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Tackling the Challenges of Visualising Digital Cadastral Plans: The Victorian Cadastre Experience

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Abstract

ePlan, as a digital cadastral data initiative, is a collaborative program between the land authorities and the surveying industry which aims to replace paper and PDF cadastral plans and surveys with digital data in LandXML format. ePlan has been adopted by Australia, New Zealand and Singapore. ePlan has been operational in the State of Victoria for 2D plans since 2013. The ePlan files are automatically converted into PDF plans by the ePlan visualisation service within the Victorian state's digital lodgement portal, namely Surveying and Planning through Electronic Applications and Referral (SPEAR). Cadastral plan in PDF format forms part of the legal title in Victoria.

Presently, ePlan, in terms of development, has limitations in visualising detailed, complex and large scaled 2D plans. The visualised plan from the LandXML file must comply with accepted Victorian survey drawing standards as the plan is a source for plan certification by council, forms part of a contract of sale, and when the plan is registered by the State of Victoria land authority, Land Use Victoria (LUV), it becomes the title diagram. In addition, through significant engagement with the Victorian Surveying industry, LUV has received feedback from surveyors that they would like to have the ability to enhance the presentation of visualised plans to create enlargements, define additional sheets, exaggerate the position of lines, and move the placement of visualised labels. These enhancement provisions would provide greater scope to ensuring plans complied with the aforementioned drawing standards. A Licensed Surveyor, the creator of the LandXML file is also duty bound to sign the visualised plan.

In addressing the abovementioned problem, a research methodology, including the conceptual, choice of technology, development and evaluation phases has been defined and implemented at LUV. The 'conceptual' phase considered the business and technical requirements for developing a tool to support surveyors to enhance the presentation of the visualised ePlans. The 'choice of technology' phase focused on defining the most suitable technologies for developing the tool. In the 'development' phase, the tool was implemented within SPEAR. The surveyors' feedback on the tool usability was collected as part of the 'evaluation' phase. The main outcome of this research has been the ePlan Visualisation Enhancement Tool (VET) developed within SPEAR based on OpenLayers technology, which enables surveyors to improve the presentation of auto-generated cadastral plans. The evaluation phase showed that end users were generally satisfied by the usability of VET and identified the areas that need further improvement.

This paper first provides an overview of the ePlan project in Victoria with a focus on the research problem and objective. The relevant interstate and international experiences are then reviewed. Next, the paper discusses the research methodology including the above four phases in detail. The outcomes of the evaluation phase are then discussed. The paper concludes with some discussions around the approach taken for this research, the surveyors' feedback and the future directions.

Keywords: ePlan, cadastre, visualisation, enhancement, VET, Victoria, Australia.

1. Introduction

Land authorities in Australia are reforming their cadastral systems to support digital cadastral data. This is mainly because the current systems are not efficient enough to cater for the current and future needs. The cadastral data needs to be provided in digital format so that they can be shareable, discoverable, retrievable and downloadable. The limitations of the current approach (paper/PDF-based plans) of a cadastral survey such as plan lodgements and registration have caused several issues to the Australian land development process (Falzon and Williamson 2001). This is why a paperless and fully automated cadastral infrastructure has been highly recommended by the Cadastre 2034 national strategy developed by the Intergovernmental Committee on Surveying and Mapping (ICSM) (ICSM 2015). ICSM is responsible for providing leadership, coordination and standards for surveying, mapping and national datasets in Australia and New Zealand.

An ePlan Working Group (eWG) was formed by ICSM that developed a national data model to transfer digital cadastral data between the Australian surveying industry and land registries in 2009 (Aien *et al.*, 2012). In 2011, an ePlan Protocol was developed to map the components of the ePlan data model to LandXML data format (Cumerford 2010). The ePlan LandXML file is an intelligent digital file containing cadastral plan and survey information that includes survey measurements, dimensions of the parcels, interests in land (e.g., easements and restrictions), land parcel descriptions, administrative information (e.g., locality), owners' corporation schedules, survey marks, traverses, radiations, connections to title, annotations, plan approval status and stakeholders' signatures.

2D ePlan is currently operational in New South Wales (NSW) and Victoria. Other jurisdictions have also participated in the eWG and are investigating their options. New Zealand is also part of the eWG and mandated e-survey (the New Zealand equivalent of ePlan) in 2007 under section 42 of Cadastral Survey (Compulsory Lodgement of Digital Cadastral Survey Datasets) Order 2007 (LINZ 2007). The Singapore Land Authority (SLA) also joined the eWG in 2013, and it has adopted the ePlan LandXML Protocol for its cadastral survey modelling and electronic lodgements (Soon 2012; Thompson *et al.*, 2017). Singapore (SG) LandXML Mapping and Structure technical paper was officially released in 2017 (SLA 2018).

Victoria commenced its investigations to the ePlan project in 2008. LUV collaborated with the eWG on developing a national data model to cover all Australian jurisdictions' cadastral and survey requirements. In 2011, the Victorian State digital plan lodgement portal, SPEAR, enabled surveyors to upload an ePlan LandXML file along with their PDF application. From 2011 to 2013, ePlan was piloted in Victoria by LUV, the surveying industry and software vendors. In May 2013, SPEAR incorporated ePlan services including visualisation, validation and data download, which are briefly discussed below (Olfat *et al.*, 2017):

- ePlan visualisation service - This service automatically converts the ePlan LandXML file into PDF. The PDF plan forms part of the legal title in Victoria. The automatic visualisation of an ePlan file is fundamental in streamlining the processes and dissemination of digital cadastral data.
- ePlan validation service - This service identifies errors and potential problems in plans at an early stage of preparation and allows surveyors to correct these issues prior to the LUV examination process. This will result in a reduction in the number of refusals and requisitions received by surveyors. SPEAR currently has 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 data download service - This service is available through the LASSI-SPEAR application. LASSI-SPEAR is a web mapping application that allows users to search and download survey information. The digital data download service allows users to draw a polygon on the map base and download a digital file in an ePlan LandXML format that contains parcel line works, administrative areas, datum, location addresses, road abuttals, survey marks and monuments. The downloaded ePlan file can be imported into surveying software packages to pre-populate the data for ePlan preparation, a saving for the surveyor.

All 2D plans under the Subdivision Act 1988 (Victorian Government 1988) are supported in ePlan. Strata plans (building subdivision plans) which include 3D (height limited) ownership rights are not yet supported.

Following the progress of the Victorian ePlan implementation since 2013, the research problem and objective underpinning this paper have been defined as follows.

1.1. Research problem

The low uptake of ePlan in Victoria is attributed to a few reasons, of which the most important is the quality of the visualised plans. The current ePlan visualisation service cannot efficiently support the display of dimensions along short boundary lines and narrow easements (e.g., party walls), and the general display of plan information that is cluttered or for detailed and large estate subdivisions. It cannot also support the creation of enlargement diagrams, which is a component of plan presentation. Feedback received from the surveying industry also indicated that in general, surveyors would like to have provision to control the plan presentation of the PDF visualised from an ePlan. Figure 1 illustrates some examples where the visualiser has not satisfactorily placed the labels due to the existence of numerous labels in a confined area, with the lack of enlargement capability.

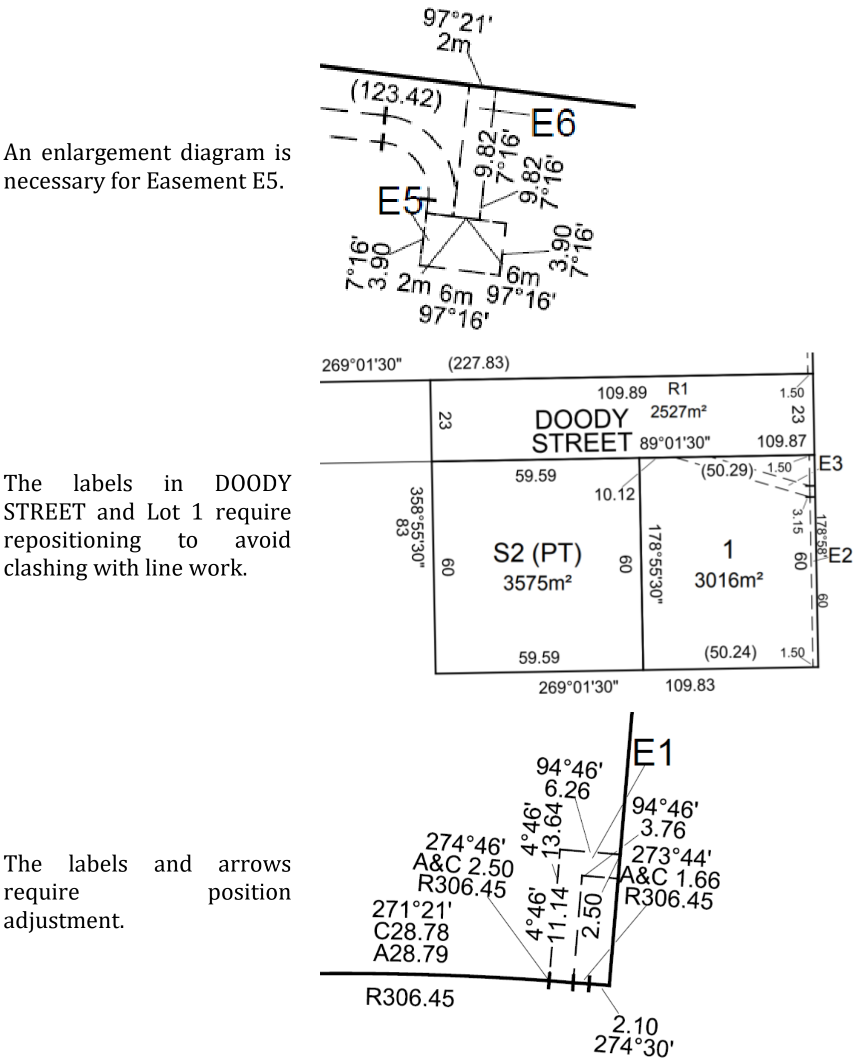


Figure 1. Examples where the ePlan visualisation service does not efficiently display labels

It can be considered that the limitations of the ePlan visualisation service have resulted in a negative impression from surveyors. The surveyors must be satisfied that the quality of visualised PDFs meets the appropriate surveying drawing standard as the plan is a representation of their work, which they must also sign as the Licensed Surveyor.

The abovementioned research problem is not specific to Victoria only. Other eWG jurisdictions that have adopted digital cadastral data lodgement (e.g., NSW, Western Australia, New Zealand and Singapore) have been dealing with similar issues for visualising legal title diagrams in PDF/TIFF format from digital data.

1.2. Research Objective

The research objective has been defined as follows:

- Design and develop an online tool that enables surveyors to improve the presentation of cadastral plans auto-visualised from digital data.

The remainder of this paper is structured as follows. Section 2 provides an overview of the relevant experiences within Australia and internationally. The research methodology including the conceptual, choice of technology, development and evaluation phases has been discussed in detail in section 3. The results of the new tool usability evaluation have been reviewed in section 4. The paper concludes in section 5 with some discussions around the new tool usability evaluation outcomes and future directions.

2. Relevant Interstate and International Experiences

Following the current legislative framework in the jurisdictions involved in eWG, the legal title diagram must be in PDF (or TIFF in NSW). The title diagram is used by different stakeholders of land subdivision process including surveyors, engineers, architects, developers, councils, referral authorities, solicitors, land registry and the public. The title diagram is also attached to the contract of sale and is used in the courts for land ownership dispute resolution purposes. As a result, there is a critical need in the ePlan-enabled jurisdictions to provide a clear representation of digital cadastral data in PDF/TIFF format.

The authors have investigated the interstate and international digital cadastral data lodgement portals and discovered that Western Australia, New Zealand and Singapore have implemented some tools to enable surveyors to enhance the presentation of auto-generated cadastral plans. These experiences have been briefly discussed in this section.

2.1. Western Australia's Experience

Western Australian Land Information Authority is a statutory authority that operates under the business name of Landgate. Landgate's New Land Registry – Plan (NLR-Plan) system has an online, cloud-based portal for surveyors to create fully digital survey data and generate the plan image with one source of truth for all cadastral information that is digitally signed and lodged with Landgate.

The Portal Design page consists of tools supporting the preparation of spatial digital plan features including lots, interests, roads, offset marks, annotations and enlargements linked with the non-spatial attribute information, including survey measurements and interests and notifications. All features are captured as data, which enables automated styling of features and placement of annotations to ensure the plan image is compliant with regulations. The designed plan can be exported to PDF through the Portal. The Portal was launched in 2017 and surveyors are being trained and encouraged to adopt it. The Portal was demonstrated to the eWG in October 2017, however the technical details and screenshots of the Portal Design page were not available to the authors at the time of writing this paper.

2.2. New Zealand's Experience

The New Zealand e-Cadastre survey process was streamlined through the Landonline system, which was rolled out in the 2000s. This was achieved by: (1) surveyor extracts digital data (including coordinates) and images of old plans for area of survey; (2) digital data imported into surveyor's software; (3) survey undertaken (calculations and field work); (4) data for new survey exported; (5) surveyor imports data into Landonline, adds any missing elements, generates plan image, and pre-validates (internal consistency and comparison against existing data); (6) surveyor formally submits survey; and (7) Land Information New Zealand (LINZ) staff validate and approve survey, data becomes official and new coordinates generated (Haanen *et al*., 2002; Bevin 2002). The cadastral data is transferred via the e-survey LandXML format.

As part of step 5 above, Landonline allows surveyors to set out their diagrams within the title and survey sheets, with functions to add text and graphic tools to enhance diagram information. Figure 2 illustrates this functionality.

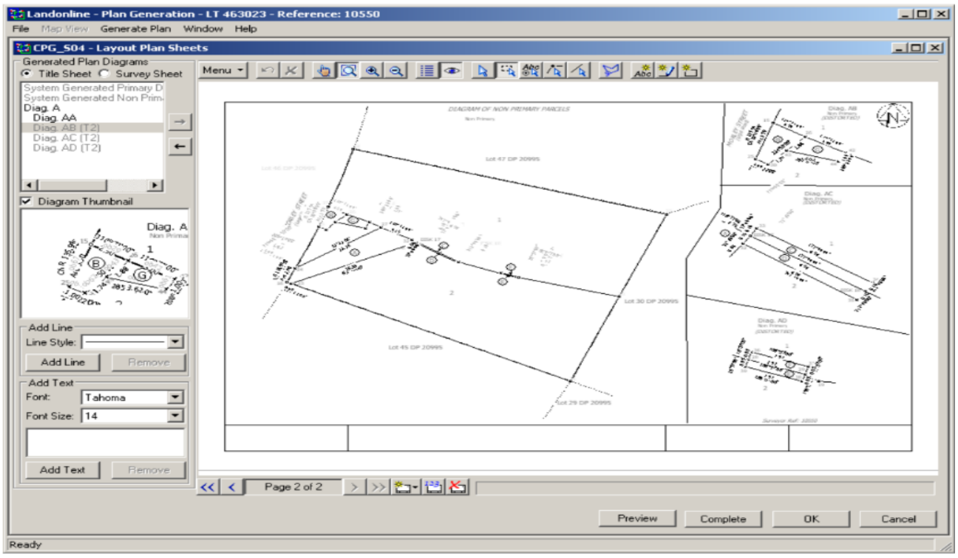


Figure 2. Layout plan sheets window (LINZ 2018)

2.3. Singapore's Experience

The SLA new cadastral system, namely Cadastral Survey Management System (CSMS), which is currently under development, has two main components. The Registered Surveyors' (RS) Portal and the SLA Inspection and Approval system (Soon *et al*., 2016). Registered surveyors will prepare their SG LandXML submissions in the office. The RS Portal will provide facility for registered surveyors and their assistants to pre-validate their submissions, and to generate cadastral plans from the submitted SG LandXML to receive updates and consultations from SLA.

To ensure the SG LandXML file and the plan submissions by surveyors are consistent, the Online Plan Generation Module of the RS Portal is designed to generate plans directly from the submitted SG LandXML (Figure 3). Understanding the presentation of annotations on the plan is technically challenging. The module allows surveyors to do some adjustments, such as moving and rotating annotations. For consistency, no additional texts or annotations can be entered in the module. Texts can only be obtained from the submitted SG LandXML file directly, and not from other sources.

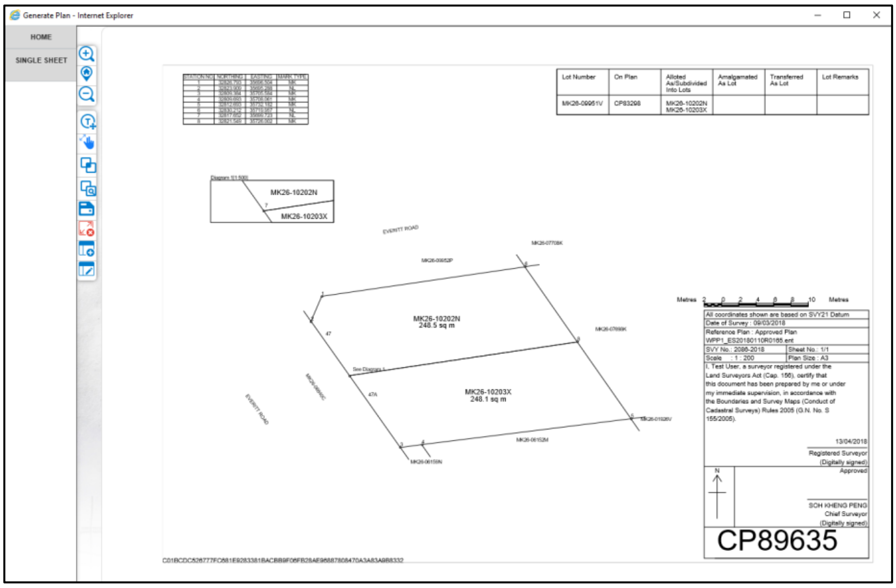


Figure 3. SLA online plan generation module

The required annotations can be prepared in and exported out from the SG LandXML software. Figure 4 illustrates an example of annotations in SG LandXML. The coordinates of the annotations have been specified to facilitate the placement of the annotations on the plan.

```
<Annotation name="EVERITT ROAD" type="RoadLabel" desc="32832.630 35697.098 32834.463 35709.670" />
<Annotation name="EVERITT ROAD" type="RoadLabel" desc="32825.255 35689.251 32810.026 35700.046" />
<Annotation name="" type="AbuttalLine" desc="32812.693 35732.182 32812.901 35733.866" />
<Annotation name="" type="AbuttalLine" desc="32809.384 35705.584 32807.995 35706.568" />
<Annotation name="MK26-09952P" type="AbuttalLot" desc="32830.620 35708.067" />
<Annotation name="MK26-07708K" type="AbuttalLot" desc="32832.639 35720.741" />
<Annotation name="47" type="HouseNumber" desc="32822.186 35696.985" />
<Annotation name="47A" type="HouseNumber" desc="32815.186 35701.919" />
```

Figure 4. Annotations in SG LandXML

The online plan generation module does not generate all types of plans. Cadastral plans that require cross-sections are not supported. These plans include airspace, subterranean and strata plans. For these plan types, surveyors must upload the plan in the DXF format. The RS Portal is then used to convert the plan into PDF.

The literature review confirmed that other jurisdictions have implemented some tools to enable surveyors to improve the presentation of the visualised cadastral data. The authors would like to highlight that when LUV commenced development to address the research problem discussed in section 2, of the three jurisdictions described in this section, only New Zealand had a visualisation enhancement tool in place. Singapore and WA commenced development at the same time or later than Victoria. As a result, there is no feedback available regarding the visualisation enhancement tools in WA and Singapore. New Zealand are also replacing Landonline, the system currently used to manage New Zealand's title and survey transactions, through the Advanced Survey and Titles Services (ASaTS) project (ASaTS Project 2018). Their plan visualisation and enhancement service which is based on old technologies from 2000s will be replaced through ASaTS too.

To address the research problem as defined in the Introduction section, the Victorian ePlan team developed a methodological approach, which is described in the next section.

3. Research Methodology

The research methodology was developed by LUV in collaboration with the University of Melbourne in four phases, as illustrated in Figure 5.

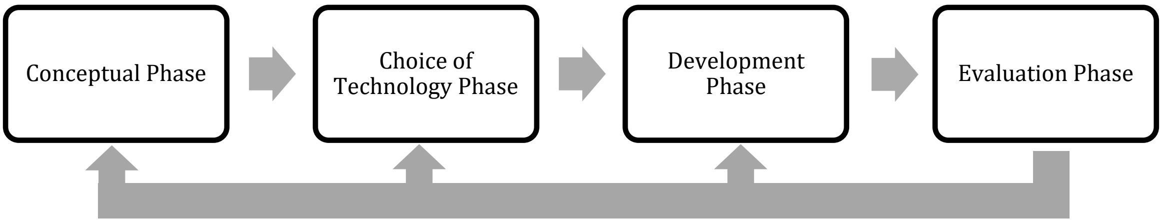


Figure 5. The methodology developed to address the research problem (adopted from Olfat, 2013)

The above phases are explained in more details below.

3.1 Conceptual Phase

In this phase, the business and technical requirements for designing and developing a tool to enhance the visualisation of ePlans were gathered and documented.

In gathering the business and technical requirements a series of workshops with the Subdivision Branch at LUV were conducted. The Subdivision Branch is responsible for examining and registering plans under Subdivision Act 1988. These requirements were presented to the surveying industry in different forums to receive their feedback.

The summary of major business requirements are as follows:

- A new online tool needs to be developed that enables surveyors to enhance the presentation of the visualised ePlans so that plans can be compliant to Victorian drawing standards. This tool is named the 'ePlan Visualisation Enhancement Tool (VET)'.
- VET needs to get integrated with the current ePlan functionality within SPEAR.
- Surveyors should be able to create an enhanced diagram file (including the plan visualisation enhancements) before and after submitting the ePlan application to SPEAR. If the enhanced diagram is generated before the application submission, the surveyor should be able to download and upload it together with the relevant ePlan LandXML file to the SPEAR ePlan visualisation service to receive a PDF file. If the enhanced diagram is generated after the application submission, SPEAR should automatically store the enhanced diagram file in its database.

The major technical requirements identified for supporting the business requirements are as follows:

- A new file format is required for exchanging the plan visualisation enhancements between the surveyor and SPEAR. The plan visualisation enhancements data cannot be stored within the LandXML file as the Victorian ePlan LandXML Protocol does not cater for storing visualisation information. Changing this Protocol is not possible as it must follow the national ePlan LandXML Protocol and the LandXML 1.2 schema.
- Presentation of labels should be adjustable. Adjustment includes label movement, rotation, copy, hide, unhide, font size change, wrap and unwrap.
- Presentation of arrows should be adjustable. Adjustments include arrow edit, hide, unhide, and snap.
- Presentation of diagrams should be adjustable. Adjustments include diagram scale down, scale up, layout change, show/hide all labels.
- Provision to add and remove sheets.
- Functions to support the creation of enlargement diagrams. The required tools include enlargement creation, removal, move, and extent change. Both to-scale and not-to-scale enlargement diagrams should be supported.
- Ability to exaggerate lines. Associated labels to a line must also be repositioned.
- Provision to preview the enhanced plan in PDF.

- VET must be compatible with SPEAR users' common browsers, including IE, Mozilla Firefox, and Google Chrome.

Once the business and technical requirements were confirmed, different technologies were evaluated to identify the most appropriate technology for developing VET.

3.2 Choice of Technology Phase

The ePlan visualisation service, the server side of VET, has been developed based on Java technology and iText library, which is responsible for generating the PDF. In this phase, based on the business and technical requirements discussed above a set of criteria was developed to select the most appropriate technology for the client-side development of VET. Among the available JavaScript libraries supporting drawings, four technologies were shortlisted and compared. They were 'three.js', 'D3.js', 'Leaflet' and 'OpenLayers'. Table 1 illustrates the results of comparing the four technologies against a set of technical and non-technical criteria developed for VET.

Table 1. VET client-side technology selection

Criteria	three.js	D3.js	Leaflet	OpenLayers
Is purpose of the software aligned to VET requirements?	No. Mainly for 3D visualisation.	No. For manipulating Document Object Model (DOM).	Yes. It is a light weight library more suitable for mobile applications.	Yes. It is a comprehensive library suitable for browser applications.
Supports drawing	✓	✓	✓	✓
Supports geometry				
point, line, polygons	✓	✓	✓	✓
symbols	✓	✓	✓	✓
Supports topological functionality	Beyond scope	✓	Possible using plug-ins such as Turf.js, JSTS	Possible using plugins such as Turf.js, JSTS
Supports text				
font types	Only for 3D	✓	✓	✓
font size	Only for 3D	✓	✓	✓
font rotation	Only for 3D	✓	✓	✓
Reliability (current and future)				
Developers	Volunteers	Volunteers	Vladimir Agafonkin (Mapbox)	OSGeo Foundation
Regular releases	✓	✓	✓	✓
Documentation	Available in detail	Available in detail	Available in detail	Available in detail
Support				
Evidence of activity on Wiki forum	✓	✓	✓	✓
Accessibility				
Cost	Free	Free	Free	Free
Open source	✓	✓	✓	✓
Portability (works in all browsers)	✓	✓	✓	✓
Interoperability				
Based on standards	Beyond scope	HTML5, CSS3	JavaScript, JSON, GeoJSON	JavaScript, JSON, GeoJSON

Table 1. VET client-side technology selection

Criteria	three.js	D3.js	Leaflet	OpenLayers
Integrates with other software	Beyond scope	With other JavaScript frameworks	With other JavaScript frameworks	With other JavaScript frameworks
Comments	A useful library for visualising 3D cadastre related products.	D3-shape could be a useful framework.	It comes with minimal features. There is a need to add extra plug-ins for additional functionality.	It comes with a large range of built-in functionality.

The study showed that OpenLayers satisfied the VET criteria, and hence it was selected for this project.

The next section reviews the development phase of the VET.

3.3 Development Phase

3.3.1 System architecture

The overall system architecture is shown in Figure 6. It shows the existing components of the system, the new components developed as part of this research and the input/output information being exchanged between these components. The system consists of three main components: 1) SPEAR, 2) ePlan visualisation service and 3) ePlan Visualisation Enhancement Tool (VET).

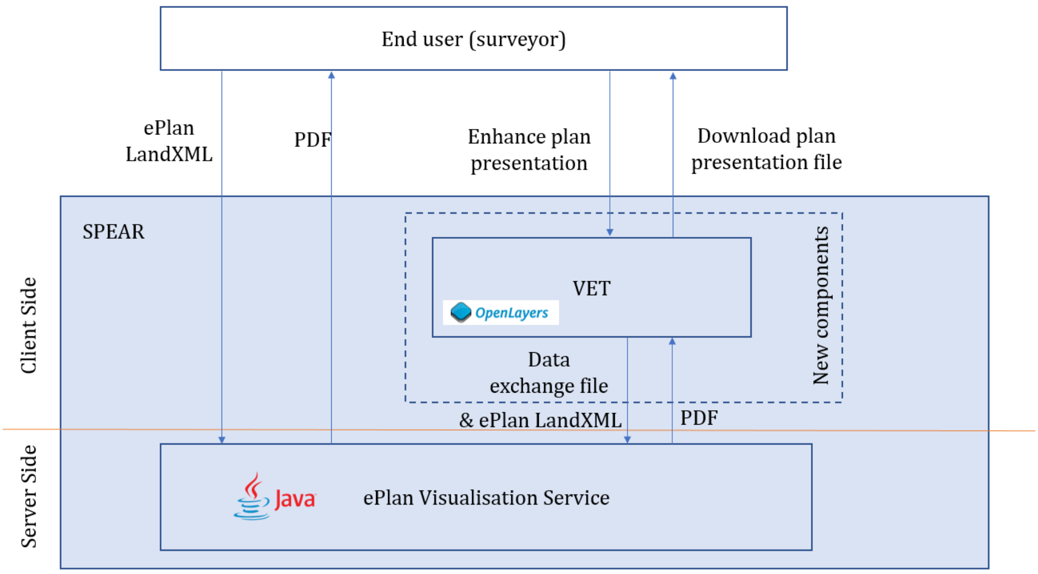


Figure 6. VET high level architecture

SPEAR is a portal which facilitates communication and interaction between the stakeholders of the land subdivision process. They include surveyors, local governments, referral authorities, land registry, solicitors and the public. Through SPEAR, a surveyor creates the application for a subdivision of land and then provides an ePlan LandXML file to LUV (Olfat *et al.*, 2018).

The visualisation service is a web service that converts an ePlan LandXML file into a plan in PDF as per the legal requirements. This service resides within the SPEAR system and can be accessed publicly via the SPEAR website by any user who uploads an ePlan. Alternatively, surveyors who are signed into SPEAR can add an ePlan to a SPEAR application that they have created, which automatically results in their plan being visualised to PDF and added to the application.

The visualisation service is built using Java, specifically it builds upon some of the drawing capabilities of the Java Graphics2D class. The visualisation service produces all the sheets in a plan, such as:

- Front sheet (includes various administrative data)
- Main Diagram sheets
- Restriction Diagram sheets
- Owners Corporation Schedule sheets

When producing the sheets that involve diagrams, all the information contained in the diagram is also exported to a data exchange file. This file contains details of parcel linework, as well as the positions of the parcel and dimension labels. The structure and contents of the data exchange file is discussed in more detail in the following section.

The VET then reads the information from the data exchange file and visualises the plan in the web browser. Surveyors can then access the editing tools in VET to make the necessary enhancements to the auto-visualised plan. Once the plan is enhanced, the data exchange file can be stored in SPEAR or downloaded by the surveyor for future use. The updated PDF is produced using the combination of ePlan LandXML and data exchange files.

3.3.2 Data exchange schema and format

The visualisation service has an algorithm that computes how to visualise an ePlan LandXML to PDF as per the legal requirements. The raw visualised information is stored in a data file, which can subsequently be provided to VET. The information is stored in JSON (JavaScript Object Notation) format, which is the native data exchange format supported by JavaScript. It is lightweight, human readable and easy for machines to parse. Since VET is built using JavaScript, JSON has been adopted as the format for data exchange. The information saved in this file consists of the following objects:

ePlan: This object is modelled to reflect an ePlan in PDF format. This object contains the plan number, name of surveyor, and name of surveyor's firm. A PDF ePlan is made up of one or more pages. Accordingly, this object has an array of "sheet" objects.

Sheet: This object reflects an individual page of the PDF. It contains the page number, page layout, and angle of the north arrow. A sheet can show one or more diagrams. Hence it has an array of "diagram" objects.

Diagram: In the PDF plan, one page is dedicated to the "main" diagram. Further, if a part of the plan requires enlargement, then the page will also have an "enlargement" diagram. These are modelled in the data file as diagram objects. A diagram object includes the scale at which the diagram is visualised, and the extent of the diagram (parts of diagram which are outside the extent are not shown on the page). A diagram comprises one or more "parcel" objects.

Parcel: A parcel object contains the parcel, area, type of parcel, and state of the parcel. The geometry of the parcel is defined by the lines that form the parcel. Hence, the parcel object has an array of "line" objects. It also contains an array of "label" objects.

Line: A line object contains two "point" objects which defines where to draw the line on that page. The individual point objects contain the coordinates which represent the position on the page. The line object will normally be associated with textual information such as the bearing and distance. Thus, it has an array of "label" objects.

Label: A label object represents the text. This can be the bearing of a line, distance, name of a parcel, area, etc. A label object contains information of the text and where to position it on the page, including its angle and font size.

Figure 7 illustrates the VET JSON schema data model.

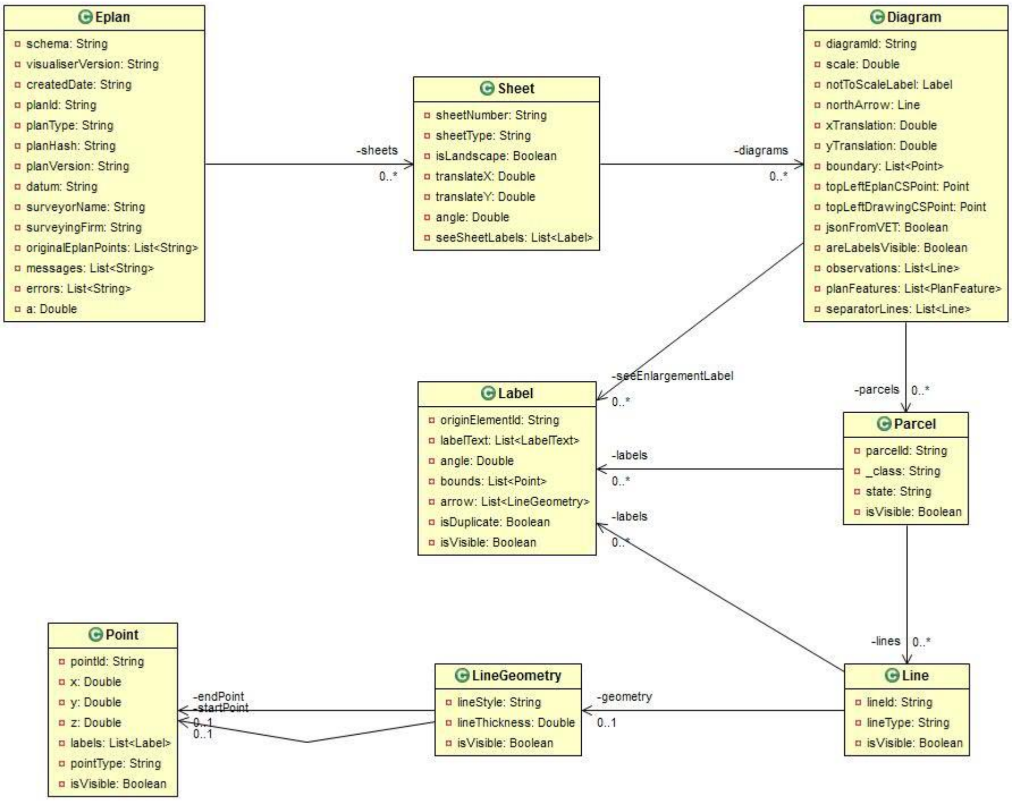


Figure 7. VET JSON schema data model

3.3.3 Graphical User Interface (GUI)

Once the information is stored in the JSON file, the file is provided to the VET. VET then reads the information from the file and renders it in the browser. This allows surveyors to view their diagram sheets. The interface of VET is shown in Figure 8. There is a toolbar at the top of the interface which provides all the functionality for enhancing the presentation of the plan.

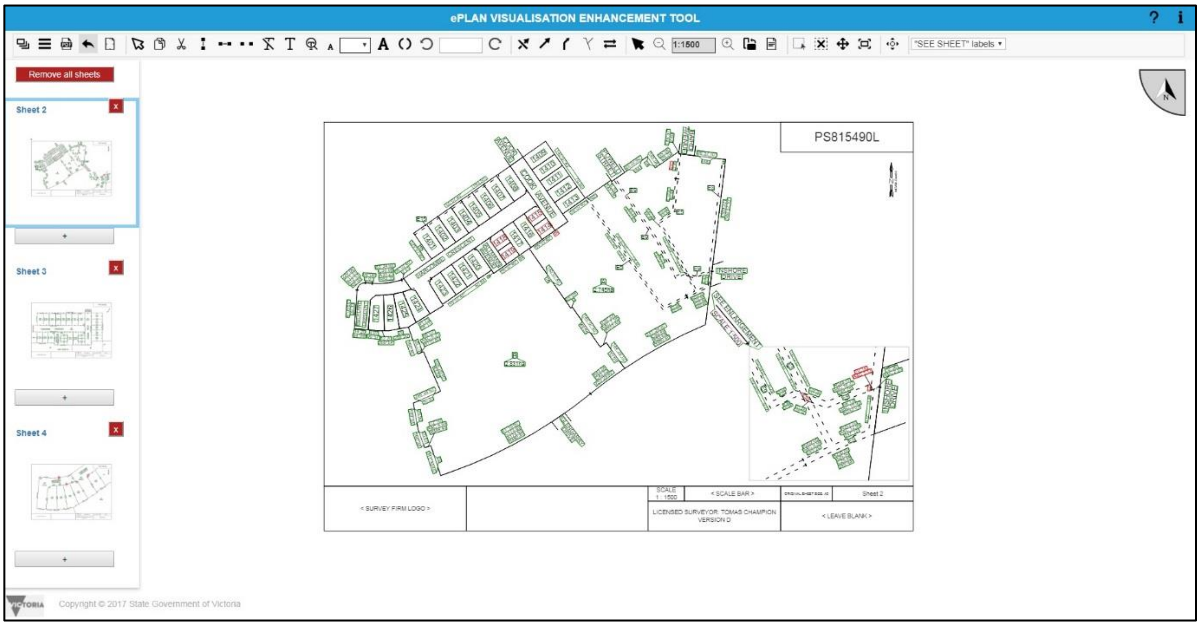
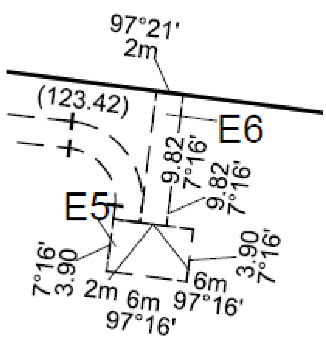
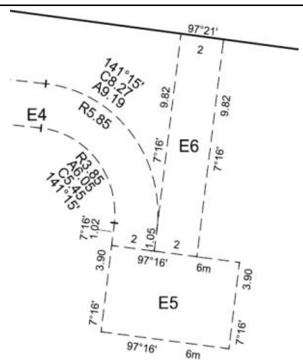


Figure 8. VET GUI screenshot

The toolbar in the VET consists of functions to add, remove and re-order sheets. Similarly, it supports adding, removing or moving enlargement diagrams, changing scale and rotating diagrams. For labels, it supports hiding, moving, rotating and changing the font size. These functions allow surveyors to overcome the limitations of an auto-visualised plan by enhancing the plan presentation to meet the legal requirements and accepted drawing standards.

Once the surveyor has enhanced the presentation of the plan, a new PDF can be generated from within the VET to show the enhanced plan. This is done by calling the visualisation service from VET. At this stage, the JSON file, along with the ePlan LandXML file are sent back to the visualisation service, which produces a new PDF file. If the PDF output is satisfactory, the surveyor can save a copy of the JSON file on the SPEAR system or download the file for any future use. A copy of the PDF can be generated at any time by providing the ePlan LandXML file with that JSON file.

Figure 9 illustrates the presentation of diagram components before and after VET.

Before VET (2016)	After VET (2018)
	

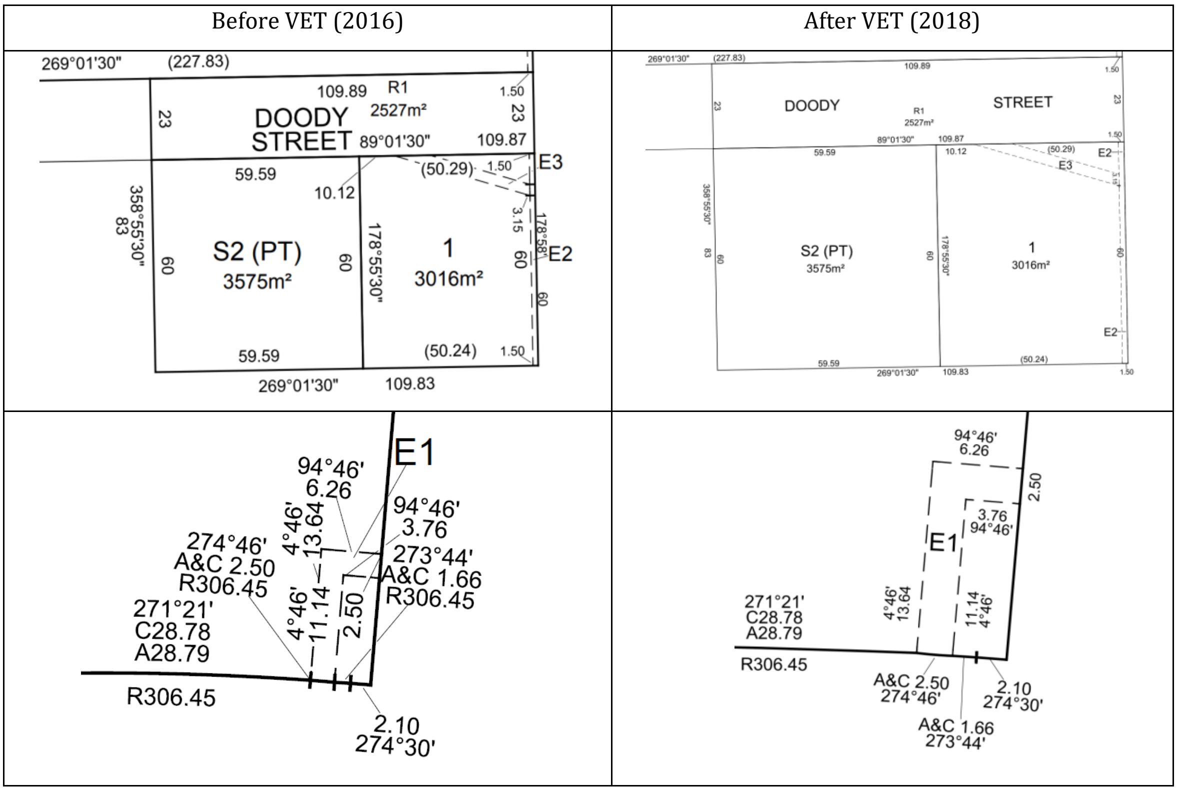


Figure 9. The presentation of diagram components before and after VET

3.3.4 Technical Challenges

Technical challenges were encountered during the implementation of the VET, which are summarised here:

Change in plan data - The normal lifespan of a typical ePlan is usually between one to two years during which it goes through council, referral authorities, LUV, etc for their approvals. During this time, the surveyor may be required to change the ePlan data. This may include adding, removing and modifying existing parcels. While generating a PDF from the ePlan LandXML file and its associated JSON file is straightforward, it is much more challenging to generate a PDF when the ePlan file is modified. In case of the later, it is important to ensure the integrity of the information is maintained. For example, if a parcel is subsequently changed in the ePlan file, then when a new PDF is generated, it should show the changed geometry of the parcel while preserving all the other enhancements made by the surveyor. To achieve this, a module has been added to the visualisation service to map all the parcels between the ePlan file and the JSON file to apply the necessary changes to the JSON file.

Change in datum - Another change that an ePlan file goes through during the course of its lifespan is the datum. A datum is the coordinate system of the earth in which all the coordinates of the ePlan file are defined. The initial ePlan file may have all coordinates defined to an arbitrary coordinate system. Then subsequently, the coordinate system is changed to the Map Grid of Australia (MGA) datum. This is done by the surveyor in their CAD software outside the SPEAR system and hence, the changes only apply to the ePlan LandXML file and not the JSON file. Therefore, the coordinates of points in the ePlan file will not match their counterpart points in the JSON file. This means the geometries cannot be mapped between the two files. Without the mapping, it is not possible to build a transformation function to convert all the points in the JSON file from the arbitrary coordinate system to the MGA datum. To resolve this problem, an image matching algorithm was adopted based on (Arkin *et al*., 1991). The algorithm compares two shapes to determine the variation, taking into consideration the scaling and rotation. By applying the algorithm to a parcel from the ePlan and JSON files, it is possible to determine if the two parcels have the same geometry.

Once the match is found, a transformation function can be calculated to convert all the relevant points in the JSON file to the new datum.

Backward compatibility - VET is currently a work in progress. It is constantly being updated to add new functionality and support. This includes changes to the code and the schema. There are many existing ePlans in SPEAR, therefore any changes to the schema or VET may impact the visualisation of these existing plans. To continue supporting the existing plans and ensure the same output can still be achieved, a separate "backward compatibility" module has been added to the visualisation service. This module interrogates the version number of the JSON file and then updates it in a linear fashion, bringing it up to date with the latest changes to the code and schema.

3.4 Evaluation Phase

To evaluate the usability of VET, it was decided that the System Usability Scale (SUS) would be a suitable survey. The SUS was developed by Brooke (1996) as a 'quick and dirty' survey scale that would allow the usability practitioner to quickly and easily assess the usability of a given product or service. In fact, SUS is a ten-item Likert scale giving a global view of subjective assessments of usability (Brooke 1996). The SUS statements considered for this survey are shown in Table 2 in Section 4. These statements actually cover a variety of aspects of system usability, including the need for support, training, and complexity, and thus has a high level of face validity for measuring the usability of a system.

Respondents should be asked to record their immediate response to each statement, rather than analysing the questions. If a respondent feels that they cannot respond to an item, they should mark the scale at the mid-point. SUS yields a single number representing a composite measure of the overall usability of the system being studied. The scores for individual items are not meaningful on their own. To calculate the SUS score, the score contributions from each item are added. Each item's score contribution will range from 0 to 4. For items 1, 3, 5, 7 and 9 the score contribution is the scale position minus 1. For items 2, 4, 6, 8 and 10, the contribution is 5 minus the scale position. Then, the sum of the scores is multiplied by 2.5 to obtain the overall value of system usability. SUS scores have a range of 0 to 100.

Bangor *et al.* (2008) discussed that the SUS survey has some advantages against other excellent alternatives, as follows:

- The survey is technology agnostic, making it flexible to assess a wide range of interface technologies.
- The survey is relatively quick and easy to use by both study participants and administrators.
- The survey provides a single score on a scale that is easily understood by the wide range of people who are typically involved in the development of products and services and who may have little or no experience in human factors and usability.
- The survey is non-proprietary, making it a cost-effective tool.

These advantages, although general in context, provided the basis for justifying the SUS as a suitable survey method in this research for evaluating the usability of VET.

As surveyors are the VET end users, the SUS survey was shared with all nine surveying firms currently creating ePlans in Victoria. All responded to the survey. Accordingly, the response rate was 100%.

The VET usability results are discussed in the next section.

4. VET Usability Evaluation Results

This section includes the results of the usability evaluation of VET based on the SUS survey illustrated in Table 2. The method to calculate the score of each statement was also discussed in Section 3.4. However, since Brooke (1996) cautioned that 'SUS scores for individual items are not meaningful on their own', the overall SUS score needed to be calculated to measure the VET usability. This overall score is outlined in this section.

Table 2. VET usability evaluation results

SUS Statements	0 Strongly Disagree	1 Disagree	2 Neither	3 Agree	4 Strongly Agree
1. I think that I would like to use VET frequently.	22%	0%	11%	22%	45%
2. I found the VET unnecessarily complex.	11%	67%	11%	11%	0%
3. I thought the VET was easy to use.	0%	22%	22%	56%	0%
4. I think that I would need the support of a technical person to be able to use the VET.	45%	33%	0%	11%	11%
5. I found the various functions in the VET were well integrated.	0%	11%	11%	78%	0%
6. I thought there was too much inconsistency in the VET.	0%	22%	67%	11%	0%
7. I would imagine that most surveyors and draftspersons would learn to use VET very quickly.	0%	11%	11%	56%	22%
8. I found the VET very cumbersome to use.	0%	67%	22%	11%	0%
9. I felt very confident using the VET.	0%	0%	22%	56%	22%
10. I needed to learn a lot of things before I could get going with VET.	56%	33%	11%	0%	0%

The overall SUS score of the VET was 68.3 out of 100. According to the rule-of-thumb standard, the so-called 'university grade analog', discussed by Bangor *et al.* (2008) and illustrated in Figure 10, the SUS score of the VET is between 'OK' and 'GOOD' ratings, among 'worst imaginable', 'poor', 'ok', 'good', 'excellent', and 'best imaginable' ratings.

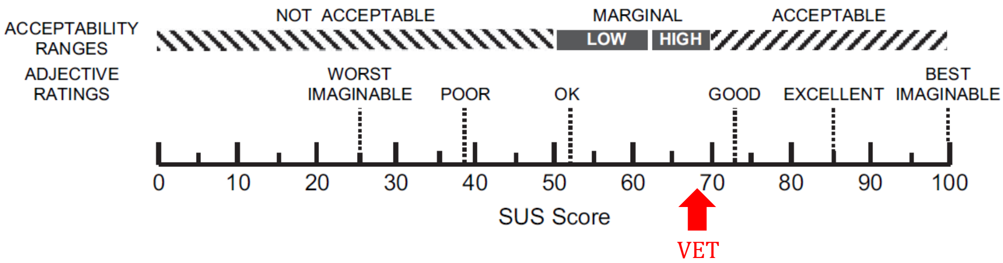


Figure 10. The rating and acceptability of the VET according to the SUS rule-of-thumb standard (adopted from Bangor *et al.* (2008)).

Based on this standard, in terms of its acceptability, the VET is located in the 'high marginal' range among 'not acceptable', 'low marginal', 'high marginal', and 'acceptable' ranges. This means that the VET should be considered a candidate for increased scrutiny and continued improvement in terms of usability to pass at least the SUS score of 70, if it is supposed to be converted to an 'acceptable' product.

The details of the VET evaluation outcomes and survey participant's feedback are discussed in the next section.

5. Discussion and Conclusions

To address the research problem discussed in the introduction section, as the inefficiency of the digital cadastral data visualisation service in Victoria and other eWG jurisdictions that have adopted digital cadastral data lodgement (e.g., NSW, Western Australia, New Zealand and Singapore) in presenting the cadastral plan information, a research methodology was defined and implemented in four phases. The 'conceptual' phase considered the business and technical requirements for developing a tool that could help the surveyors to enhance the presentation of the visualised ePlans. The 'choice of technology' phase focused on defining the most suitable technologies for developing the tool. Java and OpenLayers were selected as the server and client-side technologies respectively. In the 'development' phase, a tool, called VET, was implemented within SPEAR, the Victorian State digital plan lodgement portal. VET enables surveyors to improve the presentation of plans using sheet definition, label and arrow adjustment, enlargement diagram creation and exaggeration functions. The surveyors' feedback on VET usability were then collected as part of the 'evaluation' phase.

In their current practice, surveyors can spend several hours to days to draft their plans, depending on the complexity of the plan. Time will be saved using a combination of the ePlan visualisation service and VET. As discussed, the cadastral plan in PDF format is considered as the legal document by the Victorian cadastre. Although, the surveyor submits an ePlan to SPEAR, the ePlan still needs to be converted into PDF to satisfy the legal requirements, i.e. the PDF plan being attached to the contract of sale, certified by the local government, used in the courts for the dispute resolution, etc. However, the ICSM eWG members have been recently discussing the possibility of certifying the ePlan digital data instead of the PDF plan. Should the digital data become subject to certification only, there would be no requirement for the VET. The digital data would still need to be visualised in some form, just in the same manner, e.g., in a web browser using a unique URL for each plan. This requires comprehensive research in potential alternatives to PDF plans, in particular when 3D ePlans are being supported. Obviously, such a change will require the eWG to identify the potential impacts of introducing the cadastral plan alternatives onto the land subdivision stakeholders such as land authorities, architects, engineers, planners, solicitors, real estates, and the public.

Until such time that the digital data is certified and visualised in a format other than PDF (anticipated to be between five to ten years), the VET will be used by surveyors in Victoria. Accordingly, the usability of the VET needs to be improved constantly as confirmed by the VET usability evaluation outcomes discussed in Section 4. Among the VET evaluation survey respondents, 22% did not show a willingness to use the VET frequently. Further analysis confirmed that those participants are of this view due to two main reasons. Firstly, they were new to ePlan as compared with the other respondents and had not used the VET much. Thus, they did not have the opportunity to become familiar with the VET functionalities and as a result they found it complex. Although, the VET has a comprehensive user manual, additional training for surveyors and draftspersons seems crucial to having a good user experience. Secondly, those respondents confirmed that the VET, similar to learning other new technologies would be easier and quicker to be adopted by the younger generation. In general, the age barrier has impacted the adoption of ePlan in Victoria. The average age of licenced surveyors in Victoria is over 55 and some surveyors have expressed that they are uninterested in adopting a new process when so close to retirement.

Most of the survey respondents (89%) were of the opinion that the VET is not necessarily complex. The above-mentioned reasons would justify the feedback of the remaining 11%. The participants suggested that creating a short tutorial video would assist users to become familiar with the VET more quickly. Some respondents complained about the JSON schema backward compatibility issue, which needs to be addressed as a priority. This issue is related to the ongoing JSON schema changes which may affect the previous enhanced ePlan applications in SPEAR. In some cases, the enhancements in the old JSON files could not be preserved for the updated ePlan files.

22% of the respondents were of the view that the VET is not user-friendly. They requested some improvements within the interface, such as adding more information when hovering the mouse over each tool and changing the tool icons to being more informative. Also, 22% of respondents raised the need for accessing a technical person to work with the VET. 11% stated they could not learn the VET quickly and they found it cumbersome. One of the considerations for development is keeping the functionality comparable with AutoCAD software as much as possible, as surveyors and draftspersons in Victoria are familiar with and use this package for drafting their plans. However, following the evaluation outcomes, it seems that some users have still found the VET functionality different to AutoCAD.

The majority of participants also agreed that the label/arrow enhancement, sheet definition, enlargement creation and exaggeration functions have been well integrated within the VET. The survey also confirmed that all respondents have a degree of confidence in using the VET. The survey also collected general suggestions from the respondents for improving the VET. Examples included allowing adjustment of line weights and allowing the restriction diagrams to be enhanced.

Following the SUS rule-of-thumb standard discussed in Section 4, feedback from the nine respondents will be considered to improve the VET usability experience. However, this self-selected group of ePlan early adopters is likely to be significantly non-representative of Victorian surveyors in general and may lead to a bias in the feedback received. As a result, the evaluation survey will be run periodically to monitor the progress of the VET usability and the efficiency of plan generation (e.g., in terms of reducing errors, improving titling outcomes, etc.) as more surveyors adopt ePlan in Victoria. Currently, a three-week release management program is in place in the updating of VET. This includes the development and testing of new enhancements and fixing defect. Urgent enhancements will be considered for each planned release. The release process is anticipated to continue in the foreseeable future.

Through the ICSM eWG workshops, the NSW land authority have raised interest in adopting the VET to their ePlan infrastructure. The option to make this collaboration possible are being investigated by the LUV and the University of Melbourne. The jurisdictions involved in the ICSM eWG have a long history of collaboration and sharing experiences on the ePlan services (e.g., validation, and visualisation), which can now be extended to include the VET. The NSW's interest in adopting the VET confirms that this application and the concept behind it could be applied to other land authorities dealing with digital cadastral data adoption.

As the ePlan project in Victoria is still evolving and needs to support further 2D plan-based application types, including the Crown plans and the plans under the Transfer of Land Act (TLA) and Local Government Act (LGA), the VET may also require development to support the new application types. According to the LUV ePlan roadmap (Olfat *et al*., 2018), all 2D cadastral plans under the Subdivision Act 1988 (Victorian Government 1988), Transfer of Land Act 1958 (Victorian Government 1958) and Local Government Act 1989 (Victorian Government 1989) and Crown plans will be supported in ePlan by 2020. Again, following the roadmap, strata plans are expected to be supported in ePlan by 2025. Therefore, the investigations should focus on the visualisation of strata plans and the potential enhancements they may need. The identified requirements will form the future of the VET. New technologies should also be considered in the future development of the VET too.

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