IOP Conference Series:
Earth and
Environmental Science

PAPER • OPEN ACCESS

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To cite this article: S Ratnasabapathy *et al* 2022 *IOP Conf. Ser.: Earth Environ. Sci.* **1101** 062022

A case study of construction and demolition waste management process flow in mega infrastructure projects in Australia

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Abstract. The rapid growth of population and associated urbanization and economic development calls for increased demand for infrastructure development to meet ongoing and future demands. A better understanding of the waste management (WM) processes would help to manage large volumes of waste effectively at construction sites, maximise the value of resources and improve environmental and economic performances. This research aims to investigate the WM processes associated with different types of construction and demolition (C&D) waste generated by a mega infrastructure project through a case study approach, combining expert interviews and project-specific document reviews. The case studied project demonstrated high environmental and economic sustainability outcomes and exceeded the C&D WM targets, signifying more than 90% landfill diversion rates for both spoil and construction waste generated during the construction stage. As such, the infrastructure projects have a great potential to maximise the reuse of high-value waste through waste exchange across projects and gain economic and environmental benefits, while leading to paving a path to greener Australia in near future. The outcome of this case study is a WM process flow diagram (PFD) that maps out the WM processes, waste fates and associated waste flows involved with the diverse range of C&D waste throughout its life cycle. The PFD developed in this study serves as an operational tool to develop effective WM plans for construction projects of similar nature and thus helps to achieve higher landfill diversion rates. The outcome of this study can also contribute to the development of a generic WM PFD for the C&D waste stream.

1. Introduction

Waste generated from the construction and demolition (C&D) sector increasingly becomes a major issue from the perspective of economic, environmental and social sustainability. During the last decade, the construction industry in Australia contributed to the growth of C&D waste generation by 32% per capita [1], comparatively showing an emerging and different trend in waste generation from the other two core waste streams: Municipal Solid Waste (MSW) and Commercial & Industrial (C&I). Most of the growth in C&D waste generation in the past years has resulted from the unprecedented levels of residential and public infrastructure developments to accommodate the needs of the increased population associated with urbanisation and industrialisation, predominantly in the major cities of Australia [1]. At the same time, the construction of mega infrastructure projects such as roads, underground motorway interchanges with tunnels, railways, light rail networks and airports within highly urbanised environments faces several challenges [2] and creates detrimental impacts on the environment and social health in both short and long terms [3]. In particular, the high volume of waste and noise generated during the construction phase of these projects have a direct impact on the environment and human health while air pollution, reduced liveability of urban environments and the environmental impacts of materials used by the transport system have an indirect impact [4].

The future reputation of these types of projects, therefore, depends on how these projects are accountable for managing the waste effectively, thus not allowing the industry to move towards a resource-constrained economy. Rethinking and revising the relationship between resources and the economy and setting targets to achieve waste reduction and a high level of resource recovery becomes essential to thrive the industry to move towards the circular economy. According to Esmaeilian et al. [5], efforts from traditional waste management practices have failed to consider the complete material lifecycle, i.e. cradle-to-grave pattern of material usage. Yet, circular economy opportunities are emerging to create a waste value chain from the entire product lifecycle. A better understanding of WM processes involved in the life cycle of different types of waste generated from construction projects would lead to efficient waste and resource management in construction projects and it, in turn, will reduce waste footprint and provide more opportunities for circularity of waste within the economy.

Infrastructure projects generate a wide range of C&D waste due to their nature, involving widespread activities associated with demolition, bulk excavation, earthwork and construction and hence become the large waste generator among other projects [6]. However, existing studies in the infrastructure development projects mainly focus on environmental impacts that are related to the effects on groundwater, noise and vibration, pollution and geological impacts such as erosion during the construction [3]. There is a lack of exploration of WM processes and waste material flows associated with different types of C&D waste generated by different types of projects throughout the waste life cycle. A few studies have investigated the WM process during the construction stage. For instance, Shen et al. [7] examined the waste handling processes on-site through a case study approach and mapped out the most common processes at a high level, considering it as an alternative method for examining on-site WM. However, interim processes or WM pathways involved with the common categories of C&D were not addressed by past studies. This study focused on examining the waste management (WM) processes involved with different categories of waste generated by one of the mega transportation infrastructure projects in New South Wales (NSW), throughout the waste life cycle. The study also addresses the sustainable approaches implemented to achieve higher waste diversion targets set by the project.

2. Construction and demolition waste management process

According to the National Waste Report 2020 [1], the term ‘waste management’ is generally used to define the type of facility that receives and manages the waste (e.g. landfill, waste processing facility, compost facility, alternative waste treatment facility, etc.). WM processes are considered to be of two types: pathways and waste fates or end destinations. Pathways are the interim steps involved with the movement of waste materials from their generation phase to the end destination. They consist of the processes such as short-term storage, stockpiling, treatment, sorting, processing and export [1]. A process is defined as the transportation, transformation, or storage of materials (E.g. a processing facility transforming plastic into marketable commodities), while the waste collection is referred to as a man-made transport process. Waste fate denotes the type of actions that take place once the waste is generated and sometimes it may differ from ‘management’ types of waste. For instance, most waste types have the management as ‘landfill’, but specify the fate as ‘disposal’. Fates are categorised into disposal, recycling/remanufacturing, energy recovery and long-term storage. The whole processes involved with an integrated WM include generation, storage, collection, transportation, resource recovery, treatment and disposal [8].

An effective WM system is a multidisciplinary activity that involves several processes, information and stakeholders from the waste generation stage, causing problems related to organisation, control, logistics, planning, recycling and disposal [9, 10]. Since WM is linked with economic, environmental, institutional, social, and political aspects [11, 12], managing the high volume of C&D waste generated by infrastructure projects has become a challenging task for both industry and government. The major goals of WM, therefore, should focus on waste avoidance and minimisation through maximising the waste reuse and recycling and waste to energy options while simultaneously promoting the institutional, economic, environmental and social performance of C&D WM at project, industry and national levels [13]. In particular, infrastructure projects, which involve tunnelling and bulk excavations generate a significant volume of spoil and therefore systematic planning is essential to ensure that the spoil is managed effectively to comply with the legislative requirements [14].

3. Research Methodology

This study primarily adopted a case study approach, combining expert interviews and project-specific document reviews to collect the required data. In order to map the WM processes involved in a construction project, it is essential to identify and understand the WM processes and waste materials flow associated with each category of waste generated by that project, from the waste generation phase to the end destination phase. This requires capturing the processes, decisions, waste data, and stakeholders involved in each of the main processes of WM. The case study approach using interviews with industry experts has been considered a more appropriate approach to achieve this objective. The interviewees were selected using a purposive sampling method based on their experience and involvement with on-site and off-site WM of the project. Accordingly, three interviews: one from the construction organisation (to identify the on-site WM processes), one from waste collection and transportation service (to identify the processes related to waste collection and transportation to the recycling facility and/or landfill site), and one from WM and recycling services (to identify the off-site WM processes) were conducted. These interviews were semi-structured interviews with some guide questions accompanied by a theoretical C&D WM process flow diagram (PFD).

A PFD is a graphical representation of a system that demonstrates the primary processes and the flows between the processes involved in a system. PFDs are generally used to document a process, improve a process, or model a new process, the purpose of which varies with its use and content. Thus, functional process flow mapping techniques were used to develop the theoretical diagram and the diagram was developed through a comprehensive literature review. The theoretical C&D WM PFD was presented to the interviewees as the guide and the interviewees were requested to review and verify the project-specific WM processes involved in the studied infrastructure project. The collective output of the interviews and the data collected through the review of project-specific documents were used to refine and develop the PFD for the project. Processes that are specific to the project were considered in refining the diagram. The refined project-specific PFD developed went through a final review process by the same interviewees and their constructive feedback assisted to validate the diagram.

4. Case study: Infrastructure project

4.1. Profile of the project

The project is one of the major transportation infrastructures of the NSW government in Australia. It comprises the construction of around 24 km long tunnel combining a carriage place and ventilation tunnels, underground substation and permanent ventilation facilities, general surface work, rebuilding of bridges, roads and upgrading of the roads around where the tunnels come out and link with service network, pavement and drainage. The project value is around 7 billion Australian dollars with a construction period of 5 years and delivered by tier 1-construction companies through a joint venturing system, a collaborative project procurement system. It was an ongoing project during the conduct of the case study.

4.2. Overview of the Construction and Demolition Waste Management

A wide range of activities, which include demolition, site establishment, bulk excavation, tunnelling and cutting, and construction, involved in this project have generated several waste streams. Major categories of waste, their types, and the sources of each waste category generated by the project are summarised in Table 1. Waste classification guidelines established by the NSW Environment Protection Authority [15] have been followed in on-site waste segregation of project-specific waste. A general skip bin also was provided to store the construction waste into one bin in some parts of the sites, where limited space is available to place multiple bins, and the mixed waste is to be sorted off-site by the nominated WM contractor. Bins labelled with colour coding have been provided at all project site offices to guide on-site workers to sort the waste according to their types. Relevant guidelines and legislative and licensing requirements for segregation, reuse, storage, transportation and disposal of waste, which have been established by the Protection of the Environment Operations Act 1997 (POEO Act) have been considered in the assessment of all types of waste and development of Waste Management Plan (WMP).

Table 1. Categories of Waste and their Types Generated by the Infrastructure Project.

Waste Stream/Category	Source/Construction Activity	Types
Demolition waste (non-putrescible solid waste)	• Demolition • Site establishment	Concrete, bricks, tiles, timber (untreated and treated), scrap metal, plasterboard, carpets, electrical and plumbing fittings and furnishings (doors, windows), and Vegetation waste: trees, shrubs and ground cover
Virgin excavated natural material (VENM) or Excavated natural material (ENM) -Spoil	• Earthworks • Bulk excavation including tunnelling and cutting	VENM and ENM (excavated sandstone, soil and rock)
Hazardous or special waste (Asbestos)	• Demolition • Excavation	Waste contains hazardous materials such as asbestos-containing material (ACM), acid sulphate soils, contaminated spoil, heavy metals and other contaminated material
General construction waste (Recyclable construction waste)	• Surface work • General construction activities	Timber formwork, scrap metal, reinforcing steel, concrete (solids and washouts), asphalt, plasterboards, conduits & pipes, electrical cabling, and packaging materials (crates, pallets, cartons, plastics, metals and wrapping materials)
Liquid waste (LW)/Wastewater	• Stormwater, groundwater, tunnel water • Dust suppression • Tool washing and spill clean ups • Compounds and workshop operation • Operation and maintenance of construction vehicles and machinery	Stormwater/groundwater, tunnel water, liquid waste/wastewater from tool washing and cleaning processes, paints, adhesives, lubricants, waste fuels and oils, engine coolant, chemicals, grease, pesticides, etc.
General solid waste (recyclable/non-recyclable)	• Construction site offices	Paper, cardboard, plastic, glass and printer cartridges, domestic waste, etc.

However, WMP was prepared in consultation with Roads and Maritime Services (RMS). The WMP specifies the standard C&D waste mitigation and management measures and sustainability requirements that are essential to manage and control the potential impacts from waste generation and resource recovery during the construction of the project. The specified measures have been considered based on the principles of the waste and resource management hierarchy stipulated in the WARR Act 2001, NSW. Further, effective management of the C&D waste (minimisation, storage, handling, transportation, treatment, reuse, recycling and lawful disposal of waste) with the emphasis on protecting the environmental values through its life cycle was considered and defined as one of the preferred environmental performance outcomes in the environmental impact statement (EIS) prepared for the project.

The Environment and Sustainability Manager and Project Managers are responsible for the overall management of C&D waste generated during the construction across all the project sites. The manager who is responsible for approvals and environmental sustainability makes sure that the construction activities are carried out to fulfilling the general project requirements under the CoA and comply with the legislation and contractual obligations. The same manager deals with regulatory authorities like DPIE, EPA and RMS to facilitate the execution of the project from the environmental perspective. From the sustainability perspective, the same manager is accountable for achieving the contractual targets in WM-related sustainability. It is imperative to note that this project has established target rates and key performance indicators for the reuse/recycling of spoil generated by bulk excavation and tunnelling works and waste generated by C&D activities. The target rates were decided based on the type of waste to be generated as this project falls under the infrastructure category. The rates include 80% for reuse/recycling of both reusable excavated materials (i.e. spoil excluding contaminated materials such as Asbestos contaminated materials) and C&D waste (inert and non-hazardous materials). The waste recovery targets were set by the joint ventures in collaboration with the project's client and not regulated by DPIE. Moreover, the project targets to achieve the Infrastructure Sustainability (IS) rating developed by the Infrastructure Sustainability Council of Australia (ISCA). Waste is one of the major themes included in IS rating scheme which consistently evaluates sustainability across the design, construction and operation of infrastructure.

4.3. Mapping the Construction and Demolition Waste Management Processes

As mentioned in section 4.2, the investigation of the case study revealed that this project has adopted WM strategies in accordance with the principles of the waste hierarchy and legal requirements stipulated for the project, to achieve efficient use of resources and avoid any significant risk to the environment and social health. Being an infrastructure project, involving demolition, bulk excavation and tunnelling and construction works, the project has demonstrated various on-site and off-site WM practices to manage different types of C&D waste generated. The C&D WM PFD captures those on-site and off-site WM processes and their fates associated with major categories of common and project-specific waste from the waste generation phase to the destination. Figure 1 portrays the C&D WM PFD specifically developed for the infrastructure project studied. The diagram incorporates the on-site waste handling and management processes, off-site WM processes and waste flows associated with each major category of waste. These processes are grouped under four main processes namely: (1) waste collection & transportation, (2) waste reuse off-site, (3) waste recycling/reprocessing, and (4) waste treatment and disposal. It also addresses the legal requirements (highly recommended by NSW EPA) related to each process that are to be considered in managing waste on-site and off-site. The following sub-sections discuss the processes associated with each main function in detail.

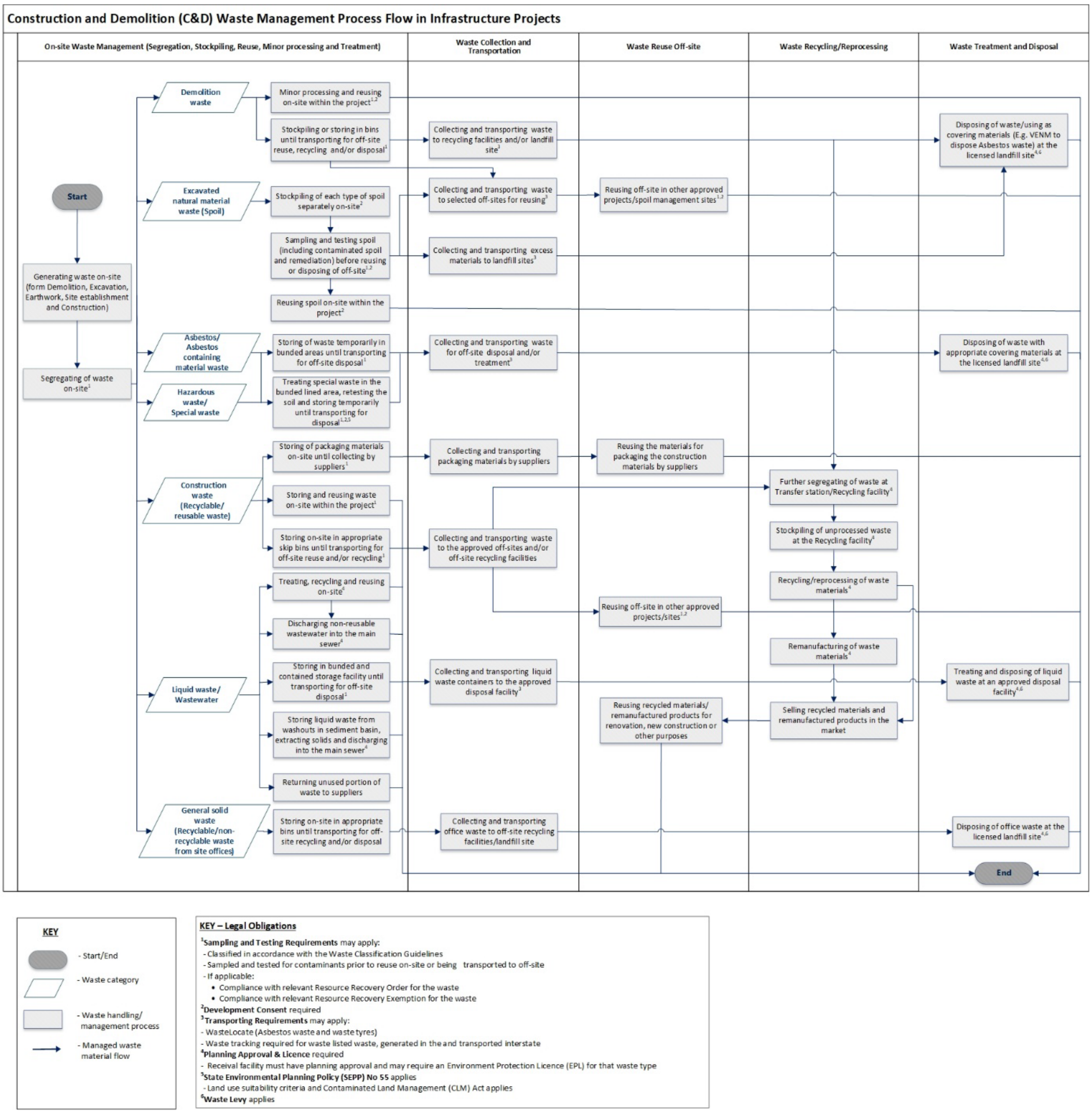

Figure 1. Construction and demolition (C&D) waste management process flow diagram for the infrastructure project

4.3.1. On-site waste handling and management

With regards to the on-site WM, the generation of waste from demolition, excavation and construction is the first process that occurs on-site followed by the initial segregation of waste by on-site workers. The site delegate foreman is responsible to make sure that all the legal requirements are followed in accordance with the EPA waste classification guidelines for on-site waste separation at each location. The follow-up processes of waste generation vary with the type of waste generated. However, they comprise main processes; particularly waste sorting, stockpiling/storing in dedicated bins, minor processing, reusing, minor treatment and collection and transportation of waste by a waste contractor for off-site reuse, recycling and disposal as shown in Figure 1. Processes related to demolition waste involve almost similar processes. Waste such as concrete, asphalt, blocks/brick and gravel is stockpiled/stored in skip bins, crushed and reused on-site as backfill, road base and on access tracks/road maintenance. Vegetation waste is stockpiled and reused on-site as mulch for landscaping as well as off-site in accordance with mulch exemption and unused waste is disposed of at a licensed facility. Scrap metals are sorted and stored in delegated bins and transported for off-site recycling.

Hazardous waste such as asbestos (and asbestos-contained materials) is temporarily stored on-site in a bunded facility until transported for off-site disposal. Special waste such as acid sulfate soil is subject to an on-site treatment process before disposing off-site at a licensed landfill site. It involves the formation of bunded lined treatment area where materials are brought out from the ground and mixed with lime. The lime is utilised to soak up the acid as outlined in the special waste treatment management plan, which has been developed in consultation with an independent soil scientist. The treated soil is retested to make sure that it meets the disposal requirements of the acid sulfate soil in accordance with the waste classification guidelines.

Excavated materials, i.e. spoil (VENM or ENM) are categorised appropriately in accordance with the guidelines and exemption requirements and stockpiled on-site separately based on their type for reusing. Reuse is the process of using the waste materials again (the reallocation of materials) in their original state for the same purpose or a different purpose without reprocessing or remanufacturing [8, 16]. Following sampling and testing of spoil, uncontaminated spoil has been reused on-site (within the project) for the backfill of retaining walls, infill of temporary access shafts, declines, landscaping and site rehabilitation purposes as well as in rail yards for contamination remediation. Excess materials are lawfully disposed of off-site at a licensed site by licensed contractors. Contaminated materials are segregated from uncontaminated material and stockpiled/stored on-site in suitable hardstand or lined areas to prevent cross-contamination. Required sampling and testing are carried out for contaminants before reusing and transporting to off-site for reuse/disposal to ensure that it meets the reuse/disposal requirements.

Except for liquid waste (LW), most of the construction waste is subject to similar processes associated with demolition waste and on-site treatment is excluded for construction waste. Waste materials such as concrete and asphalt are stockpiled and reused on-site followed by the process of crushing. These waste types are also stored in appropriate bins and reused/recycled off-site in accordance with reclaimed asphalt. Timber formwork is reused on-site and stored in general skip bins for off-site separation and recycling as well. Scrap metal, steel reinforcement, plastics, wood, cardboard, conduits and pipes, and electrical cabling are separated and stored on-site in skip bins separately allocated for each type and also stored in general skip bins for off-site separation and recycling at a licensed recycling facility. Packaging materials including wood, plastics, and cardboard are returned to suppliers for reuse as much as feasible. Materials containing asbestos are stored in bunded and appropriately contained facilities, sampled and tested for contaminants before being reused on-site or transported off-site.

Construction projects generate a considerable amount of LW from several trades during the construction stage. The main sources of LW identified in this project include tunnel construction, dust suppression, washouts, cleaning and cooling of vehicles and machinery and stormwater runoff from construction ancillary facilities. The processes followed to manage LW on-site are specified in the Soil and Surface Water Management Sub-plan (SSWMP). Around 10-15% of LW including wastewater, stormwater, groundwater and tunnel inflow water generated during construction are treated and reused on-site and the unused portions are discharged to comply with the environment protection licence (EPL). Liquid waste from washouts is stored in the sediment basin and discharged into the sewer as outlined in the soil and surface water management sub-plan. Approval is required for discharging LW and it needs to comply with the EPL. The unused portion of LW such as paints, spill clean-up, pesticides, oil, fuel, grease and other chemicals including the empty containers are returned to suppliers as much as possible. At the site, the liquids are stored in appropriate containers in a bunded facility and transported for disposal at a facility that lawfully accepts them. General solid waste (Non-putrescible) generated by site offices during construction is sorted and stored in bins and transported for off-site recycling based on their types and putrescible waste (food & domestic waste) is disposed of at a licensed landfill facility.

4.3.2. Waste collection and transportation
After the C&D waste is sorted and stockpiled/stored in dedicated skip bins/liquid waste containers, those are collected and transported for off-site reuse, recycling, treatment and disposal by the commissioned waste contractor. The transporters from waste recycling facilities and/or disposal contractors (or the haulage company) should hold the licence and permission to transport the waste type that is to be transported from on-site. The transporter is responsible to know the type of waste and the permission requirements of the location, to which the waste is transported for processing and/or disposal [17] and fulfilling the compliance required for transporting the waste, such as waste tracking applies for certain categories of waste [18]. The waste generator, the owner of the waste, is also accountable for checking the license of the recycling facility and landfill site to confirm the receiver sites can lawfully accept the waste before the waste is removed from on-site. Every spoils haulage vehicle is attached with Global Positioning System (GPS) based tracking system, essentially a mobile phone type of device to check and confirm that the waste is transported and tipped at the approved destination in real-time. Such type of system facilitates the automation of waste data reporting by generating real-time electronic disposal dockets. In particular, it minimises the risk of forgeries of dockets and illegal dumping of waste.

4.3.3. Waste reuse off-site
Reusing spoil off-sites for earthworks and engineering fill that complies with spoil exemption requirements was found to be one of the main processes involved in WM. Clean spoil, in particular, sandstone has been effectively reused in other approved projects/land outside the project. Further, certain types of C&D waste are transported and reused off-site wherever possible, while complying with exemptions for reusing each waste type. According to Ratnasabapathy et al. [19], waste trading is a '*process of buying and selling (or exchanging) reusable raw inert construction waste, recycled materials, products that contain recycled contents and energy recovered from C&D waste and/or services between people, organizations, interstates, or countries'*. As such, reuse of waste off-site can be considered as exchanging/trading of waste across the projects. The waste materials that have been recycled and remanufactured by the specialised facilities are also reused in new construction and maintenance projects. Returning packing materials/empty containers to suppliers was found to be another form of reusing waste materials in the C&D sector.

4.3.4. Waste recycling/reprocessing
Recycling of waste at the recycling facility involves several processes such as collection, further sorting, stockpiling of unprocessed waste, recycling and conversion of waste materials into raw materials that can be used in the manufacturing of new products [1]. Recycling also involves the reprocessing of a product into new materials. While remanufacturing involves the processes of recovering, disassembling, repairing and sanitizing components for resale as a "new product" to comply with required performance, quality and specifications. C&D waste that is commonly subject to recycling/reprocessing included

sandstone, brick, asphalt, scrap metal, steel reinforcing, plastics, wood, cardboard, conduits and pipes, electrical cabling, etc.

4.3.5. Waste treatment and disposal

Waste disposal is the last and least preferred process of WM. Any type of C&D waste and excess spoil that cannot be reused either on-site/off-site, recycled or reprocessed are disposed of at a landfill site or spoil management sites, meeting the legal requirements based on their classification. C&D waste such as asbestos including asbestos-contaminated materials, special waste, and LW are subject to required treatment before disposal and inert non-hazardous C&D waste (such as concrete, bricks, timber, steel, etc.), and general solid waste from the site offices are disposed of lawfully. The landfill operators are required to cover the asbestos waste with VENM unless they have approval from the EPA to use an alternative cover [20]. The landfills which receive and accept the waste for disposal should have planning approval and may require an EPL for the waste type that is to be disposed of/treated at a particular landfill site/treatment facility [18].

4.4. Sustainable practices implemented in waste management

The case study found that the infrastructure project team has committed to the efficient management of C&D waste and they highly focused on resource recovery through reuse and recycling from its commencement. The project has achieved the set targets for landfill diversion for C&D waste and exceeded both construction waste and spoil diversion targets. The spoil diversion target has been surpassed by 97% and it reflects the suboptimal performance against IS rating (40%- 60%). The management of spoil generated by tunnelling work in highly urbanised environments is one of the major challenges in most road and rail infrastructure projects in Australia [2]. However, the appointment of a special team, comprising of a Project manager and Engineers (some of them are experts in contaminated land management) on a full-time basis, has led to achieving a higher rate of landfill diversion of spoil generated in this project. The team considered several factors, such as the logistics of spoil movement including impacts on traffic, approval for off-site reuse, and economic and environmental benefits in determining the suitable options for spoil management. The spoil (uncontaminated spoil combining VENM and ENM) has been effectively reused on-site (within the project) as well as at the various off-sites that have received the approval for reuse of spoil for civil works. In particular, the sandstone extracted from tunnelling sites has been reused in two mega infrastructure projects, offering environmental and economic benefits while helping to progress both projects efficiently [21].

Besides, annual waste audits were carried out for implementing effective spoil management strategies and those audits were used as a benchmark to control spoil waste. It has been estimated that around 4.5 million tonnes of recycled aggregate sandstone will be used over the lifespan of the project. Reusing waste generated by a project in another project/site through a trading process enables cost-saving for both waste generators and consumers (the receiver site) as it reduces the cost of raw materials, transport, and disposal [19]. The target rate for construction waste exceeded 90% through the reuse of waste on-site as well as off-site to fit the purpose as much as practicable and recycling off-site. The interviewee from the construction organisation stated that they are also considering the use of recycled materials such as crushed glass waste and recycled polypropylene fibre in concrete. As such, the construction organisations have committed to ensure that the project meets the infrastructure sustainability outcomes at a high level while accommodating the requirements of urban society and enhancing the conditions of the environment and economy. Ultimately, this project has established a leading example for delivering ecological infrastructure outcomes.

5. Conclusions

This case study has examined the WM process flow of the large road infrastructure project in Australia and provided insight into the various processes involved in the C&D WM. The WM processes and the waste materials flow associated with the common and specific categories of waste generated by the project have been investigated and mapped out using simple PFD techniques. It is important to note that this study has considered LW generated during construction as one of the major categories of waste while a lack of studies found to address the management processes associated with LW in construction projects [22]. The WM PFD not only provides a better understanding of WM processes and waste fates but also highlights the sustainable WM practices followed to achieve higher landfill diversion rates in the studied project. Mapping the WM processes together with the legal requirements associated with each process involved both on-site and off-site is an effective approach to compare the WM practices associated with different types of C&D waste generated by construction projects. It would help to identify both effective and ineffective WM practices used and make informed decisions in implementing efficient and sustainable practices. The diagram serves as an operational tool to assist the development of effective WMP for other projects of similar nature, thus helping to attain higher rates for landfill diversion and minimise environmental impact. The outcome of this case study also led to the development of a generic WM PFD for the C&D stream as a follow-up study.

The investigation of the case study in the studied infrastructure project also demonstrated that the project has achieved high environmental and economic sustainability outcomes and targets in terms of C&D WM, demonstrating more than 90% landfill diversion rates for both spoil and construction waste generated during the construction stage. The outcome also proves that infrastructure projects have a very high potential to maximise re-use of high-value waste, mostly spoil, concrete, asphalt and timber through waste exchange or trading across the projects, helping those projects to progress well and gain economic and environmental benefits. Achieving more than 90% landfill diversion rate in the C&D waste stream would drive a shift towards a circular construction industry and produce a more sustainable built environment. A key part of Victoria's recycling plan is to divert more waste from landfills based on the Recycled first policy which enables the optimisation of the use of Victorian recycled and reused materials that meet existing standards and specifications in transport infrastructure projects [23]. Implementing such plans to achieve a higher landfill diversion rate in the C&D waste stream, consistently across the other states and territories would drive a major shift towards a circular economy, providing direct economic benefits and paving a path to greener Australia in the near future.

Acknowledgement

The authors would also like to thank the industry experts who participated in the case study interviews and validation of the process flow diagram.

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