Navigating Capital Upgrades from an Operational Perspective

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Abstract
Delivering capital upgrades at wastewater treatment facilities, whilst maintaining production and regulatory compliance, poses a range of operational challenges. In response to these challenges an 'operator-centric' approach is required. One which emphasises the critical role of operations personnel in Construction Hazard Assessment Implication Review (CHAIR) and Hazard and Operability (HAZOP) workshops.

This paper provides some practical insights from frontline operational teams on identifying potential hazards and operability issues often overlooked in theoretical engineering designs. Effective participation from operators in detailed design reviews, bridges the gap between engineering concepts and practical implementation. Thus enabling a focus on managing active construction sites, while simultaneously ensuring the uninterrupted performance of existing infrastructure, to meet stringent regulatory requirements.

Technical documentation, such as operation and maintenance manuals and drawings, often contain unfamiliar terminology and concepts outside basic daily operational experience. However, there are methodologies for operations staff to interpret these documents, provide feedback to design teams, and translate technical specifications into practical operational procedures, which are presented in this paper.

Finally, there must be consideration made in capital delivery projects for comprehensive staff training during transition phases, as well as communication frameworks that facilitate productive collaboration between operations and design teams. This approach ensures capital upgrades not only meet engineering standards but also achieve long-term operational targets and maintenance efficiency.

Introduction
This paper explores the critical role of operational staff in water and wastewater treatment facility design processes, highlighting how their practical expertise can identify potential issues that engineers might overlook. The author outlines several key intervention points where operators should participate—from document reviews and concept design to detailed design workshops (CHAIR 1, 2, and 3) and HAZOP assessments—emphasising that 3D models are essential for visualising complex systems beyond what 2D drawings can convey. Drawing from personal experience at facilities like Cessnock and Farley WWTWs, the discussion provides practical strategies for operators to effectively contribute to design reviews, advocate for operational improvements, identify potential safety hazards, and ensure maintainability, ultimately creating more efficient systems that serve communities better while reducing costly post-construction modifications.

Discussion
While design teams work diligently to create water and wastewater treatment facilities that meet client specifications, they may miss operational flaws that only experienced operators can identify. Early operational input prevents costly post-commissioning rework and variations. The author identifies critical design review stages where operators should contribute their practical knowledge to create more efficient, maintainable systems. Operators seek solutions that minimise manual intervention such as strategically placed hose reels or

alternative systems that eliminate lifting equipment ultimately delivering better community service through practical design improvements.

Learn Process and Instrument Drawings (P&IDs)
Process and Instrument Drawings (P&IDs) are essential documents in the design review process from concept through commissioning. Operators should verify these drawings include adequate isolation points, flushing points and instrumentation like flow meters and level indicators. For those new to reviewing P&IDs, it's recommended to study the symbols carefully and practice by comparing existing plant P&IDs with actual equipment onsite, tracing flow paths and valves to develop the ability to mentally visualise these 2D drawings in three dimensions. Building these skills will be critical in the following design review processes.

Concept Design
The concept design phase represents the first major opportunity for operational input through the CHAIR 1 review process. As operational experts, we must identify potential operability risks early by focusing on three key areas: minimising working at heights by ensuring equipment is accessible or has proper EWP access; evaluating equipment positioning to ensure operators can safely interact with related components; and considering start-up/shutdown requirements by verifying sufficient valves, penstocks, flowmeters and process equipment are included. The Cessnock WWTW exemplifies good design with built-in pump connection points for tanks and rodding points for influent distribution pipework, significantly reducing manual handling risks during maintenance operations.

Suction pipework on Anoxic Zones 1 and 2 at Cessnock WWTW

CHAIR 1 reviews also address construction aspects where operators' site knowledge proves invaluable regarding environmental conditions (heat/noise) and safety concerns (traffic/public access). This expertise helps ensure smooth project delivery while preserving budget for operability improvements. Additionally, operators should request reference site information from design teams, including photos and videos of installed equipment. Following up directly with operators at these reference sites to learn about ongoing issues and workarounds is crucial, as these practical lessons may not be known to the design team but are essential for improving the current design and avoiding repeated problems.

Detailed Design
During detailed design, contract type significantly impacts operational input effectiveness. In design-construct contracts, operators often face resistance when requesting operability improvements as constructors prioritise profit over operability. To overcome this, operators

should: quantify operational cost savings (as demonstrated at Farley WWTW where better maintainable drum screens justified a $200,000 additional investment); focus influence efforts on project managers rather than constructors; and identify cost-saving opportunities that could fund operability improvements. These strategies help bridge the natural tension between construction efficiency and long-term operability considerations.

3D models become crucial at this stage of design review—if not included in the contract, operators should actively request their development. The Farley chemical skid design illustrates this importance, where poor ergonomics resulted from reviewing separate 2D drawings without a comprehensive 3D model. In this case, three different design teams produced drawings for the walkway, chemical bund and skids separately, resulting in misaligned interfaces that weren't discovered until after construction. This required costly modifications and left operators with ergonomically challenging equipment that could have been avoided through proper 3D visualization during design reviews.

HAZOP Workshop – Key lessons

HAZOPs or Hazard and Operability Study is a key part of safety in design. When we have complex systems we break them into sections or nodes. Operationally, what we need to concentrate on is ensuring the systems have sufficient safety systems or detection mechanisms to prevent an incident. Things like flow switches or level indicators are typical inclusions in a design, but do we have sufficient coverage if a pump fails or creates a syphon effect? These are the question we need to ask ourselves and query the design. We also need to query why something has been put into the design so we can add additional value in the workshop, looking for duplication of instruments or excessive needs for that process or equipment. HAZOPs are generally completed utilising the P&IDs drawings so as discussed earlier, having some proficiency in understanding the drawings and what symbols relate to is important to ensuring your time and input is valuable during the workshop.

Some key lessons I have taken from participation in these workshops are

- **Be Prepared** - Review P&IDs beforehand and have questions prepared against the suggested guidewords normally all provided prior to the workshop. This will provide you with several key outcomes including, quality of the workshop will improve and value addition to the design.
- **Be Critical Thinkers** – This can be hard, we want to have it all, but try to be very of the likelihood of an event being significant it warrants significant additional instrumentation or increased design specifications. These all cost valuable funds and we want to ensure we spend them appropriately so we can gain the most value from the project.
- **Don’t be a Silent Participant** – Even if you don’t feel you can contribute, provide supportive opinions for or against based on your experience. Then also try to ask as many questions to draw out other participants ideas. The old adage that “There is no such thing as a dumb question” is so very true in these workshops. Any conversation can spark other ideas that build upon the process, this is where workshops go from acceptable to outstanding when we question and generate new ways or better ways.

CHAIR 2 and 3 Workshops

CHAIR 2 workshops focus exclusively on construction aspects, where operators' site-specific knowledge proves invaluable despite not being construction experts. Operators understand

critical site details like underground pipe locations and historical burial sites for screenings and biosolids that constructors may miss. Sharing this information helps prevent expensive construction variations, preserving budget that can instead be directed toward improving the site's operability and maintainability.

A common issue to watch for is design teams attempting to combine CHAIR 2 and CHAIR 3 workshops. Despite involving similar participants, these are distinct reviews with different purposes. When combined, construction safety typically dominates the discussion while operability considerations get rushed through, despite operations lasting decades longer than the construction phase. Operators should advocate for separate CHAIR 3 workshops on different days, ensuring operability and maintainability receive proper attention rather than being treated as an afterthought. If it is insisted that they are combine, ensure that specific timing for each is identified and adhered too.

One thing we can also achieve in this workshop is identifying items that are constructed for construction only such as laydown areas, that we may feel could be useful post construction. Example was a concrete area at Farley WWTW used for storage and workshops was retained after construction and is a useful laydown area for large equipment. These save both cost for demolition, but also reduce safety risks onsite during that work. Win – Win.

During CHAIR 2 workshops, operators must remain vigilant when construction safety measures might compromise operational efficiency. A notable example occurred during a HAZCHEM upgrade where above-ground pipework was proposed to avoid excavation risks. The constructors were unaware this pathway was essential for operations to move submersible mixers via trolley to and from the bioreactor. Had this design proceeded, operators would have needed to use cranes instead, significantly increasing operational costs and creating housekeeping hazards with mixers waiting in walkways. Operators must actively defend long-term operational needs against short-term construction conveniences to prevent future variations or rework.

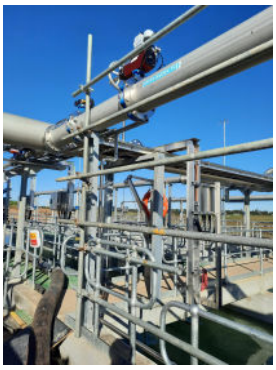
CHAIR 3 – Operability and Maintainability

Operators excel at problem-solving, the CHAIR 3 process should focus on preventing problems through design rather than creating workarounds later. However, operators must be pragmatic about their requests, prioritising what truly matters for efficient operations. At Cessnock, a mass flow meter was installed 5+ metres high due to site constraints, but since it only requires annual maintenance, providing stable EWP access was deemed sufficient. Conversely, when the SBR design lacked perimeter walkways, we successfully advocated for their addition despite constructor resistance. The constructors argued operators could simply walk 30m back to centre walkways, but operators demonstrated the efficiency gains from direct access paths. This relatively inexpensive modification significantly improved plant operability, illustrating when to compromise and when to stand firm on design requirements.

3D Models are a Must

Many issues are not identified until they are constructed when it’s too late, ether it costs a significant amount to modify or workarounds are created. Either way sometimes 3D models can identify and resolve this before the first hammer is swung. Example below of lesson we have learnt from the lack of a 3D model being used.

- Working at Heights – Can we design out any hazards related to working at heights. A good example of this being missed was in the aeration pipework design, where the control valves we installed at quite a height above the walkways, which was just not at a height, but also next to the operating plant, leading to working over water. You can see in this picture the added temporary hand railing to prevent falling into the bioreactor.



- Poor Ergonomics – The layout of equipment should be built so that we can operate and maintain the equipment without having the reach around pipework or we need to lay down or squat for long periods. The example below was identified after installation of the chemical skids that they were designed in a way which did not offer good ergonomic positioning for operators. This was missed during the CHAIR 3 workshop as we had several different 2D drawings, which were from three different design teams, mismatching RLs leading to the final outcome.

Citric Acid Dosing Cabinet with multiple equipment at ground level

- Lay of the Land – It's hard to imagine in your mind how the overall plant will look once constructed and how it will work on a significant slopping site. This was the situation at Cessnock WWTW where by the 3D model allowed us to review the various interactions we would have to perform at what height or depth. We were able to ensure that valves were not too high or low, roads or laydown areas were level or appropriate to our needs.

Operations and Maintenance Manuals (O&Ms)

Operations and Maintenance (O&M) manuals are vital reference documents used throughout a treatment plant's lifecycle, containing essential information for equipment operation and maintenance. To review these extensive documents efficiently, operators should focus on four critical areas: Operational Procedures (ensuring all necessary SOPs for startup, shutdown and operation are included); Troubleshooting guides (verifying fault codes and descriptions are comprehensive to prevent repair delays); Critical Spares listings (confirming all essential parts are identified); and Maintenance Schedules (evaluating whether manufacturer recommendations are appropriate for site-specific conditions like coastal environments).

Operators should avoid getting bogged down in design information, defects liability, or WAC drawings that are handled through other processes. For large capital upgrades with multiple

O&Ms to review, operators should negotiate with project teams to space reviews over time, allowing for thorough evaluation of each document. This targeted approach ensures the most operationally relevant information receives proper scrutiny while making efficient use of the reviewer's time

Training

Training represents a critical component of successful equipment handover to operations. The most effective approach combines classroom theory with hands-on participation during commissioning activities. Having operators actively involved in dry and wet commissioning alongside commissioning engineers provides invaluable practical experience with day-to-day operations and equipment start-up procedures. This hands-on involvement helps operators discover efficiency techniques that formal training might miss.

Standard Operating Procedures must be thoroughly tested to ensure they can be performed safely and effectively, with demonstrations to operations and maintenance teams before handover. Early in the project, it's essential to secure agreement on training requirements and associated costs, recognising that complex equipment demands more comprehensive training and operator time away from regular duties. At Cessnock WWTW, dedicating an operator to work with constructors for several months during commissioning and process proving yielded exceptional results, with the operations team achieving advanced proficiency with new processes much faster than would otherwise have been possible.

Conclusion

The integration of operational expertise throughout the water and wastewater treatment facility design process represents a critical investment that yields substantial long-term benefits. By actively involving operators from document reviews through to commissioning, organisations can avoid costly post-construction modifications, enhance plant performance, and significantly improve safety outcomes. The experiences at Cessnock and Farley WWTWs demonstrate that when operators' practical knowledge is valued and incorporated—particularly through effective use of 3D modelling, dedicated CHAIR workshops, and comprehensive training programs—the result is infrastructure that truly serves both operational staff and the broader community. Moving forward, the water industry should embrace this collaborative approach as standard practice, recognising that the relatively small upfront cost of operational involvement delivers exceptional value through reduced lifecycle costs, improved maintainability, and more sustainable infrastructure that functions effectively for decades to come.

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