira estandarrari ekarpen gehien egin dizkioten egileak. Hain zuzen ere, estandarraren egile nagusiak dira. Horrez gain, bi egileek beste lan batzuetan laguntzaile ere izan dira. Hain zuzen ere, Claude Laporte bigarren egilea da 8 argitalpenetan, eta Rory V. O'Connor beste 20 argitalpenetan.
- **ISO/IEC 29110 arauarekin zerikusia daukan zenbat jarduera garatu da?** Lehen lanaren grafiketan argitalpenen datu-base bakoitzeko joerak agertzen dira. Estandarra argitara eman zenean, oso lan gutxi argitaratu ziren: 2010ean, 11 lan izan ziren, eta 2011n, 5. Geroztik, 10 eta 18 lan bitartean argitaratu ziren 2015era arte. 2015 eta 2016aren artean, baina, argitalpenek nabarmen egin zuten gora, eta 2015ean 17 izan baziren, 2016an 37k ikusi zuten argia. Ordutik joera horri eutsi zaio.
- **Arau honekin lotura duten zein motatako lanak egin dira?** Zerikusia duten azterketak sailkatzeko eskema bat erabili da, eta emaitzak honako hau erakusten du: 43 *Evaluation Research* motatakoak dira, 59 *Solution Proposal* motatakoak eta 54 *Experience Paper* motatakoak. Hau da, batez ere esperientziak argitaratu dira. Argitalpen motari dagokionez, ordea, aurkitu dira: 35 *Conference Paper*, 86 *Journal* eta 58 *Book Section*.
- **Zeintzuk dira ikergai nagusiak?** Erabilitako sailkapenaren arabera, gaiaren araberako kopuru hauek lortu ditugu (Figure - 18 - Irudia):

    - *Education*: 44 lan argitaratu dira. Ikasketekin eta irakasletzarekin zerikusia duten azterlanak sailkatu dira hemen. Estandar desberdinen arteko *mapping*-ak eta irakasletzarekin loturiko beste alderdi batzuk daude honen barruan.

- *SPI factors*: 48 lan argitaratu dira. Besteak beste, faktore kulturalekin zerikusia duten azterlanak edo prozesuen hobekuntza gertatzen den ingurunearen azterketak aurkituko ditugu.
- *Case study*: 40 lan argitaratu dira. Esperientzia industrialak sartzen dira hemen barruan.
- *Project Management*: 35 lan argitaratu dira. Proiektuen kudeaketarekin zerikusia duten lan ugari daude, arauaren eta bere oinarrizko profilaren funtsezko alderdi bat delako.
- *Assessment method*: 12 lan argitaratu dira. Ebaluazioak gauzatzeko lan handia egin behar da, eta ebaluazioen alderdi horrekin loturiko 12 artikulu daude.

Zeintzuk dira arlo honetako ikerlaririk garrantzitsuenak?	• Lanak lehenengo egile moduan sinatu dituzten 93 egile daude • Claude Laporte (25) eta Rory V. O'Connor (11) dira estandarrari ekarpen gehien egin dizkioten egileak: estandarraren egile nagusiak dira
Zenbat ekoizpen zientifiko argitaratu dira ISO/IEC 29110 arauarekin zerikusia daukatenak?	• Oso lan gutxi argitaratu ziren: 2010ean, 11 lan izan ziren, eta 2011n, 5. • Geroztik, 10 eta 18 lan bitartean argitaratu ziren 2015era arte.2015 eta 2016aren artean, baina, argitalpenek nabarmen egin zuten gora, eta 2015ean 17 izan baziren, 2016an 37k ikusi zuten argia. • Ordutik joera horri eutsi zaio
Zein motatako lanak egin dira ISO/IEC 29110 arauari buruz?	• 43 *Evaluation Research* motatakoak • 59 *Solution Proposal* motatakoak • 54 *Evaluation Research* motatakoak. • 35 *Conference Paper*-etan, 86 *Journal*-etan eta 58 *Book Section*-etan
Zeintzuk dira gai nagusiak?	• *Education*: 44 • *SPI factors*: 48 • *Case study*: 40 • *Project Management*: 35 • *Assessment method*: 12

Figure - 18 - Irudia SM emaitzak - laburpena

10.2 Biziraupenaren azterketak

Biziraupenaren analisiari dagozkion emaitzak bigarren lanean jasota daude, eta Kaplan-Meier ereduan oinarritu dira. Eredu honetan ikus daiteke 11 eta 13 hilabete bitarteko iraupena duten esperientzia industrialek arrakastatsuak izateko aukera handiak dituztela. Hala ere, 13 hilabetetik aurrera, esperientziek huts egiteko gero eta aukera gehiago dituzte. Hau da, “Surv” balioa 1etik jaisten hasten da.

Table - 18 - Taula Kaplan-Meier arauraren emaitzak

Id	Time	Risk	Event	Censor	Surv	Upper	Lower
1	3	24	0	1	1.0000000	1.0000000	1.0000000
2	12	23	0	1	1.0000000	1.0000000	1.0000000
3	13	22	1	0	0.9545455	1.0000000	0.8713550
4	14	21	1	0	0.9090909	1.0000000	0.7965615
5	15	20	4	0	0.7272727	0.9393527	0.5630746
6	16	16	1	1	0.6818182	0.9070700	0.5125029

Horrez gain, ISO/IEC 29110 arauaren oinarrizko profilaren ereduko arlo bakoitzeko CPHRaren araberako emaitzak lortu dira. Ereduak 2 taula sortzen ditu, emaitzak jasota dituztenak. Hurrengo irudian (Figure - 21 - Irudia), software garapenaren arloaren (Figure - 20 - Irudia) eta kudeaketa arloaren (Figure - 19 - Irudia) arteko alderaketa grafikoa ikus daiteke (software garapenaren arloaren eta kudeaketa arloaren arteko alderaketa).

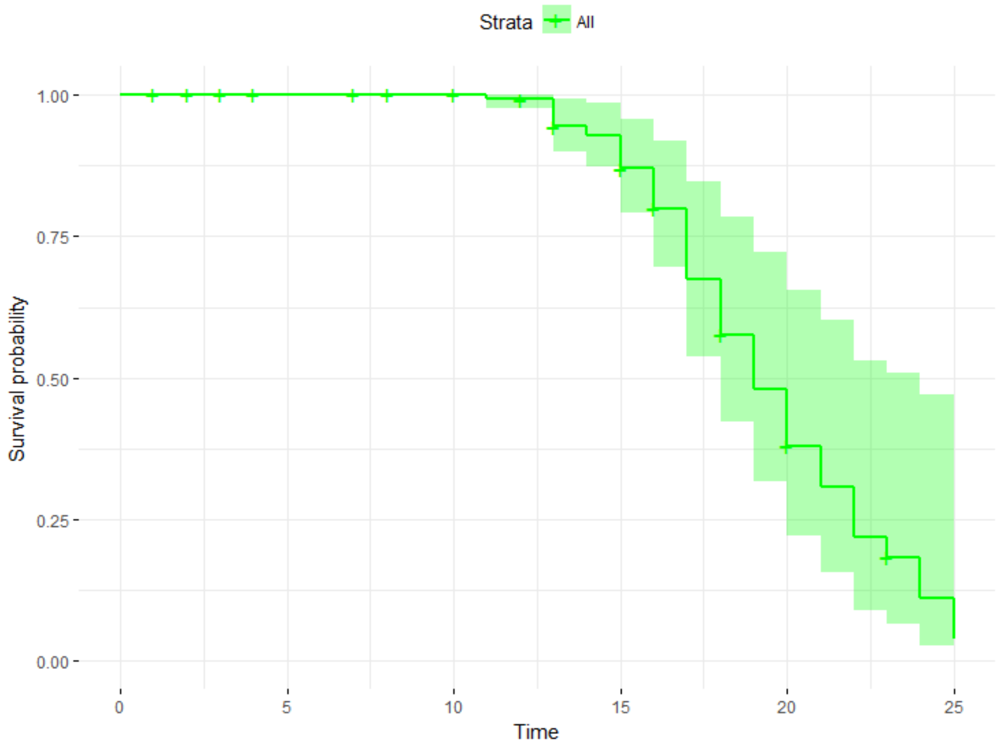

Figure - 19 - Irudia Biziraupenaren azterketak: Project Management

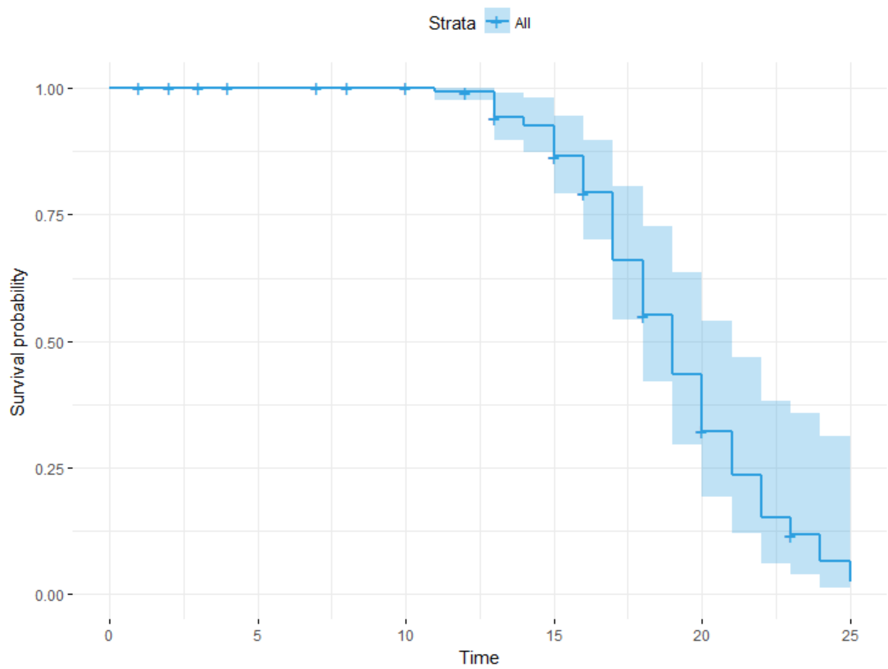

Figure - 20 - Irudia Biziraupenaren azterketak: Software Implementation

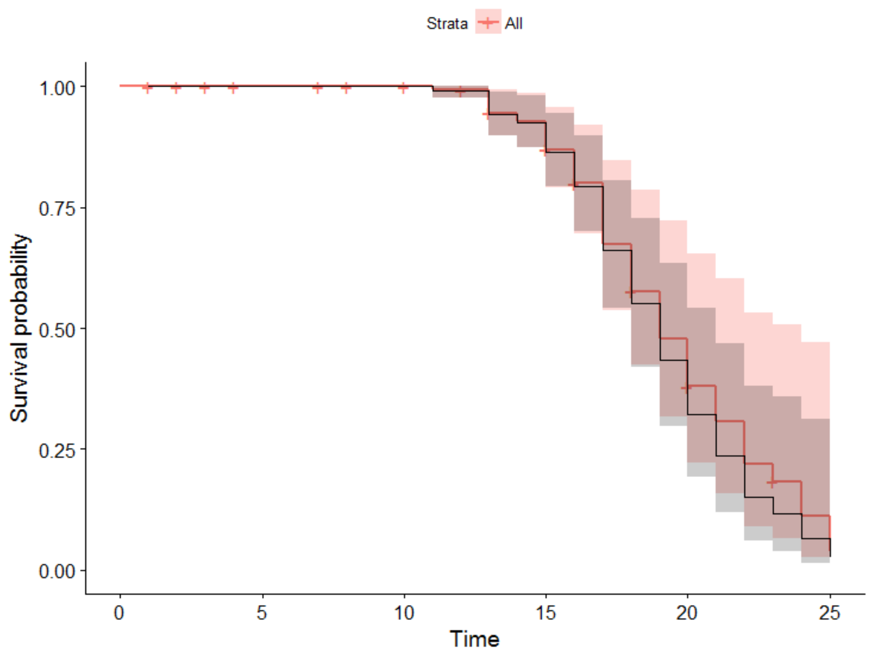

Figure - 21 - Irudia Biziraupenaren konparaketa

10.3 *Correlations* eta *clustering*

SOM algoritmoak mapa bat sortzen du ISO/IEC 29110 estandarraren aldagai bakoitzeko, eta U-Matrix matrizearekin adierazten du neuronen arteko distantzia. Gune ilunenak neuronen arteko distantziarik luzeenei dagozkie, eta gune argienak, aldiz, *clusterrak* dira. Matrizean honako emaitza hauek ikus daitezke:

- pm2: *cluster* baten moduan hartu behar da.
- si6: software konfigurazioaren arloa kontuan hartu beharreko *cluster* bat da.
- si1, si2, si3 "*software implementation*", "*requirements analysis*" eta "*software architectural and design*" *cluster* moduan hartu beharko lirateke.

ISO/IEC 29110 arauaren oinarrizko profilaren arlo bakoitza SOM aldagai bat da, eta, gainera, bereiz aztertzen da zein den arlorik esanguratsuena. Haien portaerak erabat desberdinak dira. Emaitzak ez dira beste esparru batzuetan bezain argiak, baina, edonola ere, goian azaldutako *clusterrak* identifikatu daitezke.

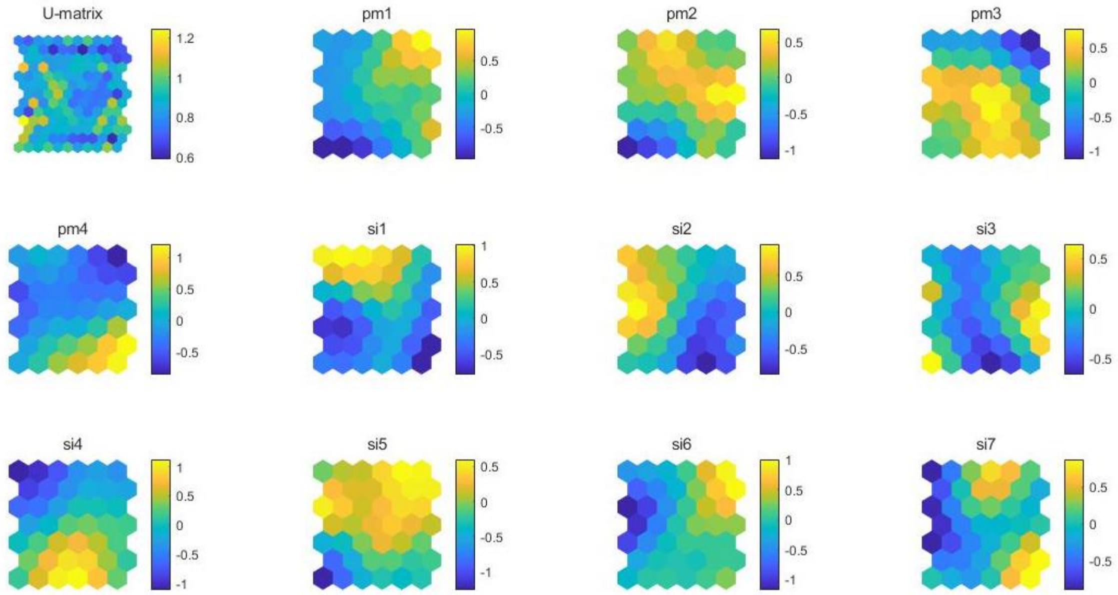

Figure - 22 - Irudia SOM: U – Matrizea eta ISO/IEC 29110-a oinarrizko profil-eremuak

10.4 *Security Debt*

Proposatutako ikuspegia transmisio neuromuskularreko gailu bat (NMT) garatu duen medikuntza-arloko VSE bati aplikatu zaio. Gailu horrek anestesistei laguntzen die, ebakuntza batean giharren erlaxazioa kontrolatzeko. Hortaz, azken produktuak segurtasun-arau jakin batzuk ziurtatu behar ditu (UNE araua, etab.).

Produktuaren bizi-zikloaren faseen identifikazioa eta ondorengo mapaketa da emaitza esanguratsu bat. VSEaren bizi-zikloaren eta estandarren eskakizunen arteko *mapping* hau identifikatu zen.

VSEaren faseen eta ISO/IEC 29110 arauaren artean ere *mapping* bat identifikatu da.

Bizi-ziklo orokorraren ikuspuntutik, *assurance cases* guztiak zikloaren fase bakoitzean hartu behar dira kontuan, honako irudi honek erakusten duen moduan.

Table - 19 - Taula Kasu industriala eta gure aipamen-egitura artean mapa egin

RGB Method ISO/IEC/IEEE15288	Concept	Development	Production	Utilization	Support	Retirement
Requirements	**X**					
Modelling	**X**	**X**				
Simulation	**X**	**X**	**X**			
Implementation			**X**			
Validation				**X**		
Operation				**X**	**X**	
Retirement						**X**

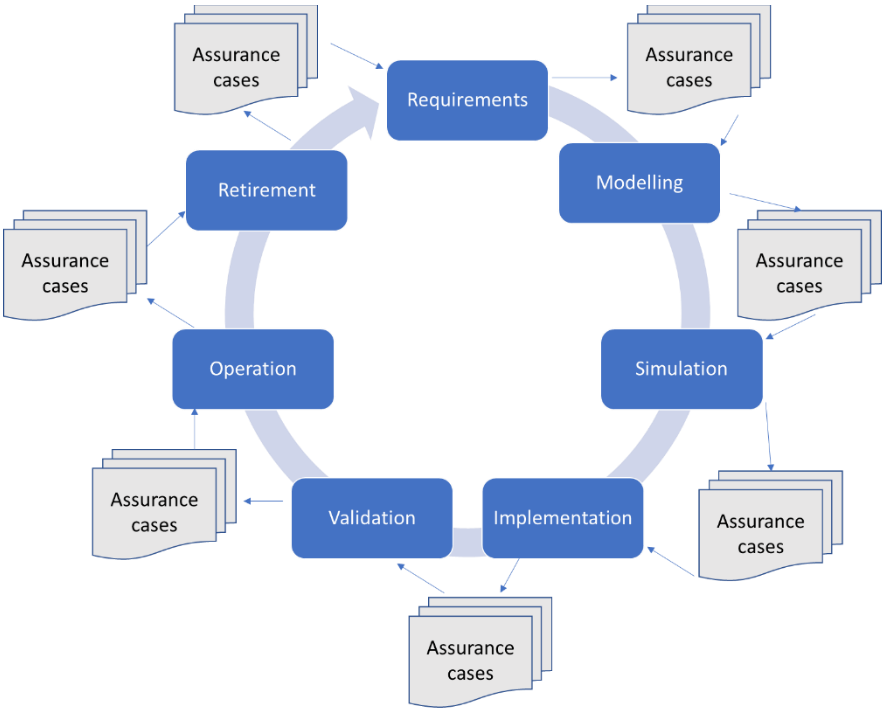

Figure - 23 - Irudia Segurtasun kasuek PLC-faseak burutu zituzten

Table - 20 - Taula ISO/ÏEC29110-a eta gure aipamen-egitura artean mapa egin

	Require_ ments	Modelling	Simula_ tion	Imple_ mentation.	Validation	Operation	Retirement
PM. 1. Project Planning	X	X					
PM. 2. Project Plan execution		X	X	X			
PM.3. Project Assessment and Control					X	X	
PM.4. Project Closure							X
SI.1.Software implementation Initiation	X						
SI.2. Software requirements Analysis	X						
SI.3. Software architectural and detailed design		X	X	X			
SI. 4. Software Construction				X			
SI. 5. Software integration and Tests					X		
SI. 6. Product Delivery						X	X

11 Eztabaida // Discussion

Ikerketa hau 4 lanetan banatuta badago ere, ekarpen guztiak elkarren artean lotuta daude, eta batez ere VSE-ek prozesuak hobetzeko burututako ekimenen biziraupenarekin dute lotura.

11.1 *Mapping* ISO/IEC 29110

Lehenengo lanak ISO/IEC 29110 arauaren esparruan orain arte egin diren ekarpenen laburpen bat eskaintzen du. Estandarraren editore nagusia, Claude Y. Laporte, lehen egile moduan argitalpen gehien dituen egilea dela nabarmendu behar da. Estandarraren editorea denez, estandarraren aukerak hobekien ezagutzen dituen pertsona da, bai eta izan ditzakeen hutsuneak ere. Nolanahi ere, desiragarria izango litzateke egile gehiago egotea ekarpen kopuru handiagoarekin, arlo endogamiko bat izan ez dadin.

Nabarmena da, halaber, ekarpenen igoera 2017 eta 2018an. Estandarra argitaratu zenetik denbora tarte bat igaro delako gertatu da hori, eta gero eta esperientzia (54) eta konponbiderako proposamen gehiago dagoelako (59). Nagusiki, ikergaiek hezkuntza-arloko alderdiak izaten dituzte ardatz (44), bai eta prozesuen hobekuntzan zerikusia duten faktoreen analisia ere (48). Emaitzek erakusten dute alderdi horietan ikerketa gehiago egin behar dela, hobekuntza-ekimenak arrakastatsuak izateko gakoa baita. Hain zuzen ere, arau horren aplikazioaren esperientzia gehiago argitaratu behar dira, orain arte egin diren ekarpenak sendotzeko helburuarekin. SPI faktoreekin, azterketa kasuekin eta proiektuen kudeaketarekin zerikusia duten lanen kopurua nabarmen handitu da azkenaldian. Zehatz esateko, 2016tik egin dute gora, hain zuzen ere, alderdi hauek denbora behar dutelako martxan jartzeko. Berrikuntza bat ezarri ondorengo zabalpen-prozesuak [31] denbora jakin bat behar du, bai eta bere argitalpenak ere.

Azterketa mota honetan, emaitzen balioarekin loturiko mehatxuak aztertu behar dira [56]. Hortaz, balioa aztertzeko hainbat alderdi hartu behar dira kontuan, hala nola bere eraikuntza, barne-balioa, kanpo-balioa eta emaitzen fidagarritasuna. Analisi hau jasota eta zehaztuta dago argitaratutako artikuluetan.

11.2 Biziraupen-azterketak

Biziraupen-ereduarekin loturiko bigarren lanak agerian uzten du erakundeek 13 hilabete baino gutxiago erabiltzen dituztela hobekuntza-eredu bat ezartzeko. Une horretatik aurrera, arrakasta izateko aukerak pixkanaka murrizten dira. Goi-zuzendaritzaren laguntza eta konpromisoa funtsezkoak dira, ekimenaren babesleak baitira eta eredua arrakastaz ezartzeko beharrezkoak diren baliabideak erabiltzea ahalbidetzen dutelako. Esperientzien datu-basea, noski, etengabe hazten eta datu berriak biltzen ari da.

11.3 *Correlations and clustering*

ISO/IEC 29110 arauaren oinarrizko profila aplikatuta eman diren esperientzien arteko korrelazioak ikus daitezke hirugarren lanean. Horrez gain, lotutako arlo guztiak jasota ditu SOM mapa batean. SOM eredua gainbegiratu gabeko ikasketa-teknika bat da, eta testuinguru honen ezaugarrietara egokitzen delako erabili da. Gainbegiratutako ikasketa-teknikak aplikatzeak eta prozesuak hobetzeko esperientzien jarraipena egiteak ikuspegi osagarri bat emango liguke. Une honetan, gainbegiratutako ikasketa-ikuspuntu hau garapen bidean dago, baina oro har, koste handiagoak ditu, baliabide gehiago erabili behar direlako.

Aurreko kasuetan bezala, ikuspuntuak hainbat mugapen ditu:

- Ekimenen hasierako eta amaierako datak ezagutu behar dira.
- Praktika guztien ebidentziak bildu eta haien ezaugarriak zehaztu behar dira.

Hala ere, oro har, SPItik datozen datuek aztertu eta erabiltzeko ikuspuntu berritzaile bat eskaintzen digute. Gauzak horrela, SPI ebaluazioen osagai subjektibo batzuk murrizten ditugu.

11.4 *Security Debt*

Laugarren lanak azterlana osatzen du, eta prozesuen hobekuntzaren zati handi bati segurtasun-arloko alderdiak gehitzen dizkio. Horrez gain, beste alderdi batzuk ere barne hartzen ditu, hala nola kontuan hartu beharreko segurtasun-arloko praktikak eta zor teknikoa.

Azterketa kasu honetatik [57] software garapenean segurtasun-arloko alderdiak sartu nahi dituzten eta, horrekin batera, zor teknikoa kudeatu nahi duten VSE-entzako hainbat gomendio atera daitezke:

- Aseguratze-kasuak eta laguntza-tresna bat zehaztea. Kasuetan erabaki zehatzak jaso behar dira, zorra ebaluatu ahal izateko.
- Aseguratze-kasuetan segurtasun-arloko eskakizunak gehitzea.
- Segurtasun-arloko eskakizunak argi eta garbi zehaztea eta tabuladoreak erabiltzea ulermena errazteko.
- Eskakizunen arteko harremana modu argi eta eztabaidaezinean adieraztea maila guztietan: erabiltzailearen eskakizunak, sistemen eskakizun funtzional eta teknikoak, etab.
- Eskakizunak eta haren eraginpeko produktuak lotzea, zehazki, eskakizunarekin loturiko iturri-kodearen zati batekin, trazabilitatea egin ahal izateko. Garatutako tresnak lotura hori egiteko aukera ematen du.
- PLC osoan arriskuen analisia eta arriskuen ebaluazioa egiteko tresna zehaztea eta kudeatzea.
- Bizi-zikloan zor teknikoa sartzea. Zor teknikoak osagai hauek ditu: izena, data, kokapena, azalpena eta finantza-arloko alderdiak, hala nola zorra bera eta aplikatutako interesa.
- Zor teknikoa eta identifikatutako arriskuak lotzea.
- Kode seguruaren analisi bat egitea.
- Argudiaketa bizi-ziklo osora zabaltzea.

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12 Ondorioak

12.1 *Mapping* ISO/IEC 29110

Hona hemen azterlan honen ondorio nagusien laburpena:

- 2009tik ISO/IEC 29110 estandarrari buruzko lanak argitaratu dira, eta, ordutik, argitalpenen aniztasuna oso handia izan da.
- Argitalpenen joerak ISO/IEC 29110 estandarraren inguruko interesa hazten ari dela erakusten du.
- Arlo honetan egindako ekarpenen egoera zehazteko 184 artikulu aztertu dira.
- Orain arte argitaratutako ikergaiak askotarikoak izan dira, baina sailkapen-eskema baten arabera sailkatu dira.
- VSE-ek egoera zehatz batzuetan zein portaera duten behatzeko, ikerketa eta esperientzia gehiago behar dira.

12.2 Biziraupen-azterketak

Hona hemen azterlan honen ondorio nagusien laburpena:

- Prozesuak hobetzeko 90 ekimenek osatzen dute ebaluazioen emaitzak dituen datu-basea.
- Ekimen bakoitzetik beharrezko informazioa identifikatu eta ateratzeko prozesua oso nekagarria da.
- Informazio hori CPHR eta Kaplan-Meier eredurako erabiltzen da, ikuspuntu positibo batetik. Hau da, gertakari negatiboak behatu beharrean, gertakari positiboak behatzen dira.
- Proiektuen kudeaketarekin loturiko jardunek software garapenarekin loturikoek baino garrantzia handiagoa daukate.

- VSE-etan prozesuen hobekuntzak arrakasta izateko aukera 13 hilabeteak baino lehen handiagoa da. 13 hilabetetik aurrera, arrakastatsua izateko aukera txikitu egiten da.
- Software garapenaren jardunean aldakortasuna txikiagoa da proiektuen kudeaketaren jardunean baino.

12.3 *Correlations* eta *clustering*

Hona hemen azterlan honen ondorio nagusien laburpena:

- VSE-ek muga eta oztopo asko dituzte SPI testuinguru baten barruan.
- Esperientziaren esparruan, ISO/IEC 29110 oinarrizko profilaren arloek elkarren arteko loturak dituzte. Korrelazioen azterketaren arabera, lotura argia dago bi arlo hauen artean: “SI3: *Software Architectural and Detailed Design*” eta “SI4: *Software Construction*”. Software garapenaren arloen arteko loturak (si5, si6, si7) eta proiektuen kudeaketarenak (pm1, pm2, pm3, pm4) agerikoak dira.
- SOMen oinarrituriko *clusterrak* ez dira oso argiak, mugen arteko bereizketa ez delako nabarmena. Hala ere, zenbait *cluster* identifikatu dira, hala nola “s1 *software implementation*”, “s2 *requirements analysis*”, eta “s3 *software architectural and design*”.

12.4 Security Debt

Hona hemen azterlan honen ondorio nagusien laburpena:

- VSE-etara egokitutako metodologia bat garatu da, ISO/IEC/IEEE 152888 arauan oinarrituta eta NIST edo NASA segurtasun-markoak aintzat hartuta.
- Segurtasun-arloko erabakiak jaso behar dira aseguratze-kasuetan.
- Eskakizun guztiek aseguratze-kasuen parte izan behar dute.
- Segurtasunarekin loturiko erabaki bakoitzak lotutako zor tekniko bat dauka, bizi-zikloan kudeatu beharko dena.
- Kode osoaren analisi estatiko bat egin behar da.
- Segurtasun-arloko eskakizunekin loturiko kodearen atalak identifikatu behar dira.
- Ikuspuntuari laguntzeko tresna bat garatu da.

- Momentuz, ikuspuntu hau ezin da VSE guztietara estrapolatu.

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