# CBD cable pit refurbishments

## CP BUS 4.06

## Regulatory proposal 2021–2026

CitiPower

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# Contents

# 1 Overview

We own and manage a large population of cable pits in the Melbourne central business district (**CBD**). These cable pits allow us to access network and communications cables for installation and repair works without the need to excavate roads and footpaths.

The condition of our cable pit population has been deteriorating, and recent inspections have revealed that up to 20% of pits inspected require remediation. The condition of these pits is particularly impacted by the effects of corrosion and increased traffic density (relative to their initial design standards, noting some of these pits were installed in the 1930s).

Previously, we have managed cable pit assets via a reactive approach, whereby remediation work was driven by the immediate need to access a pit to carry out planned works and other operational events. Since 2018, we have adopted a proactive management approach to ensure the safety of our employees and the public, and maintain the reliability of supply in the CBD.

For the 2021–2026 regulatory period, we propose to target the remediation of pits installed in or adjacent to roadways. These pits are subject to high and variable dynamic loadings, which puts greater stress on these structures. The consequence of a roof or cover failure in one of these pits could be catastrophic.

The proposed works continue our proactive approach to the growing risks carried by these assets. Our forecast is supported by our risk-monetisation analysis.[1]

A summary of the forecast capital investment required in the 2021–2026 regulatory period is outlined in table 1.

**Table 1 Expenditure forecasts for preferred option ($ million, 2021)**

| Expenditure forecast | 2021/22 | 2022/23 | 2023/24 | 202/254 | 2025/26 | Total |
|---|---|---|---|---|---|---|
| Capital expenditure | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 14.1 |

Source: CitiPower

1 CP MOD 4.05 - CBD cable pits - Jan2020 - Public

# 2 Background

We own and manages approximately 1,129 cable pits in the Melbourne CBD.[2] These cable pits form part of the pit and conduit system, which has been progressively installed since the 1930s.

## 2.1 Cable pit function

Our cable pit system provides easy access to our high voltage (**HV**) and low voltage (**LV**) network, as well as communications cables. The size and shape of the pits vary, but they are typically the size of a small room with access provided at surface level via ladders from one or more 'Gatic' covers (as shown in figure 1).[3]

Figure 1 Example of roadway pit with Gatic cover lid


Source: CitiPower

The ducts between pits allow us to install new cables and replace faulty cables, significantly reducing the need to excavate roads and footpaths in the CBD when conducting installation and repair work. This occurs by opening adjacent pits and pulling cables though the conduits connecting the pits. Cable jointing is also carried out in these pits.

An example of the internal arrangement of a cable pit in shown in figure 2. In this example, walls are made of bricks and mortar with steel beams supporting the roof. The HV and LV cables enter the pit through conduits in the wall joints between cable sections.

2 Cable pits refer to large accessible cable pits and do not include low voltage service pits.

Figure 2 Typical cable pit internal arrangement

Source: CitiPower

## 2.2 Revising our asset management approach

Until recently, our approach to managing cable pits as an asset class was solely reactive in nature, with remedial works being initiated when issues were identified during normal operations. For example, works were driven by the immediate need to access a pit to carry out planned works, such as augmentation or customer projects, or cable repairs following a fault. Remedial works may involve introducing temporary supports until planned repair or replacement can be undertaken.

Our reactive approach to managing cable pits had many disadvantages (to our employees and the public), including:

- increased the immediate safety risks to the public and workers exposed to these defects as remediation is carried out
- was not optimised to address safety issues, as inspections were dictated by existing works, and not targeted at a population of pits which carry a higher risk of defect (e.g. roadside pits)
- did not allow us to improve our knowledge of the condition of our pit population and plan interventions; rather, we would only inspect and accumulate knowledge of pits on a gradual basis as planned works are carried out
- may delay and increase the costs of planned projects while any immediate remediation is undertaken.

## 2.3 Our new proactive asset management approach

In 2018, we revised our asset management approach to pit defects following heightened concerns expressed by civil engineers. In particular, we determined that a reactive approach was creating an unacceptable safety risk to employees, the public and our assets after a number of pits were found to be compromised during augmentation works and customer projects.

Accordingly, we begun implementing a more structured and proactive inspection and remediation regime from 2018. Moving to a proactive approach allows us to inspect more pits each year and to improve our knowledge of the conditions of our pit population. This in turn will allow us to optimise planned interventions to correct defects before risks become unacceptable to employees and the public, as well as to reduce costs as fewer incidences of urgent repair or replacement are required.

### 2.3.1 Our inspection regime

The condition of cable pits cannot be assessed or estimated from above-ground inspections. Instead, the only way to ascertain the observed and measured condition of a pit's structural components is for appropriately qualified and experienced personnel to open the pit and perform a detailed inspection from the inside.

In 2019, we partnered with Swinburne University of Technology (**Swinburne**) to pioneer a new approach to inspect and manage cable pits. Under the first stage of works, civil engineers from Swinburne developed a standardised methodology to assess pit conditions and their ability to meet dynamic loads. Under the second and third stages, we will enhance our understanding of how pits perform under various conditions so we can efficiently carry out ongoing maintenance and remediation activities.

The standardised methodology developed by Swinburne ensures consistency of the data we gather in the field when carrying out inspections so that we can effectively compare asset condition between different structures. This data is used with condition based risk management (**CBRM**) principles (discussed in section 5) to define the most efficient ongoing inspection and maintenance strategy.

### 2.3.2 Assessing existing structural load capacities

The construction of our pit population varies from walls made of bricks and mortar in older examples, to modern pre-cast concrete. In today's environment, however, the design specifications that pits were initially built to are no longer sufficient—for example:

- in the 1950s, maximum design limits were generally based on a 15-tonne tractor
- between 1950 and 1976, the design standard was based on a 33 tonne semi-trailer
- between 1976 and 2000, designs were based on 44 tonne semi-trailer
- since 2000, designs were based on the SM1600 standard, which reflects a 160-tonne load.

As part of our asset management approach, therefore, we also assess the structural load capacity of the masonry walls and suspended roofs in the pit, taking account of the specific pit size and geometry. Being below ground level, pits must safely support the static load of the ground above it, as well as the dynamic loads applied by traffic and works above and in the pit.

The capacity of the walls—in terms of out-of-plane bending, in-plane shear and axial load capacity—are determined based on the classification of the pit and the effect of the service penetrations in the form of the cable ducts in reducing these capacities. These values are compared against those in AS5100-2018 to determine what, if any, strengthening may be required.[4] Similarly, the capacity of roof slabs is determined based on the dimensional classifications and compared against the maximum wheel loadings contained in AS5100-2018.

[4] AS5100-2018 represents international best practice for the design, rehabilitation and assessment of the structural capacity of older bridges for current traffic loads.

A non-destructive test method is being developed to allow the use of Schmidt Hammer test to determine the strength of masonry walls. This will involve testing at least 20 masonry cores from existing pits and correlation of the Schmidt Hammer Results with the test results. This method will allow a direct assessment of the wall strength on site using non-destructive means.

After determining the potential deficiencies between the load capacity of different pit types and the requirements of AS5100-2018 we will develop best practice repair protocols and methodologies to strengthen walls to counter out of plane bending and in plane shear weaknesses. Remediation includes detailed investigation by a structural expert and replacement of corroded items and structures as advised.

# 3 Identified need

The identified need is to maintain a safe and reliable supply of electricity to customers in our CBD supply area as our existing assets deteriorate over time.

## 3.1 Increasing risk to cable pits

Since 2018, our inspections of cable pits have found that 20% of our sites require remedial repair or replacement works due to corrosion. The remediation work typically includes the urgent installation of temporary supports to maintain the integrity of the pit roof until the repair of replacement works can be undertaken.

The deteriorating condition of our cable pit population is largely due to the impacts of corrosion. Corrosion in cable pits occurs due to moisture seeping in through the pit walls and openings, as well as via the banks of conduits. This results in a weakening of the supporting steel structures over time, spalling of the reinforced concrete, and cracking in the bricks and mortar (which allows further seepage of water into the pit).

An example of the impacts of corrosion on our cable pit population is shown in figure 3.

Figure 3 Damage uncovered in CBD cable pits

**Corroded supporting steelwork inside a CBD cable pit** | **Corroded reinforcing steel and spalled concrete** | **Cracks in masonry wall**

Source: CitiPower

The increased traffic density and larger size and mass of individual vehicles traversing over our roadway pits is further increasing the risk associated with our ageing pit population. Of our total cable pit population, 480 pits are known to be on or adjacent to roads. There are an additional 264 pits whose precise location is not known (given the timeframe over which these assets were installed and corresponding record keeping practices). If we assume these pits of unknown location are in a similar proportion to those locations that are known, then a further 146 pits may also be located in roadways, totalling 626 roadside pits.

# 4 Options assessment

We have considered two options to address the identified need—continuing our proactive program for cable pit management, or reverting to a reactive approach. Our assessment of these options is supported by our risk-monetisation, as set out in section 5.

## 4.1 Continue proactive approach

Our preferred option is to continue our existing asset management practice of planned inspections from which a prioritised replacement of defective pit lids, cover supports, and structural components will be identified. This asset management approach commenced in 2018.

This approach will allow us to prioritise the remediation of the highest risk pits (i.e. pits located in or adjacent to the roadside). The investment required for this option over the 2021–2026 regulatory period is set out in table 2. These volumes and costs are based on the inspection and remediation data currently available.

Table 2 Proactive approach: total volumes and costs over the 2021–2026 regulatory period ($ million, 2021)

| Description | Total volume | Total cost |
|---|---|---|
| Continue with a programme of planned inspections from which a prioritised replacement of defective pit lids, cover supports, and structural components will be identified | 45 | 14.1 |

Source: CitiPower

As demonstrated in section 5, the efficient timing of this option is determined based on a comparison of the annualised costs of the proactive program against the risk-costs of a reactive approach.

## 4.2 Revert to reactive approach

By reverting to a purely reactive approach to the repair, refurbishment and replacement of cable pits, we will identify cable pits in an unacceptable condition during the course of augmentation works, cable repairs and the provision of new supplies. This will require us to install temporary supports followed by a planned repair, refurbishment or replacement.

This approach will not result in prioritising and remedying the highest risk roadside cable pits first. In addition to carrying a higher risk, reactive works are almost always more expensive than planned interventions.

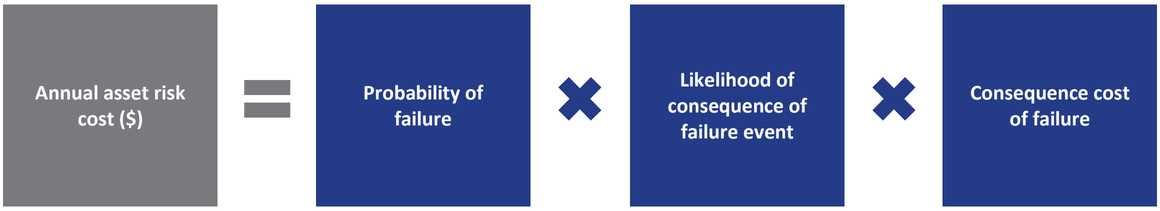
Based on the average cost of pit works conducted in 2017 and 2018, a reactive approach would require total capital expenditure over the 2021–2026 regulatory period of approximately $2.9 million.

# 5 Asset risk monetisation

This section explains our risk monetisation process and how it has been used to inform our CBD pit program.

We monetise risk when assessing investment decisions by determining the annual asset risk cost (as shown in figure 4). This approach is applied to all identified failure modes for an asset, and the sum of the annual asset risk cost for all of failure modes is compared to the annualised cost of the preferred option to determine the economic timing for any intervention. This approach is consistent with the AER's recent asset replacement guidance practice note.[5]

Figure 4 Calculation of annual asset-risk cost




Source: Powercor

Our approach to risk monetisation employs CBRM to provide a robust methodology for the preparation and application of the required input information (i.e. the probability of failure, and the likelihood and consequence cost of failure).[6] CBRM enables us to use current asset information, engineering knowledge and practical experience to predict future asset condition, performance and risk for our assets. It is a comprehensive management methodology.

## 5.1 Probability of failure

The probability of failure is determined by assessing the current condition of cable pits which have been inspected, and how they will continue to degrade over time. For our cable pit population, the probability of failure has been determined for the failure modes set out in table 3.

5 CP ATT099: AER, *Industry practice application note: asset replacement planning*, January 2019.

6 The CBRM is a proprietary model developed by EA Technologies. The model is an ageing algorithm that takes into account a range of inputs to produce a health index for each asset in a range from zero to 10 (where zero is a new asset and 10 represents end of life). The health index provides a means of comparing similar assets in terms of their calculated probability of failure.

Table 3 Failure mode definitions for cable pits

| Failure mode | Description |
|---|---|
| Pit collapse due to vehicle | Traffic loading causes roof support to fail, with the surface subsiding into the void and damaging assets within the pit with consequent loss of supplies |
| Pit collapse due to pedestrian | Pedestrian loading causes roof support to fail, with the surface subsiding into the void and damaging assets within the pit with consequent loss of supplies |
| Internal section failure: pulling eyes | Pulling eye fails under tension and part of wall is damaged |
| Internal section failure: ladder supports | Ladder supports fail and ladder falls in the access shaft |

Source: CitiPower

From our experiences, we estimated that up to 5% of our roadway pits are in a hazardous condition (i.e. they have a health index above 7.0), such that they are at end of life and without remediation, one of these pits would fail within the next 10 years. This equates to 24 cable pits, implying a failure rate for these hazard-rated pits of 0.4%.

Taking this failure rate and applying it across the population of pits located in or adjacent to roadways suggests an average failure rate of 0.009% (for any given pit in the total population of roadside pits). Applying this failure rate to the whole population and calculating a probability of failure formula yields a 9.15% probability that a single roadside pit will fail due to dynamic loading from traffic. Hence, despite the probability of failure of any one specific pit being very low (i.e. around one in ten thousand), the probability of a failure of any of the pit population is much higher (just less than one in ten).

It is expected that the potential for failure due to a pedestrian is significantly lower than for dynamic loading due to a vehicle. Specifically, it has been assumed that the failure rate for a hazardous cable pit due to pedestrian loading is 10% of that for a vehicle loading. Applying this failure rate to the whole population (as pedestrians could walk on both those in the footpath and those in the roadway) yields a probability of failure of 0.96%.

## 5.2 Consequences of failure

Our risk monetisation approach identifies three consequence categories that capture the potential impact on electricity customers of asset failures relating to cable pits. Table 4 shows these risk categories and the associated consequences, each of which can be quantified in dollar terms.

Table 4 Consequence of failure categories and inputs

| Consequence category | Consequence inputs |
|---|---|
| Network performance | • Unserved energy |
| Safety | • Minor injuries<br>• Serious injuries<br>• Fatality |
| Financial | • Repair and replacement costs |

Source: CitiPower

The calculation of the consequence of failure in CBRM uses the same failure modes as the probability of failure. For each of these consequence categories, any actual consequences of failure are considered and used to produce a reference cost of failure, which represents the ‘typical’ impact of a failure based on historical data.

Each of the consequence categories are discussed in further detail below.

### 5.2.1 Network performance: consequence cost and likelihood

The collapse of a pit roof into the cable pit (due to failure modes associated with traffic or pedestrians, with the results being the same) could be expected to damage the cables within the pit. This would affect the supply of electricity to the CBD, and recognises that cables within a pit may also form part of the interconnection options which would otherwise facilitate restoration of supplies.

There are several cables in each pit and the typical demand on a CBD circuit is in the region of 2–3MW. Our cost estimates, therefore, are based on four circuits being affected by the collapse of the pit, and that each supplies 2.5MW (i.e. 10MW in total would be interrupted). If the supplies are restored after around an hour, then based on the existing value of customer reliability (**VCR**) applicable to the CBD, then approximately $0.5 million of societal costs are attributed to the failure.

For cable pit failure modes where structural damage occurs, the network performance consequence is assumed to have a 100% likelihood. Even if the damage was not sufficient to cause protection equipment to operate, it would be necessary to shutdown the circuits for the safety of ours and emergency services staff attending the incident.

### 5.2.2 Safety: consequence cost and likelihood

The safety consequence of failure represents the quantification of the societal value of preventing an accident, serious injury or fatality. The value of fatality is based on the value of a statistical life (**VSL**) and a disproportionality factor of three.

The failure and collapse of a pit roof present potentially dangerous situations for anyone in the vicinity at the time of the collapse:

- if the collapse occurs when a vehicle is above the pit, there is a danger the vehicle and its occupants will fall into the hole created as the surface subsides into the collapsed pit
- if the collapse occurs under the weight of pedestrians, there would likely be several pedestrians on the surface of the pit meaning that there would be a potential for several fatalities
- cable pits are equipped with pulling eyes embedded in the walls to allow cables to be pulled into the ducts, and failure of these eyes during pulling would present a safety hazard which may result in injury
- a failure of the ladder or ladder supports could result in injury for anyone accessing the pit ladders.

The likelihood of safety consequences related to the collapse of a pit roof and the subsidence of the ground into the void together with vehicles or people on top of the roof has been assessed as 20%. The likelihood of injury for either a pulling eye failure or a ladder failure have been assessed at 50% and 80% respectively.

### 5.2.3 Financial: consequence cost and likelihood

The financial consequences of failure represent the average financial cost we will incur when a failure occurs. The financial costs include the capital expenditure of repair or replacement of the cable pit post-failure, and an assessment of the societal costs of damage to telecommunications cables and the interruption of these services within part of the CBD. The operating expenditure consequences arise from the costs associated with supply restoration and repairs.

Based on the defined failure modes, the likelihood of these costs being incurred is 100%.

### 5.2.4 Summary of consequence costs and likelihoods

A summary of the consequence of failure for each cable pit failure mode is set out below. Further detail is provided in the attached CBD cable pit risk monetisation model.[7]

Table 5 Pit collapse due to vehicle or pedestrian: consequence of failure ($ million, 2021)

| Description | Total risk value | Likelihood of consequence | Cost of consequence |
|---|---|---|---|
| Expected average unserved energy | 0.50 | 100% | 0.50 |
| Safety consequence | 14.28 | 20% | 2.86 |
| Pit repair costs | 0.50 | 100% | 0.50 |
| Electrical asset repair costs | 0.40 | 100% | 0.40 |
| Damage to telecommunications assets | 0.50 | 20% | 0.10 |

Source: CitiPower

Table 6 Internal section failure (pulling eyes): consequence of failure ($ million, 2021)

| Description | Total risk value | Likelihood of consequence | Cost of consequence |
|---|---|---|---|
| Safety consequence | 0.50 | 50% | 0.25 |
| Pit repair costs | 0.05 | 100% | 0.05 |

Source: CitiPower

Table 7 Internal section failure (ladder supports): consequence of failure ($ million, 2021)

| Description | Total risk value | Likelihood of consequence | Cost of consequence |
|---|---|---|---|
| Safety consequence | 0.50 | 80% | 0.40 |
| Pit repair costs | 0.05 | 100% | 0.05 |

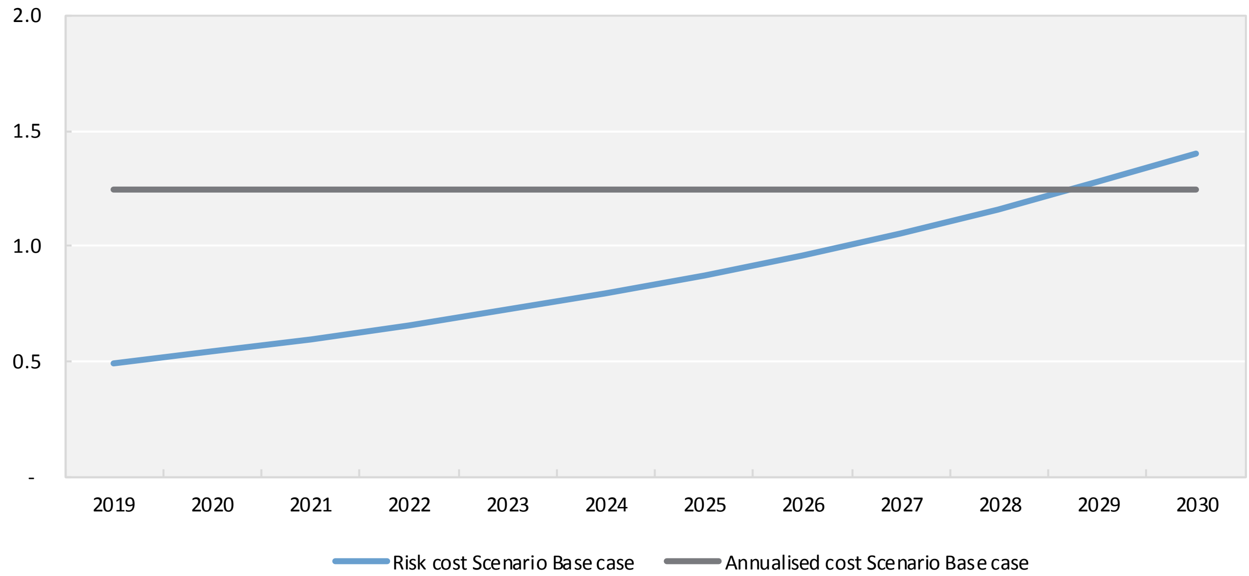
Source: CitiPower

## 5.3 Optimal timing of asset replacement

The optimal timing of asset replacement is based on a comparison of the asset risk and the annualised cost of the preferred option. Figure 5 shows this comparison for the base case scenario, which reflects our central input assumptions.

[7] CP MOD 4.05 - CBD cable pits - Jan2020 - Public

Figure 5 CBD cable pits: comparison of asset risk and annualised cost for base case ($ million, 2021)




Source: CitiPower

Under the base case scenario, the annual asset risk cost is higher than the annualised replacement cost from 2029. However, this is a long-term program of works which cannot be completed in a single year, or even within the next regulatory period (we estimate this program will take around 10 years). Therefore, we are ramping up works from 2019, ahead of the optimum time, to ensure we efficiently manage risk as the assets degrade further.

The results of the sensitivity analysis for four other scenarios (as detailed in our risk monetisation model) are shown in table 8.

Table 8 CBD cable pits: summary of sensitivity analysis

| Scenario | Optimum timing |
|---|---|
| Base case | 2029 |
| Scenario A | 2031 |
| Scenario B | 2030 |
| Scenario C | 2029 |
| Scenario D | 2027 |

Source: CitiPower

# 6 Recommendation

Without action, our cable pit population poses risks to employees, the public and network assets that will only increase with time due to extensive corrosion. Failure of these pits could result in the collapse of the pit roof or pit covers at the surface opening.

The preferred option, as set out in section 4, is to continue with a planned and targeted programme of cable pit inspections that prioritises the remediation of the highest risk pits in a way that minimises delays and associated costs to planned works and other operational events.

The forecast capital expenditure requirements for the 2021–2026 regulatory period is outlined in table 9.

Table 9 Expenditure forecasts for preferred option ($ million, 2021)

| Expenditure forecast | 2021/22 | 2022/23 | 2023/24 | 202/254 | 2025/26 | Total |
|---|---|---|---|---|---|---|
| Total capital expenditure | 2.8 | 2.8 | 2.8 | 2.8 | 2.8 | 14.1 |

Source: CitiPower
Note: Total does not reconcile due to rounding.