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Moving Towards a Single Smart Cadastral Platform in Victoria, Australia

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Abstract: Various jurisdictions are currently in the process of reforming their cadastral systems to achieve a smart and multidimensional system that provides a range of land administration services to the wider community. The state of Victoria in Australia has been actively modernizing its cadastral system since the 1990s by developing a digital cadastre database, an online digital cadastral plan lodgment portal named SPEAR, and smart cadastre services for validating and visualizing digital data in the ePlan (LandXML) format. However, due to challenges in the implementation of the smart cadastre lifecycle in Victoria, the uptake of ePlan is currently low across the surveying industry. This study aims to explore the feasibility of implementing a smart platform for managing ePlan lodgments in Victoria, which provides all required services within an integrated digital environment. To achieve this aim, the business and technical requirements for realizing a single smart cadastral platform are first explored. A proof of concept (PoC) is then developed to showcase a suitable approach for developing this platform. The evaluation of the PoC confirmed that integration of smart cadastre services into a single environment could significantly streamline the digital cadastral data management processes in Victoria.

Keywords: smart cadastre; digital lodgment; ePlan; PoC; Victoria

1. Introduction

A cadastral system defines and records the spatial location and extent of property rights, restrictions, and responsibilities [1]. It includes a geometric description of land parcels linked to other records describing the nature of the interests and the ownership or control of these interests [2]. Traditional cadastral systems adopted a fragmented approach for storing, disseminating and curating cadastral datasets. Nowadays, various jurisdictions around the world are in the process of reforming their cadastral systems to achieve a smart and spatially accurate cadastre, catering for multidimensional data (including height and time series—which refers to changes over time and thus, captures the dynamic nature of land and property elements). The examples include Australia [1], New Zealand [3], Singapore [4], Malaysia [5], Netherlands [6–8], China [9], and Serbia [10].

The Land Administration Domain Model (LADM) has played a significant role in modernizing cadastral systems, particularly in developing jurisdictions that do not have a robust spatial data infrastructure for managing land and property information. The LADM standard is a flexible model that can be used and adapted for reforming cadastral systems. The existing literature indicates that the viability of LADM implementation was investigated in different jurisdictions [11]. These jurisdictions include China [9,12,13], Czech Republic [14,15], Croatia [16–19], Greece [20–22], Korea [23,24], Serbia [10,25–27], Malaysia [5,28–31], Netherlands [32], Russia [33,34], Trinidad and Tobago [35], and Turkey [36–38]. Despite the widespread adoption of LADM worldwide, Australian jurisdictions considered the ePlan as the core data model to implement smart cadastral systems. The reason is that LADM is a conceptual model and there is no official technical encoding for its implementation; however, ePlan is encoded in LandXML format, which has been already adopted in Australia before the emergence of LADM. A comprehensive comparison between LADM and LandXML standards has been conducted by Stubkjaer [39]. Five major domains have been considered in this comparison, namely parcel, naming/identifying spatial objects, document referencing, legal/administrative aspects, and features of terrain objects and project elements. Table 1 provides a summary of this comparison.

Table 1. Comparison of LandXML and LADM standards, adapted from [39].

Sub-domain	LandXML	LADM
Parcel	Parcels Parcel Parcel+parcelType	LA_BAUnit LA_Parcel LA_LegalSpaceBuildingUnit LA_LegalSpaceUtilityNetwork
	CoordinateGeometry::CoordGeom	LA_Point LA_BoundaryFaceString LA_BoundaryFace
	CoordinateGeometry::Center Parcel+area Parcel+volume	LA_Parcel+referencePoint LA_Parcel+area LA_Parcel+volume
Naming/identifying spatial objects	Parcel+buildingLevelNo Parcel+buildingNo Parcel+name Parcel+refer.ces(LocationAddress) Parcel+references (Title) Parcel+taxid	~ LA_Parcel+extAddressID LA_LegalSpaceBuildingUnit+extPhys.Build.UnitID LA_Parcel+suID LA_Parcel+extAddressID
Document	Core::FieldNote SurveyHeader	LA_Party (Survey and FieldNote author) LA_AdministrativeSource LA_SpatialSource
Legal/administrative aspects	Parcel+liabilityApportionment Parcel+lotEntitlements Parcel+owner Parcel+setbackF..R..S Parcel+state Parcel+useOfParcel	Not supported LA_PartyMember+share LA_Party (as owner) LA_Restriction (~easement) LA_Restriction (~easement)
Features of terrain objects and project elements	Core::Feature SurveyMonument	LA_Point+monumentation

In a further study conducted by Pouliot et al. [40], LADM and LandXML were compared using schema matching techniques. The comparison results indicate that there is a 10 percent syntactic matching between LADM and LandXML, while the semantic matching rate between these two standards is 59 percent. However, these results were found to be uncertain when comparing them with the findings of [39].

In Australia, the state of Victoria has been the leading jurisdiction that adopted the ePlan model based on LandXML for digital lodgment of cadastral plans. ePlan aims to replace PDF cadastral plans with digital data (in LandXML format). More specifically, the Victorian jurisdiction provides various land registry services based on the ePlan model, including [41–44]:

- ePlan validation service: This service identifies errors and potential problems in plans at the early stage of preparation and allows surveyors to correct these issues prior to the plan examination process. This service results in a significant reduction in the number of plan refusals and requisitions. The validation service currently relies on 130 ePlan validation rules, which cover four main areas: the 'ePlan schema compliancy', 'survey accuracy (e.g., parcel area, parcel observations closure)', 'survey examination rules (e.g., appropriate title connections)', and 'metadata completeness (e.g., easement purpose)'.
- ePlan visualization service: This service converts the ePlan LandXML file into a PDF plan. The PDF plan becomes the legal title diagram in Victoria.
- ePlan visualization enhancement tool: This tool allows surveyors to enhance the visualization of a PDF plan using the following main functions: adjust labels and arrows, create enlargement diagrams, define sheets, define exaggerations, and adjust title connections.
- ePlan data viewer: This service allows surveyors and plan examiners to visualize a LandXML file in different layers (e.g., points, observations and parcels) superimposed over the Victorian map base and aerial imagery.
- ePlan data storage: This service stores the registered ePlan LandXML files in a structured Oracle database, which allows the digital data to be made available for search, query, analysis, sharing, and reuse.

All 2D plans under the Subdivision Act 1988 [45] in Victoria are currently supported in the ePlan format. However, strata plans (building subdivisions) are not yet supported. The investigations of the technical aspects of a 3D digital cadastre (e.g., 3D data modelling, validation, and visualization) are in progress in Victoria [46–50]. Building on this, a roadmap has been developed for implementing the Victorian 3D digital cadastre by 2025 [51].

Another initiative towards a smart cadastre in Victoria is the Digital Cadastre Modernisation (DCM) project to upgrade the digital cadastre. The timeframe for this project is 2019–2022 and includes four stages [52]: (1) back capture: to convert paper cadastral plans and surveys to digital format in LandXML, (2) adjustment: to ensure data from individual plans are joined and adjusted to an accuracy approaching 0.1 m metro and 0.5 m rural, (3) integration: to ensure the new location of parcel boundaries will be used to update other Vicmap layers (e.g., planning zones and transport), and (4) automation: to develop automated processes that keep the digital cadastre and other Vicmap layers up-to-date and spatially accurate.

1.1. Research Problem

The smart cadastre lifecycle developed by LUV is illustrated in Figure 1. According to this figure, the ePlan LandXML file is first created, then validated, and potential issues are flagged. The ePlan file is visualized and superimposed over the map base using an online environment. A PDF plan is created from ePlan and its presentation enhanced by the surveyor. The ePlan file is uploaded to SPEAR as part of a subdivision application submitted to the council for approval. When the application is lodged at LUV, the ePlan is examined and the title system is updated using the ePlan data. The ePlan LandXML file is stored in an Oracle database after registration. Finally, the ePlan file is available for download by surveyors for reuse.

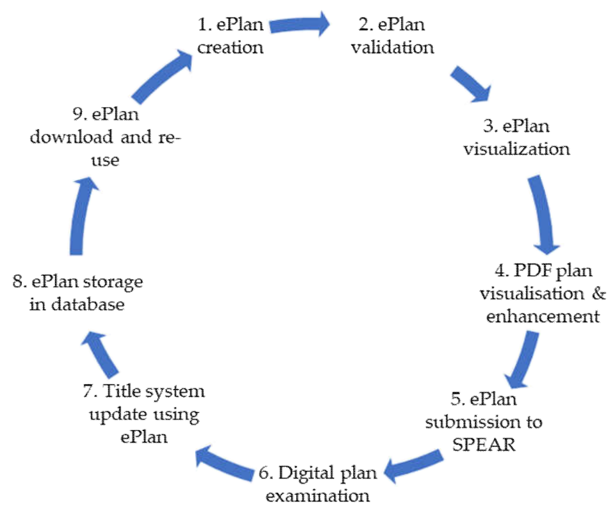

Figure 1. Smart cadastre lifecycle in Victoria.

Among the lifecycle steps, the ePlan creation is the only step that has been developed by external CAD software vendors. To date, the following issues have been identified:

- Software packages are not user friendly and not all software companies have invested in ePlan (e.g., Bentley);
- The ePlan data entry required for creating an ePlan is labor-intensive and time consuming;
- Surveyors must have access to the latest version of the ePlan software package, which enforces extra costs to surveying firms who need to subscribe for annual support and maintenance;
- Software packages do not recognize or minimize human errors, and
- Vendors need to regularly update their software with ongoing changes made to the ePlan protocol, enumerations, surveying regulations, LUV business policies, etc. However, their responsiveness to regularly keep their software up-to-date has been slow to unresponsive.

The other steps of the lifecycle have either been developed by LUV and are under ongoing maintenance (steps 2–5, 7, and 8), or will be considered for development when the digital cadastre modernization project is completed (steps 6 and 9).

The research problem underpinning this research has been identified by exploring the current practice for lodging cadastral plans in the land registry organization (LUV). The current practice for digital cadastral plans lodgment is relying on various services including data creation, validation, visualization, enhancement, examination, storage, and download. However, the problem is that these land registry services have been developed in separate environments, which may not be under the land registry's control and ongoing maintenance, which makes the lodgment process difficult for land surveyors.

1.2. Research Aim

To address the above-mentioned research problem, this research aims to design and develop a single platform that streamlines the digital cadastral data management and lodgment process in Victoria.

The remainder of this paper is structured as follows. In Section 2, relevant international experiences have been explored. The research approach has been discussed in detail in Section 3. The conceptual design, proof of concept development, and evaluation are discussed in Sections 4, 5 and 6 respectively. The research findings are summarized in Section 7. The paper concludes with future directions in Section 8.

2. Relevant Experiences

The land administration systems in various jurisdictions around the world are being modernized to support integrated processes that rely on accurate digital data. This includes New Zealand, Singapore, Australian States (New South Wales, Western Australia), and the Netherlands. In this section, we will review the relevant experiences that occurred in these jurisdictions to contextualize the benefits of reforming land administration systems and transforming into a digital environment.

2.1. New Zealand

The New Zealand government proposed automating its cadastral survey and title system in 1996 at a national level [53]. The aim of this proposal was to integrate all land administration processes including surveying, submission, and validation in an integrated digital data environment and consequently, reduce the associated costs and improve data delivery and the quality of cadastral data. This has resulted in the implementation of an integrated cadastral information system called Landonline [54]. With the introduction of the Landonline system, most cadastral survey practices have been increasingly shifted into digital environments. Among the digital cadastral data lifecycle steps, the creation of a LandXML file is still within the surveyors' domain and undertaken through an external CAD software package. Haanen and Gulliver [55] highlighted the main benefits of a digitally enabled cadastral system in New Zealand in terms of capturing, validating, integrating, and reusing cadastral data. These benefits include avoiding errors, ensuring survey data integrity, automating data validation tests, rigorous integration of a new survey dataset into the existing cadastral survey network for the entire country, and reusing digital cadastral data by various stakeholders including surveyors and other professionals involved in land administration.

2.2. Singapore

The Singapore Land Authority (SLA) considered four major initiatives to digitalize and modernize the land administration system in Singapore: GPS infrastructure, implementation of a coordinated cadastre, information/GIS technology, and regulations [56]. Implementation of a coordinated cadastre, as a cadastre of which its property boundaries are legally defined by coordinates guaranteed by the government, was the most significant initiative, playing a fundamental role in the modernization of Singapore's cadastral system [57]. The land administration workflow based on electronic submissions was achieved through a portal named CORENET. The plans submitted via this portal are formatted as images or data files. In these formats, the contents of the plans are not readable by computers, which in turn decreases productivity in examining, managing, and disseminating cadastral data. In response to these challenges, SLA is currently designing a new system named the Cadastral Survey Management System (CSMS). Three main objectives were considered in CSMS: (1) supporting the third dimension and time, (2) adoption of open standards to enable data interoperability and achieve automation, and (3) provision of a platform to facilitate communication with land surveyors. The initial design of CSMS relied on three fundamental components, namely SG LandXML to support automatic cadastral validation, Singapore profile of LADM to support 3D and provenance, and the portal for communicating with registered surveyors [58].

2.3. Australia

Australian jurisdictions agreed on adopting ePlan, which is encoded in the LandXML format, as a national model for exchanging digital cadastral information in 2009 [59]. However, each jurisdiction implemented ePlan in different ways to modernize their cadastral systems. The Victorian, New South Wales (NSW) and Western Australia (WA) jurisdictions are leading the way and demonstrating major implementation of ePlan in the move towards modern land administration

[41]. Here, we review the NSW and WA cadastre modernization related activities to help differentiate between the work undertaken.

2.3.1. NSW

The NSW land registry services have developed an electronic plan lodgment and validation system based on ePlan [60]. This system comprises two services: LandXML validation service and LandXML rendering service [61,62]. The LandXML validation service performs a wide range of automatic data validation checks on the ePlan files. This service can be used to identify potential errors in the digital cadastral data before lodgment. The validation results are produced in a tabular format that shows whether a particular validation rule is passed or not. If a validation rule fails, the user will be presented with an error message that explains the reason for failing the validation rule. The rendering service creates a plan, which is compliant with the standard form for plans in NSW, based on the ePlan file. The plan is produced in a TIFF format and can be downloaded via the portal. Additionally, a digital plan examination application has been developed in NSW for streamlining the examination of ePlans.

2.3.2. WA

In WA, the land information authority adopted the business name Landgate to provide land titling services that secure land and property rights for the community in a digital economy [63]. Landgate has recently implemented a new cloud-based platform, known as New Land Registry (NLR), to receive survey datasets in a digital format (e.g., CAD or ASCII) and produce images of a cadastral plan that is lodged and signed digitally [42]. The NLR platform provides a wide range of tools that support the creation of cadastral features, such as lots, roads, easements, offsets, and enlargements in a digital environment. The cadastral features are also related to the relevant non-geometric attributes such as surveying measurements, ownership information, and annotations. All cadastral features are stored in a digital formation, which subsequently automates the creation of various styles for the features, and the placement of annotations within the plan images, all in line with legislation requirements. The created plan images can be converted into PDF format in the NLR platform.

2.4. Netherlands

The Dutch land register is owned and managed by the Kadaster (Cadastre, Land Registry, and Mapping Agency). Kadaster undertakes responsibility for registering spatial information and semantic attributes related to ownership rights and interests affecting all land parcels. The INSPIRE initiative that commenced in 2007 influenced national land regulations in the Netherlands. As a result, these regulations were amended in response to new international standards regarding environmental policies. Kadaster was amongst the early relevant stakeholders who planned to implement a centralized platform to be used by many land administration users, subsequently leading to a significant reduction in costs [64]. For this purpose, the "Public Services On the Map" (PDOK) platform was implemented [65]. As input, Kadaster provided a specification to describe how the non-INSPIRE data maps can be harmonized with cadastral data defined in the current (Dutch) format. The desired output was working map/features services, making the INSPIRE harmonized cadastral dataset available to the community.

Table 2 provides a comparison of the above-mentioned jurisdictions using a set of criteria. These criteria are important for delivering land registry services required throughout the lifecycle of digital cadastral data lodgment. The criteria include data creation, visualization, validation, enhancement, examination, database storage, and data download.

Table 2. Cross-jurisdictional comparison of land registry services required for supporting digital lodgment of cadastral data, +: Supported, −: Not Supported.

Jurisdiction\Criterion	Data Creation	Visualization	Validation	Enhancement	Examination	Database Storage	Data Download
New Zealand	−	+	+	+	+	+	+
Singapore	−	+	+	+	+	+	+
NSW	−	+	+	−	+	−	+
WA	Only modifications	+	+	+	−	+	+
The Netherlands	−	+	+	−	−	+	+

The investigated jurisdictions do not provide a service for creating cadastral data; this service is typically supported by third party vendors offering CAD software packages. The WA portal allows for the creation of additional features and modification of existing features once the plan is dodged. The enhancement service is not offered by all jurisdictions. The enhancement service provides a cadastral surveyor with the ability to enhance visualization of cadastral plans in terms of manipulating visual aspects of the plan, such as creating enlargement diagrams, manipulating labels, and changing diagrams' scale. The most significant gap in the investigated cases is that none of them provide all the land registry services, including data creation, visualization, validation, enhancement, examination, database storage, and data download, in an integrated and common environment. In other words, the lifecycle of digital cadastral data lodgment is fragmented in separate environments, which results in significant delays and costs for the land development industry. To address this, in the next section, we will present the methodology for developing an integrated spatial system to provide all services that are required to support the various stages of lodging cadastral data.

3. Research Approach

The research approach underpinning this study is predicated on design science methodology [66], which has been mainly used to improve the information science aspect of cadastral systems [67]. In this methodology, a new artefact with an embedded solution is developed in response to a research problem perceived in real-world practices. There are six main stages in any research conducted based on design science (Figure 2). In the context of this study, these steps are:

1. Identify the research problem: The research problem has been identified by exploring the current practice for lodging cadastral plans in the land registry organization. The current practice for digital cadastral plans lodgment relies on various services including data creation, validation, visualization, enhancement, examination, storage, and download. However, the problem is that these land registry services have been developed in separate environments which may not be under the land registry's control, and ongoing maintenance which makes the lodgment process difficult for land surveyors.
2. Definition of the requirements of a solution: In this step, a set of important requirements are considered for developing the artefact that provides a feasible solution in response to the research problem. In the context of this research, the adopted approach for identifying requirements was based on a consultative workshop [68]. Consultative workshops are a specific form of participation mode, whereby people are consulted regarding their views prior to making any innovation [69]. In this phase, the business and technical requirements for designing and developing a single smart cadastral platform were gathered and documented. To identify the business and technical requirements, a series of consultative workshops with the Subdivision Branch at LUV were conducted. The Subdivision Branch is responsible for examining and registering plans under the Subdivision Act 1988. These requirements were presented to the surveying industry in different forums to receive their feedback.
3. Design an artefact: A new integrated cadastral platform is designed as an artefact to address the research problem and to meet the requirements. This means that the constituent components of

the integrated cadastral platform will be developed based on the requirements that are identified for integrating land registry services.

4. Demonstration of the artefact: A proof of concept (PoC) is implemented to demonstrate the feasibility of the artefact designed for responding to the research problem. The proof of concept is an instance of the artefact that is applied to a suitable case study.
5. Evaluation of the artefact: The evaluation mainly specifies how well the artefact solves the explicated problem. In this research, two types of evaluation strategies are adopted, namely subjective and objective [70]. Objective evaluation refers to a process that is purely based on quantifiable evidence. However, subjective evaluation refers to experts' perspectives or opinions about the developed artefact.
6. Communication of the artefact: Finally, the results of a design science research work are communicated to the researchers and practitioners. This paper is a form of communication of an integrated cadastral platform developed as a new artefact in the cadastral research domain.

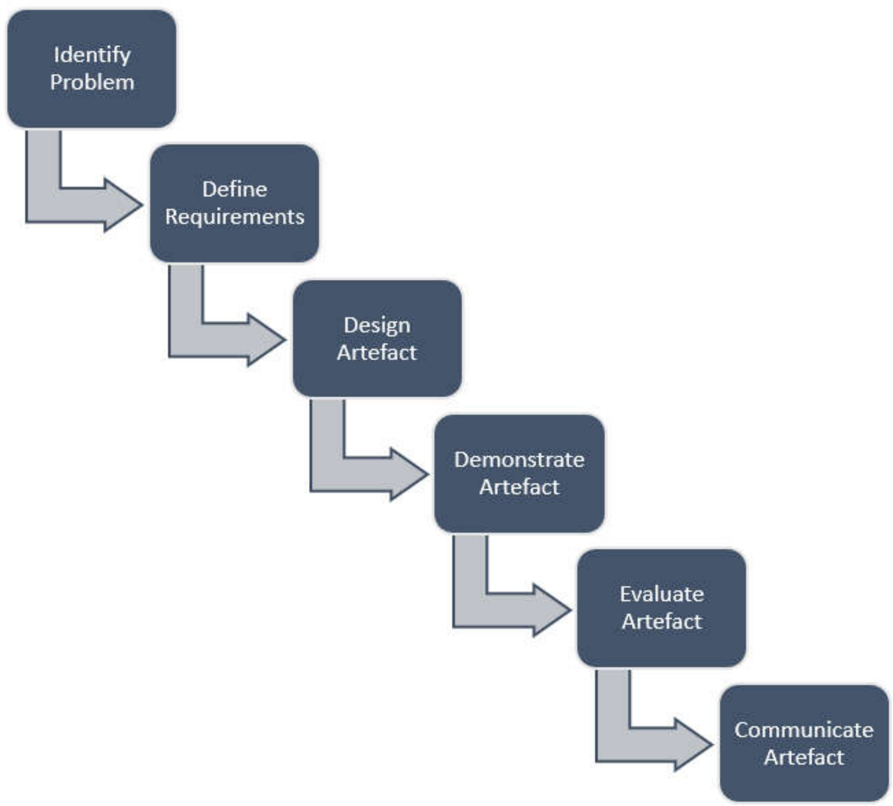

Figure 2. Research approach.

The steps involved in our research approach, except the 'Identify Problem' step, which was already described in the Introduction Section, are explained further in the next sections.

4. Conceptual Design

The conceptual design includes the 'Define Requirements' and 'Design Artefact' steps of the research approach. Therefore, in this phase, the business and technical requirements for designing and developing a single smart cadastral platform were firstly gathered and documented. To identify the business and technical requirements, a series of consultative workshops with the Subdivision

Branch at LUV were conducted. These requirements were presented to the surveying industry in different consultative workshop to receive their feedback.

The major business and technical requirements are:

- Developing a single online platform that provides users (land administration stakeholders i.e., surveyors, councils, referral authorities, LUV) with access to the relevant smart cadastral services for managing submissions of ePlan. Services to be incorporated include digital cadastral data (ePlan) creation, validation, title diagram visualization (presented digitally on screen and in PDF format) and visualization enhancement, survey details on-screen visualization, ePlan data download, export, search and query, digital plan examination, as well as basic GIS functions (e.g., features identification, layers control, zoom in/out, and measure).
- A platform that interacts with the digital plan lodgment portal through web services.
- The platform should be based on profile access relevant to a user's role.
- The creation of an ePlan should be undertaken by surveyors in an efficient and easy manner.
- As LUV is in the process of standardizing a CAD file format for cadastral plan lodgments, the platform should be able to convert the standard CAD file into LandXML format.
- The platform should support the automation of ePlan metadata entry by extracting data from existing LUV system databases through web services.
- The platform should provide an interactive validation report in a manner that highlights elements of the ePlan causing error on the map base and screen for better interpretation.
- The platform should provide users with access to registered ePlans stored in the Oracle database as well as ePlan files back-captured through the DCM project for visualization, query and download purposes.
- The platform should support exporting data to GIS common formats, e.g., shapefile, KML, GeoJSON.
- The platform should expose the ePlan web services to software vendors, so that those services can be consumed into CAD software packages.

The identified requirements served as key inputs for designing the Victorian Single Smart Cadastral Platform as a new artefact that integrates all land registry services in a common environment. The components of the platform are illustrated in Figure 3.

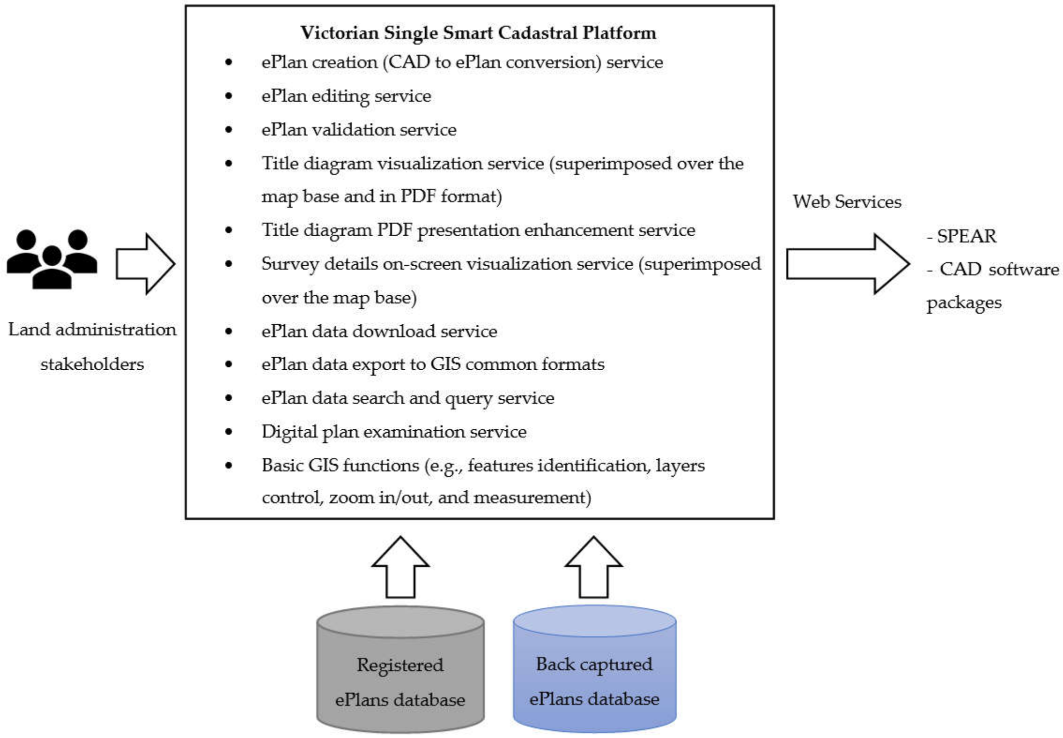

Figure 3. Victorian single smart cadastral platform components.

To streamline the ePlan creation process, and to respond to the research problem discussed in Section 1.1, the feasibility of automating ePlan geometrical and attribute data was also studied in this phase. Data that were found to be automated include:

- Licensed surveyor's name and registration number from the Surveyors Registration Board of Victoria (SRBV) web service;
- Geometry and attributes of the cadastral plan and survey components recorded in CAD standard layers (through a mapping between the CAD layers and LandXML components);
- Coordinate system, subdivided parcel identifier and address, administrative areas, Crown description, and abutting parcels information (e.g., road connections) from a Vicmap web service;
- Survey marks and monuments information from the Survey Marks Enquiry Service (SMES) web service which provides free and online access to registered survey control mark information managed by LUV;
- Title reference number (volume/folio) from the Victorian Online Title System (VOTS) web service, which provides access to a record of all Victorian titles.

However, there are still some ePlan attributes that require key-entry because they either cannot be predefined or no register exists for the data in Victoria. The examples include: plan details (e.g., plan purpose), new survey marks information (unavailable in SMES), monuments information for marks unavailable in SMES (e.g., type, condition), natural boundary description (e.g., river's name), easements information (e.g., name, purpose, beneficiary, origin), restrictions information (e.g., depth limitation, description, expiry date, burdened/benefited lots), plan notations, created roads and reserves name and beneficiary, and occupation information (e.g., fence description).

5. PoC Development

PoC development refers to the 'Demonstrate Artefact' step in the research approach. Among the smart cadastral services illustrated in Figure 3, the digital plan examination service, and survey details on-screen visualization service (superimposed over the map base) require access to a spatially accurate map base, due to be complete and accessible by the end of 2022. In this phase, a PoC was developed to provide the services that do not require access to a spatially accurate map base in a single location, as follows:

- ePlan creation (CAD to ePlan conversion) service;
- ePlan editing service;
- ePlan validation service;
- Title diagram visualization service (in PDF format);
- ePlan data download service;
- ePlan data search service;
- Basic GIS functions (e.g., features identification, layers control, zoom in/out, and measurement).

In this phase, suitable technologies were evaluated for implementing a single smart cadastral platform and automating the data requirements discussed in Section 4.

As the standardized CAD file format had not been confirmed by LUV at the time of developing the PoC, a CAD file structure containing 77 layers was proposed to define the complete dataset of cadastral plan and survey requirements (e.g., survey marks, traverse, radiation, subdivided lots, created lots) and a sample dataset was prepared in 'DWG' format based on those layers.

In terms of technology selection, Java and Open Design Alliance (ODA) Software Development Kits (SDKs) were selected for the back-end development. Java was selected because all the existing ePlan services are based on this technology. ODA SDKs were selected since they are a professional solution for engineering applications—from simple utilities to comprehensive CAD editors [71], and also, ODA provided us with a free educational license for one year to use their products. node.js (runtime environment based on JavaScript) and OpenLayers were selected for front-end development. OpenLayers was already selected as the suitable library for cadastral data visualization among a number of other alternatives [42]. The overall system architecture is shown in Figure 4.

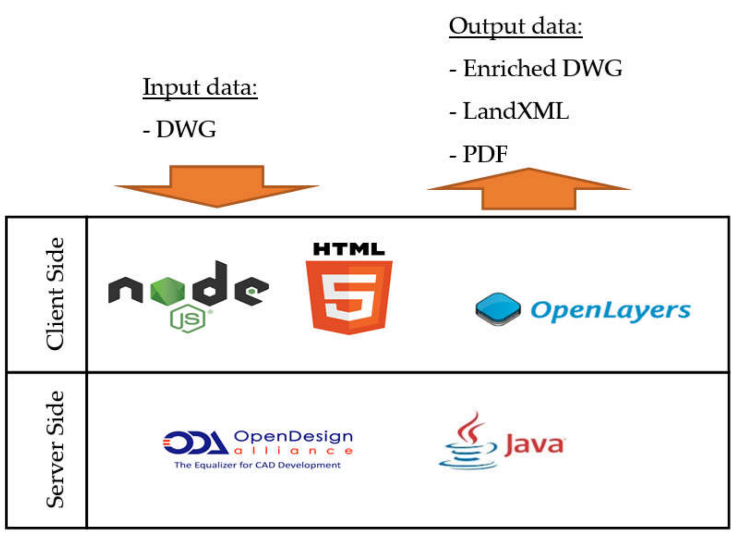

Figure 4. The overall system architecture for single smart cadastral platform PoC.

According to Figure 4, a standard CAD file (based on LUV's proposed CAD structure) in 'DWG' format is the input for the PoC. As illustrated in Figure 5, the PoC introduces three steps for converting a standard CAD file to an ePlan LandXML file. In step 1, the user is asked to locate and select the subject parcel for their application (i.e., the parcel being subdivided). Once the subject parcel is selected in Vicmap, in step 2, the standard CAD file is uploaded to the PoC. For this study, a sample CAD file in DWG format is imported into the PoC. Through this process, the CAD data are converted into LandXML and ePlan metadata prepopulated through the web services discussed in previous section (e.g., Vicmap and SMES). The attributes that cannot be automatically populated (e.g., easements information) are flagged by the PoC to the surveyor, who must enter in step 3.

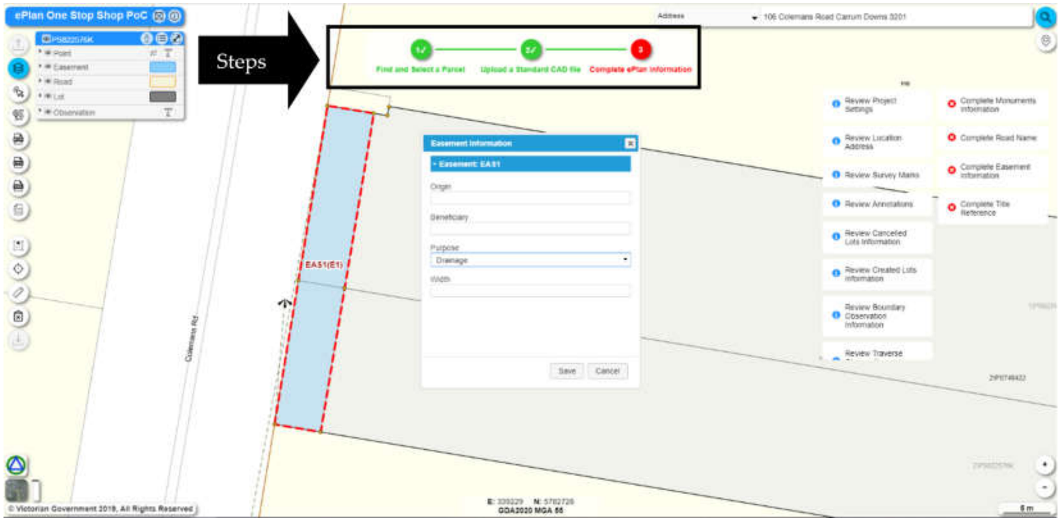

Figure 5. The steps of converting a standard CAD file to an ePlan LandXML file developed in PoC.

Once the ePlan metadata entry is completed, PoC notifies the surveyor that the LandXML file is ready for download or submission to SPEAR. The data can then be downloaded in the following formats:

- Enriched DWG—a DWG file that contains ePlan metadata along with geometries;
- LandXML—for submission to SPEAR;
- PDF—title diagram visualized in PDF format.

To create the enriched DWG file in this study, the extended object data (xdata) capability in AutoCAD was utilized. Using xdata, the ePlan metadata, which were populated either automatically or manually by the surveyor, were embedded within the DWG file. A structure was developed for storing the xdata in the sample dataset used for the PoC development. In addition to streamlining the ePlan creation process, interactive validation functionality was also developed within the PoC. This functionality uses a web service to send the LandXML file existing in the PoC to the ePlan validation engine and displays the results on the screen. Any object causing errors is highlighted on the screen for ease of interpretation by the surveyor. As shown in Figure 6, the validation of data has failed as the easement information, including name, origin, and purpose, is missing. The easement polygon is also highlighted within the diagram to show the affected ePlan object.

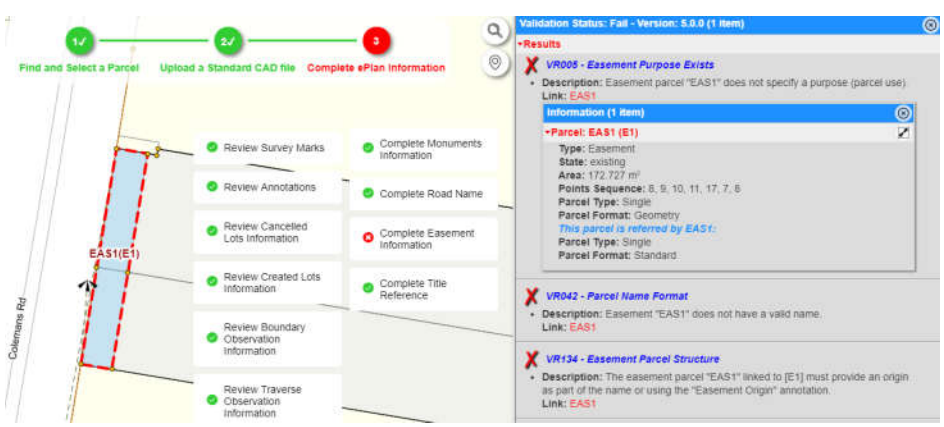

Figure 6. Interactive validation functionality built in the PoC.

The validation functionality can be used at any stage during the ePlan creation process, reducing the potential of an ePlan LandXML file being submitted to SPEAR with errors.

6. PoC Evaluation

The PoC went through a mixed objective/subjective evaluation approach. The objective evaluation aimed at understanding how much time and effort will be saved for surveyors using PoC as compared to the existing ePlan creation method. The subjective evaluation aimed at receiving the feedback of a selected group of surveyors, who had raised interest to be involved in the CAD structure standardization project, on the PoC functionality. Figure 7 illustrates the mixed evaluation approach developed for this study.

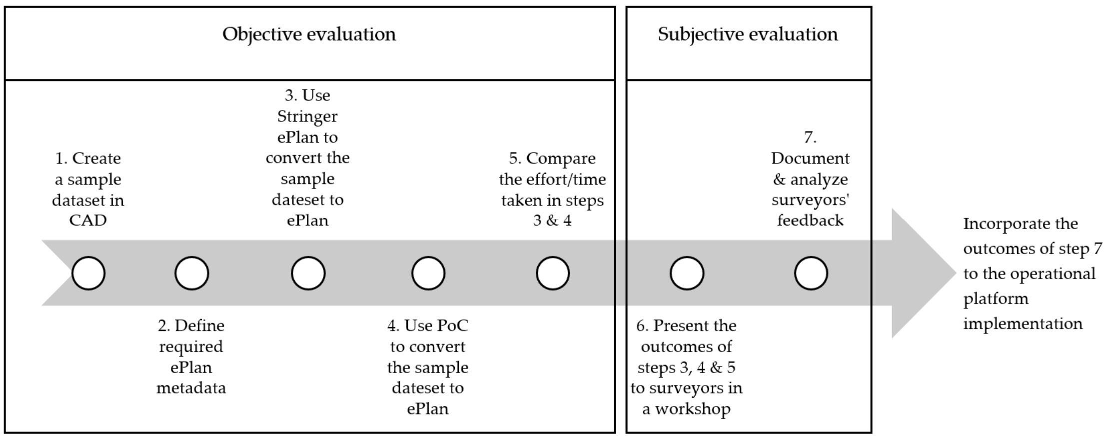

Figure 7. Mixed evaluation approach used in this study.

To evaluate the PoC in regards to saving time and effort for surveyors, a sample CAD dataset was first created in CAD environment in DWG format. This dataset, as shown in Figure 8, contains one subdivided lot, two created lots, one easement, two abutting roads, three control marks, two traverse points, five monuments, traverses, and radiations.

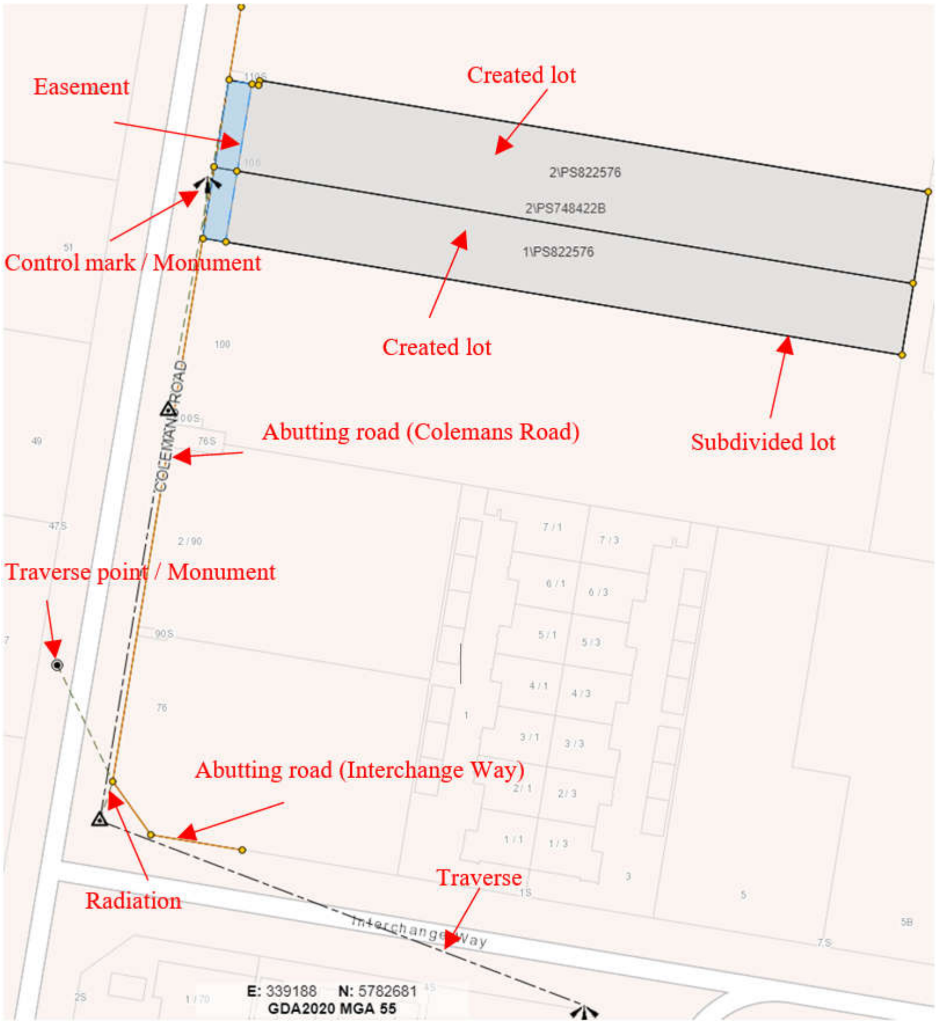

Figure 8. Sample dataset used for the PoC evaluation.

Next, the required ePlan metadata elements for the sample dataset were defined, as below:

- Plan details (e.g., Plan Number, Act, Dealing Type, Surveyor's details, administrative areas);
- Subject parcel details (Standard Parcel Identifier (SPI), parcel state (cancelled), parcel class (lot), address, area, title identifier (volume/folio));
- Created lots details (SPI, parcel state (created), parcel class (lot), area);
- Abutting roads details (parcel state (existing), parcel class (road), road name);
- Traverses details (line type (traverse), distance, bearing);
- Radiations details (line type (radiation), distance, bearing);
- Traverse points details (point state (e.g., existing, new), point type (traverse));
- Control marks details (e.g., identifier, description, creation date, status);
- Monuments (monument state (e.g., existing, new), monument condition (e.g., OK, replaced), monument type (e.g., nail, peg);
- Easement details (identifier, origin, beneficiary, width, purpose (e.g., drainage));
- Annotations (e.g., Crown details, general plan notation).

The sample dataset was converted into an ePlan LandXML file using Stringer ePlan, which is an ePlan plug-in for AutoCAD developed by Civil Survey Solutions commonly used in Victoria. Since there is no ePlan data automation capability in Stringer ePlan, all metadata must be manually entered by the surveyor once the drawing of the diagram has been finalized. Figure 9 shows the ePlan creation workflow in Stringer ePlan.

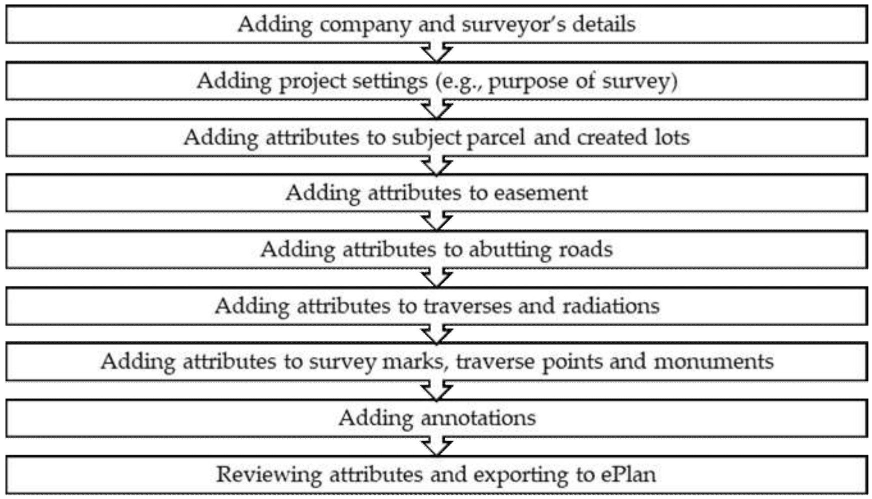

Figure 9. The ePlan creation workflow in Stringer ePlan.

The sample dataset was converted into an ePlan LandXML file using the PoC. Figure 10 shows the ePlan creation workflow in the PoC.

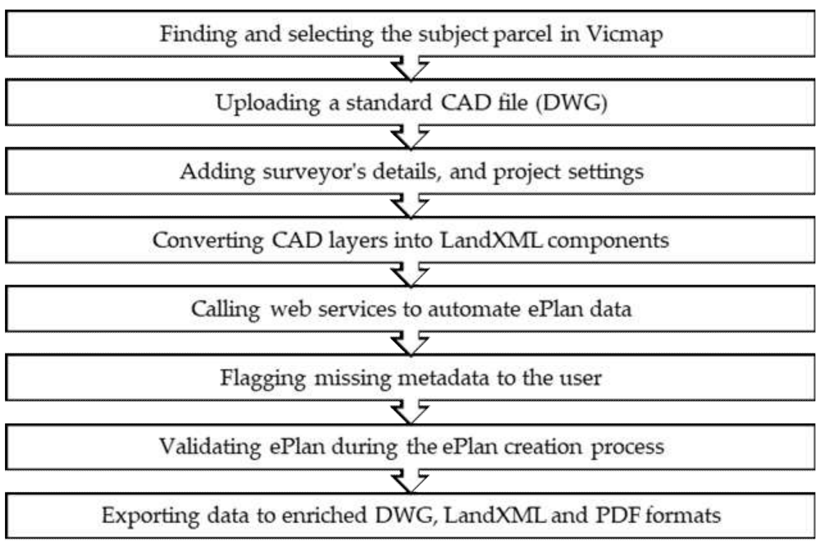

Figure 10. The ePlan creation workflow in the PoC.

According to Table 3, creating an ePlan using Stringer ePlan took around 20 min for an experienced user. Using the PoC took around 4 min for the same user, since most of the metadata were populated automatically through existing web services.

Table 3. ePlan creation approach in Stringer ePlan vs. newly developed approach in PoC.

Action–Metadata Entry for:	Stringer ePlan	PoC
Plan details	Manual entry required	Manual entry required
Subject parcel	Manual entry required	Automatic using Vicmap web service
Created lots	Manual entry required	Automatic using CAD layers
Abutting roads	Manual entry required	Automatic using Vicmap web service
Traverses	Manual entry required	Automatic using CAD layers
Radiations	Manual entry required	Automatic using CAD layers
Traverse points	Manual entry required	Manual entry required
Control marks	Manual entry required	Automatic using SMES web service
Monuments	Manual entry required	Manual entry required only for survey marks unavailable in SMES
Easement	Manual entry required	Manual entry required
Annotations	Manual entry required	Manual entry required
Total time	20 min	4 min

The ePlan creation workflows illustrated in Figures 9 and 10, as well as the PoC, were demonstrated to a consultative workshop conducted on 28th February 2020, with approximately 70 participants from across the Victorian surveying industry. In the workshop, the further development required to transform the PoC into an operational platform was discussed. The main feedback provided in the workshop, which needs to be incorporated to the operational version of Victorian single smart cadastral platform, is summarized below:

- The purpose of creating a PDF plan from ePlan was queried. Moving towards a fully digital workflow was suggested.
- Consideration should be given to the digital data copyright issues.
- It was suggested that DXF (Drawing eXchange Format developed by Autodesk for enabling data interoperability between AutoCAD and other programs) might be a better option than DWG as the file format for ePlan creation, since DWG is a proprietary file format, while DXF is an open data format.
- xdata mechanism used in the PoC for metadata storage may be broken in non-AutoCAD software applications (e.g., LISCAD). This needs further investigation and possibly, an alternative mechanism should be selected or developed.
- The allowance for provisional plans creation should be considered in the platform, as surveyors usually create multiple versions of the cadastral plan during the lifespan of a project.
- Metadata need to be preserved in the platform for the next versions of the CAD file.
- Bringing in plan and surveyor's information from digital plan lodgment portal (SPEAR) to the platform is required to maximize consistency and lower errors.
- The usability of the platform needs to be evaluated by the users before the production release.
- Service continuity should be considered. The down time of the platform should be minimized.

The findings of our study are discussed in more detail in the next section.

7. Discussion

Among the business and technical requirements considered in developing a single smart cadastral platform for managing ePlan submissions discussed in Section 4, the PoC mainly focused on four areas, including: (a) selecting the suitable technologies for developing a platform, (b) streamlining the ePlan creation process, (c) exporting data to different file formats (DWG, LandXML and PDF), and (d) validating ePlan data in an interactive manner. The remaining requirements will be incorporated once the DCM project is completed.

Currently, surveyors need to use multiple applications/interfaces for managing their ePlans. They use a CAD plug-in to create ePlans and use the ePlan services within SPEAR to validate, visualize, and enhance the presentation of their ePlans. The PoC confirmed the feasibility of integrating ePlan services into a single environment, which results in providing a better and more efficient experience for surveyors. Using the PoC, the CAD file, which is prepared as part of surveyors' work, can be distributed internally between different departments e.g., surveying, planning, and engineering, and utilized as the input data for ePlan creation. The enriched CAD file exported from the PoC can be returned to the surveyor for their internal processes and for managing subsequent changes to their ePlan, keeping the impact of ePlan on surveyors' processes to a minimum.

The conversion of the PoC to a fully functional application depends on the surveying industry agreeing to the adoption of a single CAD 'DWG' format. This initiative, which aims to define a standardized CAD file format for cadastral plan and survey data in Victoria, is in progress at the time of writing this paper. The CAD layers and file format will be confirmed by the surveying industry through this initiative. The single smart cadastral platform for managing ePlan submissions needs to be developed in a manner that can convert the standard CAD file into LandXML efficiently and easily. The data format that will be agreed upon will significantly impact the PoC conversion to an operational platform, as it has been built based on the technologies dedicated to the 'DWG' format. If different data formats, e.g., DXF, are required, the technology selection will require reviewing.

In Victoria, it is common that several versions of a cadastral plan are uploaded to SPEAR throughout the lifecycle of an application. It might be because of clients changing their mind, councils or referral authorities requesting changes to the plan, LUV requisitioning the plan, etc. Accordingly, it is a critical requirement that the enriched CAD file can be reused by the surveyor for any new version of the plan without losing any metadata. In other words, the metadata attached to the plan must be preserved in the platform every time the CAD file is uploaded. The PoC has been developed to meet this requirement.

Although, querying and downloading the registered ePlan files stored in the Oracle database and back-captured through the DCM project were considered in Section 4 for developing a single smart cadastral platform, these capabilities were not built into the PoC. The reason is due to a copyright issue in Victoria when sharing and accessing ePlans either submitted to SPEAR or captured through the DCM project. The LUV legal department is currently investigating this issue.

The PoC does provide the basis for ePlan examination, including the functionality to visualize ePlan layers superimposed over the state map base and aerial imagery, accessing attributes embedded in an ePlan file, accessing survey marks from SMES, measuring dimensions between points, and validating ePlans. However, there is still a gap between what plan examiners check for PDF plans and what is available in the PoC. As part of developing this platform, the plan examination process needs to be comprehensively reviewed, and examination checks (e.g., plan re-establishment) should be developed in the platform. The digital plan examination functionality will be implemented once the modernized digital cadastre becomes available.

The platform needs to expose the ePlan web services to software vendors to enable surveyors who prefer to conduct all their work in the CAD software. The CAD to LandXML conversion service will be developed as a web application programming interface (API), so that it can be consumed by the software vendors too. By consuming this web service, the ePlan-enabled software packages will be able to send a standard CAD file to the platform and receive an enriched CAD file containing ePlan metadata in return. The missing metadata should then be flagged to the user by the software package.

8. Conclusions

This paper explored the potential of developing a single smart cadastral platform in Victoria to provide land administration stakeholders with access to all integrated smart cadastral services including digital cadastral data creation, validation, examination, visualization, export, query, download, etc. The current Victorian smart cadastre (ePlan) services are accessible through multiple applications. The ePlan creation is administered by external CAD vendors and faces a few challenges, causing the low uptake of ePlan in this jurisdiction. The proof of concept (PoC) methodology applied in this study confirmed that it is feasible to integrate the smart cadastral services into a single environment. It was also proved that the ePlan creation process will be significantly improved through utilizing the web services that can automate the ePlan metadata population.

For conversion of the PoC to an operational platform, the business requirements collected in the conceptual design phase of this study will be prioritized for implementation. The prerequisite of developing an operational platform would be the completion of the CAD file format standardization project. The standard CAD layers as well as CAD file format (e.g., DWG or DXF) need to be confirmed. The platform will be connected to the Oracle database, once the ePlan copyright issue is addressed by LUV. The business and technical requirements for developing an ePlan examination functionality will also be gathered and analyzed. In addition, to achieve the fully digital workflow suggested by the surveyors in the evaluation phase, the feasibility of digital presentation of title diagrams and survey details, which are currently prepared in PDF format, will be studied. The legal impact of this change, i.e., using a digital representation (e.g., a URL pointing to a digital representation of the diagram) in the contract of sale and dispute resolution, needs to be analyzed carefully.

This study has focused predominantly on the Victorian jurisdiction smart cadastre; however, a modification of our approach could be applied to other jurisdictions in Australia or other countries with respect to the specific smart cadastre services and data requirements considered in that particular jurisdiction.

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