School of Property, Construction and Project Management

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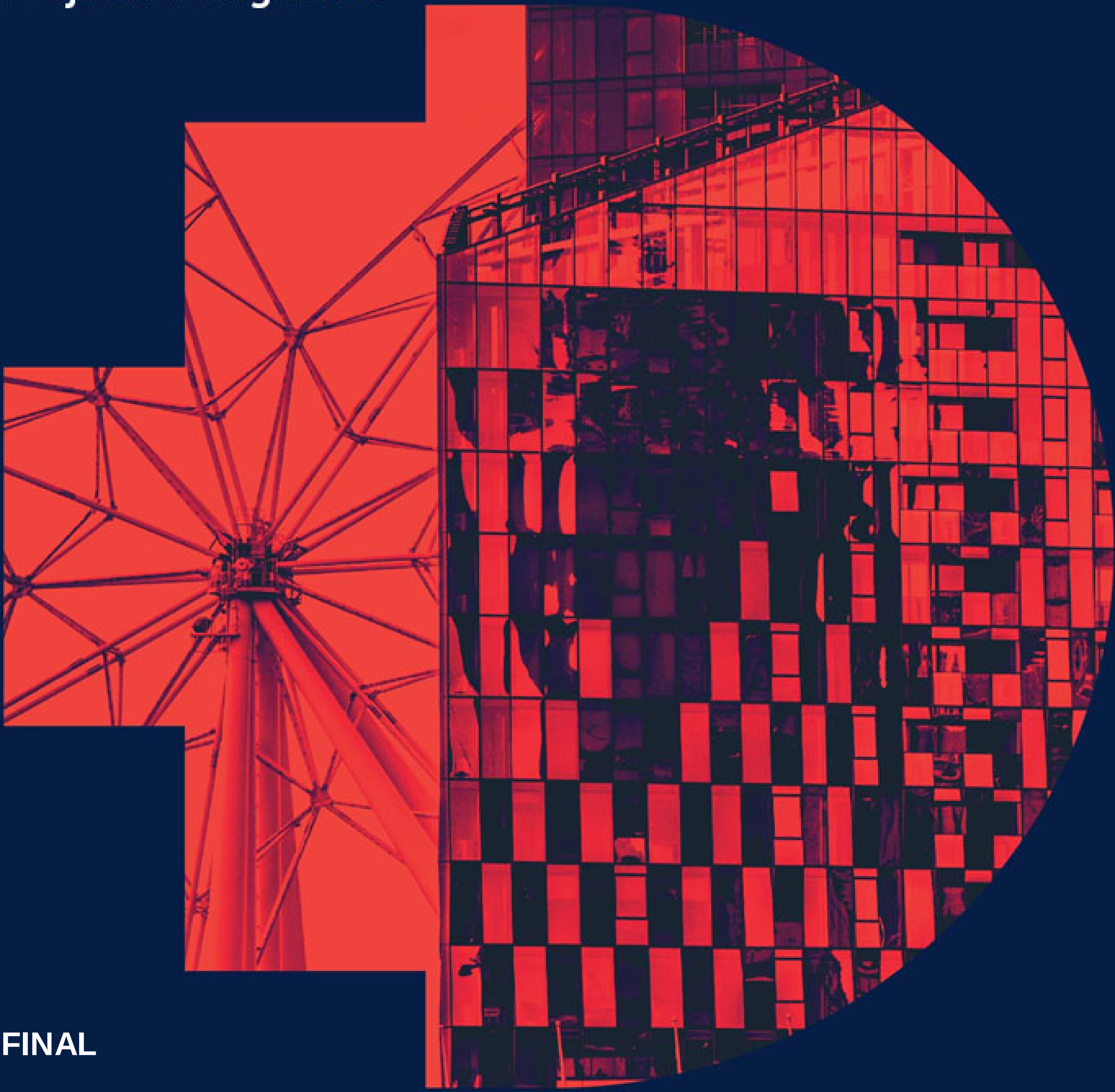

FINAL

Building Process Mapping

The Regulatory System and Potential for Digital Information Capture

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Executive summary

The report produced by RMIT's School of Property, Construction and Project Management for the Victorian Building Authority provides a high level summary of the lifecycle of a National Construction Code Class 2 building (i.e. a multi-unit residential building) from feasibility to demolition.

Information is presented in a map **Building Process Map: Opportunities for digital information capture across the lifecycle of a building.** The map shows the major stages of a building lifecycle including key activities and key inputs and outputs. Inputs and outputs are labelled to show opportunities for digital information capture. The map also shows detail of regulatory processes at each stage including responsibilities.

The map reflects traditional, sequential stages used for traditional project delivery and a note describing how this changes for integrated project delivery (IPD). The report also includes commentary on:

- How lifecycle processes are changed by use of integrated project delivery (IPD) techniques,
- Opportunities for digital information capture at each stage, and
- How regulatory processes function in practice.

Part 1: Introduction

The Victorian Building Authority (VBA) regulates building and plumbing practitioners to ensure the achievement of efficient and competitive building and plumbing industries in Victoria. The sector is operating in a dynamic environment as a result of issues highlighted by recent cladding problems and the imminent digitisation of much of the information produced and used in the building construction process.

As such, there is a need within VBA to enhance understanding and hence governance of critical building information. As a first stage in research to support this goal, this project maps information generation and communication throughout the building lifecycle.

The report is a companion to a process map which illustrates the lifecycle of a Class 2 building and the associated activities, inputs, outputs and regulatory processes.

Part 2 details the scope of the project and the methods used to produce the map and associated commentary.

Part 3 details the map itself.

Part 4 describes how the building process varies for integrated project delivery methods.

Part 5 looks closely at the input and outputs of each stage in the building process and details options for digital information capture.

Part 6 summarises what is known about actual industry practices of the issues covered in the process map.

Part 2: Scope and methods

The scope of the project is to produce a graphical map of the lifecycle of a typical Class 2 building from conception through to demolition. The base map shows key activities at each lifecycle stage (feasibility, design, construction, occupancy, demolition) and the responsible parties. The map describes:

- Key information inputs and outputs at each stage (based on our interpretation and experience of typical building practices),
- Opportunities for digital information capture at each stage,
- Links to regulatory processes (permits, inspections, dispute resolution etc), and
- Parties responsible for actions.

The map has been produced using MS Visio but is provided here as a PDF file.

The process varies depending on the project delivery strategy adopted for the design and construct phases. The map illustrates traditional project delivery, typically with separate design and construction contractors and sequential design and construction stages as this is the building lifecycle for which regulatory processes were originally designed. An integrated delivery model with design and construction undertaken together by a single (often consortium-based) contractor is now another commonly used option. Differences in inputs, outputs, activities and responsibilities for this mode of delivery compared to a traditional model are described in Part 4 of the report. This is also illustrated on the map.

Some other scope items are covered in commentary. Sections of this report describe opportunities for digital information capture (Part 5) and an indication of how the regulatory system works in practice (Part 6).

Please note that while RMIT has a good deal of experience on typical industry practices, a fully evidenced study of industry practice regarding both information flows and regulatory behaviours would require interviews with practitioners. This is beyond the scope of this small project, which is based on existing knowledge of the RMIT project team supplemented by a review of relevant legislation and recent reviews of the building sector.

Part 3: Map details

Based on an analysis of building project processes and a review of relevant Acts and Regulations, a graphical map has been produced to illustrate the lifecycle of a Class 2 building project and the associated activities, inputs, outputs and regulatory processes. It have been developed within the context of using a traditional project delivery, i.e. the design and construction stages are separated and undertaken by different organisations.

Table 3.1 provides a brief depiction of: 1) major stages involved in the lifecycle of a Class 2 building project and 2) key regulatory processes at each stage.

Table 3.1: Building lifecycle stages and associated regulatory processes

Building lifecycle stages	Key regulatory processes
Feasibility	-
Design	Planning permit preparation, review and approval Building permit preparation, review and approval
Construction	Five statutory inspections[1] Granting of occupancy permit
Occupancy	Maintenance of essential safety measures, insurance for building and plumbing work, and building defects and claims
Refurbishment	Planning / building permits depending on scope
Demolition	Demolition permit preparation, review and approval

Overall, five project stages have been identified:

- *Feasibility stage*, where the activity of project inception and initiation is undertaken by a building owner and/or the owner's agent to produce information required to develop a project brief.
- *Design stage*, where concept design and design development are undertaken by designers to produce necessary design information required for firstly a planning permit application and then a building permit application.
- *Construction stage*, where various building works are carried out by builder(s) in compliance with regulatory requirements and standards. At this stage, a relevant building surveyor conducts mandatory inspections at specified stages of building works to enforce

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1 It should be noted that the prescribed mandatory inspections are the minimum number of inspections which must be carried out under the legislation. The relevant building surveyor may request additional inspections to be carried out during building work under section 35 of the Building Act 1993.

compliance. Upon satisfactory inspections, the relevant building surveyor issues an occupancy permit when all building works are completed.

- *Occupancy stage*, where the building owner and occupants perform ongoing maintenance of the building in accordance to the requirements specified in the occupancy permit. The building owner may also propose an alteration or an extension to the building at this stage. The building owner and/or owner's agent can consult with the local council to seek advice regarding whether a planning permit or a building permit is required to conduct the proposed building works.
- *Demolition stage*, a demolisher partly or completely dismantles the building. However, a demolition permit needs to be sought from a relevant building surveyor by the building owner or owner's agent and the demolisher before any demolition work commences. In some cases, a planning permit is required from local council for demolition work, e.g. the building is on heritage register.

It is acknowledged that the process map produced does not include every scenario that possibly occurs in a Class 2 building project due to the summary nature and the limited scope of engagement of the map. In preparing the process map, it is assumed that the building project is carried out in an uninterrupted manner, without any eligibility or legal issues experienced by the builder. For example, the map does not reflect the special circumstance that the building work is discontinued because the builder's registration is suspended due to registration expiry, disciplinary action, insolvency, etc.

The map lists various sub-activities and detailed inputs and outputs for each project stage. Specifically, the detailed inputs and outputs specify relevant and necessary documents and information required for developing a project brief, applying for various regulatory permits and conducting mandatory inspections. This is particularly relevant when it comes to considering the potential for digital information capture. Options for digital capture are shown, specifically:

- *Document management systems and word processing systems,* are a combination of tools and systems to reduce the need for paper based documents.
- *Scheduling software,* are tools to develop the schedule of the project and communicate the schedule across multiple stakeholders. Often these tools can work with resource management tools to specify resource allocation.
- *Cost planning software,* are tools to develop cost planning of the project and can often work in conjunction with different accounting systems within the organisations.
- *Building information modelling systems (BIM),* is an overarching term referring to combinations of tools and technologies that facilitate digital representation of the components of the built environment and processes that are involved in constructing those components (International Standards Organization, 2010).
- *Geographical information systems (GIS),* refer to systems and tools to manage spatial and geographical data including the coordinates, their attributes as well as their interrelations such as topology (Burrough et al., 2015).
- *Interface management systems (IMS),* are systems to align the actions of different organisations and coordinate their collaborations through management of their communication, relationships and deliverables (Shokri et al., 2016; Shen et al., 2018).

- *Digital collaborative platforms,* are tailored tools as part of the interface management systems that facilitate collaboration and data sharing using different sources among the project stakeholders.
- *Digital ledgers*, or distributed ledger technologies (DLT) refer to a range of technologies to decentralise approval, transparency, and auditability of transactions and certifications through peer to peer networks (Dunphy et al., 2016).
- *Video and audio capture,* is here referred to any technology and tool that can help in recording the images or videos of the components of the built environment or processes for future reference.
- *Sensors,* refer to receptors to collect data from the environment that will be recorded for further investigation and processing.
- *Scanners,* refer to tools to capture images of the printed material and can be used for reading information from documents or barcodes.
- *Virtual reality models (VR)*, refer to computer technologies to create a visual representation of real world objects by completely recreating them in a virtual environment (Milgram and Colquhoun, 1999; Dunston, 2008)
- *Augmented reality models (AR),* refer to computer technologies to create visual representation of real world objects by super-imposing the virtual objects on predominantly real world scenes (Milgram and Colquhoun, 1999; Dunston, 2008).

The map also depicts the overall regulatory processes for a Class 2 building project through the project phases. Specifically, it details the processes of issuing various regulatory permits, including the planning and building permits at the design stage, the occupancy permit at the end of construction stage, and the demolition permit at the demolition stage. It also details the inspection processes undertaken by relevant building surveyors in the construction stage to oversee the quality of construction works. Dispute and defect processes are also summarised on the map at key stages.

Responsible parties for all activities are also shown, including:

- *Building owner*, who needs to ensure that the planning and building permits are applied for and granted before the commencement of building works, and an occupancy permit is obtained before the building can be occupied.
- *Owner's agent*, who assists the building owner in seeking regulatory permits and overseeing the project processes.
- *Designers*, who prepare detailed architectural and working drawings and specifications in accordance to the Building Code of Australia and relevant Australian Standards. Those documents are to be included in the applications for planning and building permits.
- *Builder*, who carries out building works in accordance with the Acts, Regulations and the building permit issued in relation to the building works.
- *Local council (planning authority)*, who issues planning permits and ensures that the proposed building works comply with the local Planning Scheme.
- *Municipal building surveyor*, who is employed by a council. A building surveyor is responsible for issuing building permits, conducting mandatory inspections of building works, and issuing occupancy permits.
- *Private building surveyor*, who assumes the same responsibilities as a municipal building surveyor but operates as an independent and private entity.

- *Relevant building surveyor*, who can either be a municipal building surveyor or a private building surveyor, i.e. the building surveyor appointed by building owner or owner's agent for a building project.
- *Reporting authority*, from whom a report or consent needs to be obtained when the building work may affect assets, infrastructure or amenity of the local community (e.g. building over an easement). Prescribed reporting authorities include the chief officer, a relevant council, a relevant service authority, and a relevant electricity supply authority.
- *Victorian Civil and Administrative Tribunal (VCAT),* part of the Victorian justice system which resolves disputes through negotiation, mediation and hearings.
- *Domestic Building Dispute Resolution Victoria (DBDRV*), an independent government agency designed to help resolve domestic building disputes.
- *Building Appeals Board (BAB),* an independent government board which makes decisions about matters related to building regulation.
- *Victorian Building Authority (VBA)*, an independent government agency which regulates Victoria's building and plumbing industries.
- *Insurer,* a financial entity that provides domestic building insurance (DBI) and plumbing insurance to builders
- *Fire safety engineer*, who designs systems and specifies building products that prevent fire damage in the building. A fire safety engineer may inspect building works in relation to fire safety matters.
- *Resident/Tenant*, who becomes the occupant of the building and assumes the responsibility relating to maintenance of the essential safety measures in the building.
- *Demolisher*, who seeks a demolition permit, carries out demolition work according to permit approved procedures, and implements precautionary measures during the demolition process.

Part 4: Integrated Project Delivery

Integrated project delivery (IPD) is a term used to refer to the increasing trend for joint activities among traditionally separate organisations to deliver projects (Fisher et al., 2017). This report focuses specifically on a form of IPD that integrates design and construction stages. IPD aims to increase collaboration between design and construction organisations to achieve higher efficiency and agility through common resources and shared goals (Walker et al., 2002; Mesa et al., 2016). With reference to the building process map, these changes in the project delivery mode will result in parallel execution of design and construction stages and earlier involvement of builders. For example, the start of the construction stage will not depend on the completion of the full design and will start based on the completion of the design components required for early construction activities. Furthermore, the designer and the builder will work together from the feasibility stage.

This change has several implications within the regulatory process, as the current permitting process was designed for the traditional project delivery with its stage-wise approach. These implications can be categorised as: (1) the structural implications of the process, or to answer the question of which permit is required when? (2) implications for the involved actors, as a higher level of integration means that the designer and builder may create a single joint corporate structure specifically for the purposes of project execution (sometimes known as a special purpose vehicle or SPV), or the designer may be contracted by the builder in a design-and-construct arrangement.

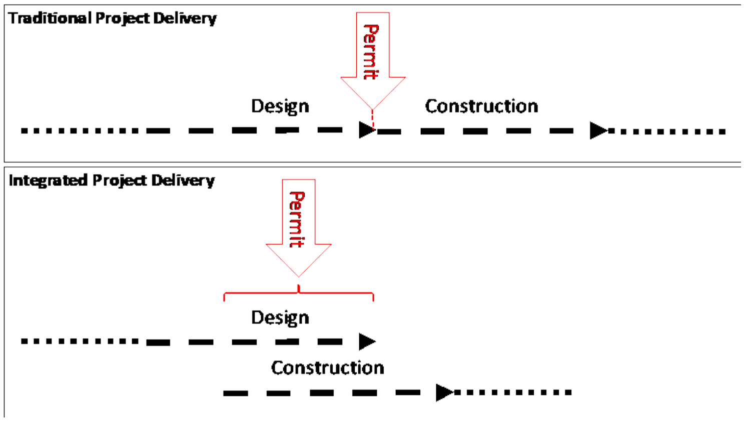

Figure 4.1: Challenges of regulatory process in alternative project delivery methods

In practice, these implications manifest themselves as changes to the design after the building permit is obtained. The arrangements between the builder and the designer mean that the design is more fluid, and it changes through the building process at the request of the builder or other parties as construction progresses. The building surveyor is by necessity much more dynamic in this arrangement requiring a greater oversight and understanding of design changes and their implications for the construction process and the completed building. Record keeping is also particularly important so that design changes are tracked and compliance with relevant codes is maintained.

The integrated project delivery process can work well and deliver a more efficient project outcome, but there are risks in the process if rigorous document control and change approval processes are not established by the parties involved. Some risks include design errors, inappropriate material substitutions, shortcuts in the construction process and inadequate designer supervision of the construction process. In addition, it is important to note that regulatory processes were established with traditional project delivery in mind. Regulatory practices to ensure that IPD projects remain compliant need to reflect the dynamic nature of IPD, which may result in higher resource requirements to enforce the regulations. The best practices for the alternative delivery methods should consider: (1) how the language and structure of permits can allow the required flexibility, (2) how the actors can integrate changes at the later stages within the already approved permits, (3) how such revisions are then included in the compliance process, (4) what additional resources are required for monitoring and control by the responsible person such as the surveyor, (5) who will be accountable for the deviation as the activities are executed in a collaborative manner. These nuances highlight the need to reflect the complexities of the alternative project delivery methods within the regulatory process.

Part 5: Opportunities for digital information capture

As depicted in the map, the process of building construction involves a range of actors that require exchange of information at different stages. The building industry is increasingly information intensive, with the information types including documents, drawings, maps, numerical analysis and graphs, as well as photos and videos. As a boundary object between these actors (Taylor, 2007), the information can be in the form of traditional, physical, and often paper-based items or they can be developed in a digital form. Digital information is collected, processed, and shared between the actors through the use of video and audio capture tools, sensors and scanners, mobile apps, and interface management systems within digital collaborative platforms (Shokri et al., 2016; Shen et al., 2018; Oracle, 2019). The discussion in this section aims to cover a categorisation of the types of systems that can be used and the opportunities for digitalisation. We emphasise the increasing need for a collaborative digital platform to ensure smooth sharing of data and information among stakeholders, as well as the potential for digital ledgers to ensure the validity of supervision and authorisation processes.

Digital information capture across the building process stages

At the feasibility stage, information to be captured and shared is mainly concerned with the potential conception of the project as detailed in the project brief. The associated information in this stage is primarily related to the building owner’s needs analysis, business case justification, cost/benefit analysis, financial evaluation, risk analysis, and preliminary plans. This information is often captured through specialised software such as document management systems and word processing tools for objectives and plans, stakeholder management, risk management and design requirements, scheduling through software such as Primavera, and spreadsheets or accounting software for cost control. This information can also be supported by preliminary input from technologies for preliminary drawings through Building Information Modelling (BIM) and spatial and geographical data capture such as Geographical Information Systems (GIS). However, involvement of multiple actors increasingly necessitates use of interface management systems (IMS) that can provide a basis for the use of digital collaborative platforms during the construction phase, such as Aconex by Oracle, ProjectWise by Bentley, or Procore (Fig. 5.1).

The design stage is predominantly concerned with the information needed for the planning and building permits. The planning and building permit applications are themselves online forms that require submission of certified documents, such as certificate of title or metropolitan levy certificate, with the potential for digital capture through digital ledgers such as Blockchain. The building permit can be issued in a standard form as well, which contains detailed information specified by the surveyor regarding expected performance standards. This information is critical as it serves as the basis for building inspection and quality monitoring. The rest of the required documents are more detailed versions of those developed at the feasibility stage and include an urban context report, proposed design, planning controls, strategic planning policy framework and design response in terms of complying with the regulation. Therefore, similar digital technology can be used in this stage to facilitate the process of final design across multiple actors.

At the construction stage, tools and technologies for digital information capture are related to supervision and certification, in addition to the documents that are used in the feasibility and the design stages. Several technologies such as video and audio captures, sensors, or scanners that update virtual reality (VR) and augmented reality (AR) models can be used at this stage, such as the Reconstruct platform by Oracle. Furthermore, digital ledgers can be used for certification at each stage based on the data collected through sensors, scanners as well as cameras. At this stage and with the prevalence of personal devices such as mobile phones, crowdsourcing of the data can be considered to reduce the cost of capturing digital information. However, crowdsourcing requires validation and verification techniques to be meticulously established. The actions for digital information capture at this stage can eventually be directed and used in the process of obtaining the occupancy permit.

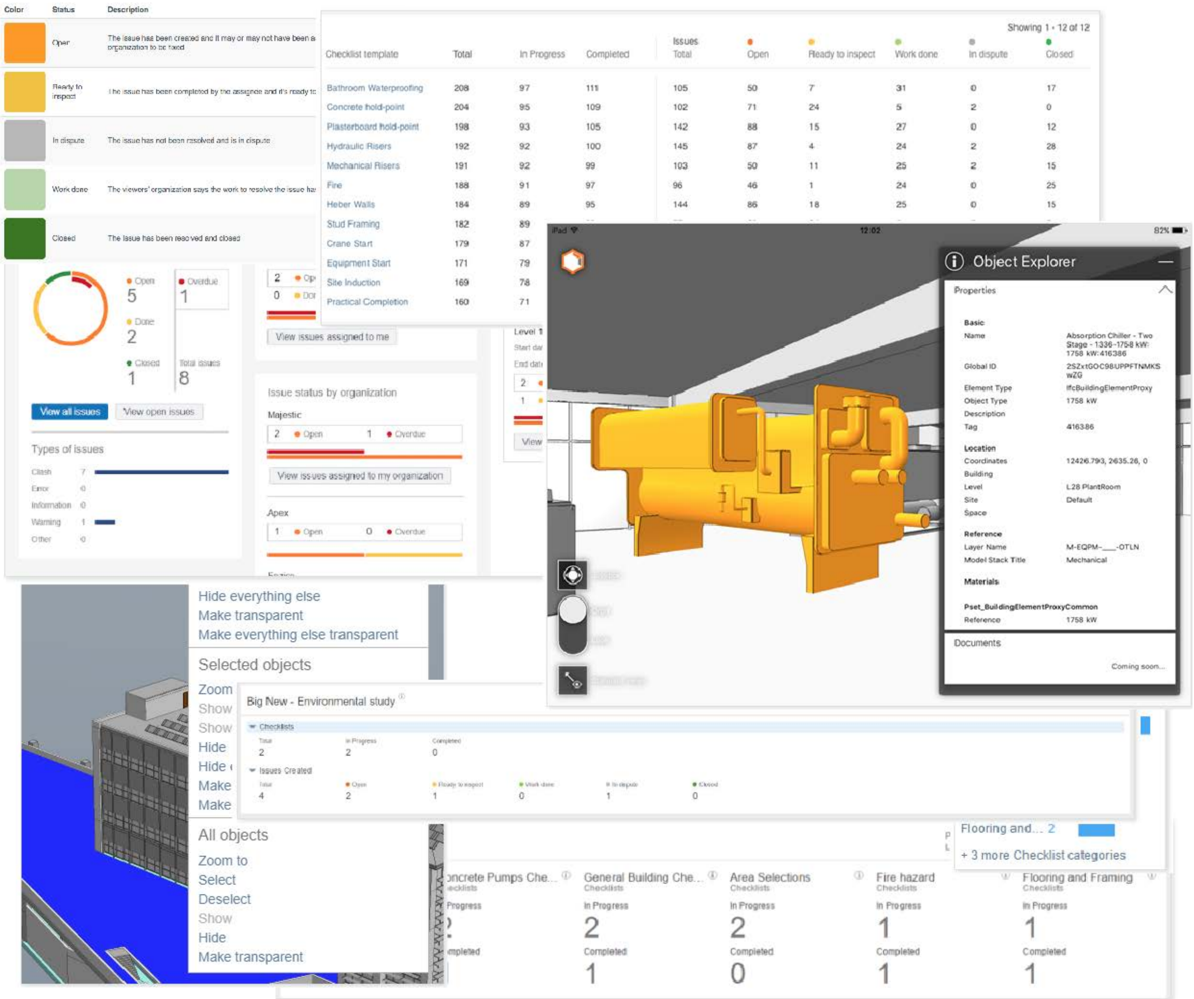

Figure 5.1: Different features of the digital collaborative platform (Source: https://help.aconex.com/)

While these tools and technologies can be further used at the modification and demolition stages of the building lifecycle, a major challenge needs to be carefully considered: often the lifecycle of digital technology and its supporting software and hardware is shorter than the lifecycle of buildings. As a result, there is a need to ensure a future-proof archiving process to ensure accessibility of the digitally captured information during or even after the lifetime of the buildings. This may include archiving required information in physical format or formats that have a higher potential for accessibility in decades to come and less reliance on associated technology to access, analyse and interpret the captured information.

Future steps

The building process mapping detailed in the previous section can be explored in view of the knowledge pyramid framework proposed by Ackoff (1989) and further developed by Naderpajouh et al. (2016). In this framework, the use of digital innovation is mapped through the process from data to information, knowledge, wisdom, which is then translated into actions. Within this process, data are defined as the observable symbols to reflect characteristics of processes such as collected logs on an activity (Rowley, 2007). Information is the data processed through analysis such as observing the trends on the collected logs (Rowley, 2007; Woldesenbet et al., 2015). Knowledge, or actionable information, is then the structured collection of information to support actions of decision makers, for example, efficiency of the workers based on the trends of the collected logs (Rowley, 2007; Woldesenbet et al., 2015). Finally, wisdom or insight is the ability to use knowledge in an efficient way to drive informed actions, such as how to improve efficiency (Rowley, 2007; LaValle et al., 2013; Woldesenbet et al., 2015). Mapping the building process in view of the process from data to action can facilitate the choice of digital information capture tools related to both communication and authentication processes (Fig. 5.2). That is, the decision maker can tie the choices to the outcome and assess the benefits for the organisation in view of the cost of each alternative by having the wider picture on digital information capture and its use.

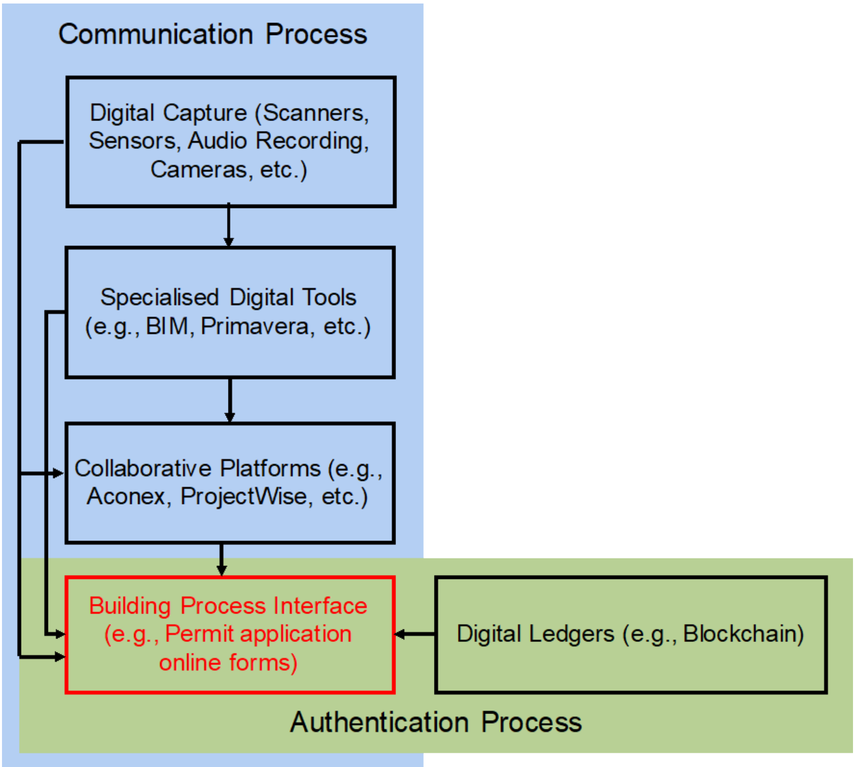

Figure 5.2: Future steps for digitalisation across the involved stakeholders

The identified approaches to digital information capture can then be evaluated within the process from data to action, considering options such as: automated forms, interfaces, GIS tools and models, BIM, virtual reality, augmented reality (or variations such as mixed reality), digital ledgers, spreadsheets, simulation models, analytics dashboards, sensing, scanning, video, audio, and photo capturing tools towards an ultimate digital twin. It should be noted that the value obtained through the adoption of digital innovations in projects is affected by the decisions made throughout this process, starting from data preparation and system configuration all the way to analytics, interpretation, and intelligent action. Steps to consider the opportunities for digital information capture are:

Step 1) Identification of the technologies and tools for digital information capture by involved actors,

Step 2) Investigation of the compatibility and interoperability of the range of technologies and tools used by the involved actors,

Step 3) Identification of collaborative digital platforms and their interface management systems (IMS) that can accommodate the digital capture of the involved actors,

Step 4) Integration and synching of the identified collaborative digital platforms and their IMS with the online forms for permits such as planning, building, and occupancy permits,

Step 5) Integration of digital ledgers to ensure authentication and validity of certification and supervision processes

Within these steps are several challenges including: (1) compatibility and interoperability issues, and (2) the chronological extension of the decision to the lifecycle cost of the digital information capture. While the compatibility issue is already discussed and understood in practice, the lifecycle issues need further emphasis. As discussed above, the digital information capture needs to be future-proofed against obsolescence of the required tools and technology. Using the proposed framework from data to information, knowledge, wisdom, and action can facilitate these managerial nuances as it facilitates systematic analysis of the decisions for the use of digital information capture to consider current issues such as compatibility and lifetime of different components or more broadly human-centred use of technology.

Part 6: Industry practices

The map of the building process and building regulation show what policy makers and system authors see as the best way to achieve the desired outcomes. This can be described as ‘work as imagined’ – how those who are often remote from worksites and design offices believe things should be done. Actual practice is bound to vary and can be described as ‘work as done’. In this section, we draw on two major reviews of the building sector and building regulation to describe what is known about how the Victorian building sector functions in practice.

Broadly speaking and as noted above, industry practices are driven by regulatory requirements and in particular the requirements of the National Construction Code (NCC), which is referenced in regulation. Receiving regulatory approval at various stages is a significant project risk and so drives the timing of investment and key activities. Compliance with regulatory requirements costs money, so how approvals processes work in practice and the level of enforcement of legislated requirements significantly drives industry compliance, which is in itself a major driver of industry practice overall. For these reasons, a review of industry practice is, to a large extent, a review of the enforcement / compliance relationship between regulators and industry.

The Shergold Weir report (Shergold & Weir, 2018) summarises a range of problems in the building sector across Australia:

(a) Serious compliance failures in recently constructed buildings,
(b) Many industry practitioners do not understand the requirements of the NCC,
(c) Poor design documentation leads to key decisions being improvised by builders during construction, further resulting in lack of appropriate regulatory oversight and an inability to manage key building safety issues during occupancy, and
(d) Weak regulatory oversight.

While this was a national review, the recent Victorian building sector experiences with cladding suggest that these issues apply here as much as in other states. The report’s findings are also broadly consistent with our understanding of building practices in this state. The report makes 24 recommendations, some of which can be linked to the building process as follows:

The criticality of design documentation (Recommendations 13 to 17)

As the process map shows, design activity as documented in drawings and specifications is a key input to both the planning permit and building permit. It is also the way in which the designers’ intent (including engineering details linked to occupant safety) is communicated to builders. Problems in design documentation mean that builders may be left to make decisions that are not a legitimate part of their role. It also means that inspections of work done may be lacking a firm basis to inspect against. Lack of complete drawings may have long term implications too as building modifications in the occupancy phase may have no firm starting point regarding key structural or fire safety issues.

The criticality of fit for purpose inspections (Recommendations 5 to 7 and 9 to 11)

As the process map illustrates, the integrity of the final product relies heavily on a series of statutory inspections done by building surveyors at various points through the construction process. If these inspections are not done rigorously, the final approval for the building to be occupied is compromised. In addition to documentation, another key factor in ensuring that NCC requirements have been met is the competence, capacity and authority of building surveyors. Shergold and Weir made several recommendations on this subject including the need for an overall state audit strategy (based on risk to occupants), enhanced building surveyor reporting obligations, and development of a code of conduct for building surveyors.

Other recommendations relate to commercial buildings (in their scope but not the scope of this project) or matters which are not readily illustrated by the process map.

It must be noted that these problems are not confined to Australia. Following the Grenfell Tower disaster in the UK in 2017, Dame Judith Hackitt was commissioned to review the UK building regulation system. Her final report (Hackitt, 2018) identified four issues underpinning the regulatory failure in the UK. These are:

- Ignorance
- Indifference
- Lack of clarity on roles and responsibilities
- Inadequate regulatory oversight and enforcement tools.

The first, third and fourth of these points are consistent with Shergold and Weir's (2018) findings regarding the Australian building sector. This adds further weight to the need for change and the extent to which the problems are systemic, driven by structural factors in the industry and regulatory arrangements, and the relationship between the two.

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Part 8: Appendix

As noted in **Building Process Map: Opportunities for digital information capture across the lifecycle of a building**, the person authorised to undertake the final inspection must ensure that the provisions and conditions of the Building Permit are satisfied. These conditions and provisions are listed below:

- Roof drainage connected to an approved point of discharge
- Required safety systems (such as handrails and balustrades) completed and compliant
- Stair construction
- Glazing meets human impact, structural and weather resistance provisions
- Provision of relevant sanitary and other facilities
- The building is constructed to prevent the penetration of water and dampness to the internal areas of the building
- Waterproofing of wet areas completed to the satisfaction of the relevant building surveyor (RBS)
- Smoke detection and alarm systems installed and fully operational
- Energy efficiency provisions have been met
- Power connected to the satisfaction of the electricity supply authority, where electricity is required for mechanical ventilation, artificial lighting or hard-wired smoke alarms
- If gas cooking is to be provided, the pipework is connected to the unit and completed to a stage ready for connection to the gas supply
- Water supply connected to the building
- Swimming pool and spa safety barriers
- Exits
- Firefighting equipment, such as hydrants, hose reels and portable fire extinguishers
- Sprinkler systems
- Smoke hazard management systems
- Fire resisting construction
- Fire dampers
- Fire rating of penetrations of walls, floors, fire doors and door sets
- Fire windows
- Fire hazard properties
- Emergency lighting and exit signs
- Structural stability
- Disabled access and facilities
- Mechanical ventilation systems.