Appendix E

Current practices in different countries

E.2 CURRENT PRACTICE IN NORTH AMERICA

E.2.1 Planning phase

In North America, planning for a wastewater treatment infrastructure project is almost universally done at the owner level. The development of the plan itself is either done by the owner or by a designer/engineer hired by the owner to work with them on developing an appropriate plan. In either situation, the risk for the planning decisions rests with the owner.

At the planning level, cost estimation used for budgeting purposes for capital improvements should follow American Society of Testing and Materials (ASTM) standard E2516 (ASTM, 2011). This standard developed a five-tiered cost estimation matrix based on the degree of project definition. As the degree of project definition increases, the accuracy of the estimate will be more refined. At the planning-level stage, this matrix defines the level of accuracy to be between – 60% and +120% of the cost estimate developed.

The following sections describe how different project delivery methods transfer risk.

E.2.2 Design−bid−build contracts

E.2.2.1 Preliminary design

The design−bid−build approach is very common in North America. Historically, in North America, design criteria for processes have been selected from one of a number of sources including local regulatory requirements or industry-accepted design standards that are generally published for reference when undertaking the process design and operation of the facility. Some examples of these design standards include:

- Water Environment Federation Manual of Practice 8 (WEF MOP-8, 2009)
- Wastewater Engineering: Treatment and Resource Recovery 5th Edition (Metcalf & Eddy Inc. *et al.*, 2013); (Tchobanoglous *et al.*, 2003)

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- EPA Nitrogen Control Manual (USEPA, 1993).
- EPA Phosphorus Removal Design Manual (USEPA, 1987)
- Biological Wastewater Treatment (Grady *et al.*, 2011)
- Methods for Wastewater Characterization in Activated Sludge Modeling (Melcer *et al.*, 2003)
- WERF/CRTC Protocols for Evaluating Secondary Clarifier Performance (Wahlberg, 2004)
- Virginia's Sewage Collection and Treatment Regulations (Virginia DEQ, 2008)
- Biological Nutrient Removal (BNR) Operation in Wastewater Treatment Plants (WEF MOP-29, 2005)
- Great Lakes Upper Mississippi River Board, Recommended Standards for Wastewater Treatment Facilities (Ten State Standards) (GLUMRB, 2014).

North American engineers place safety in their design in a few key process variables, most of which describe the most important sources of uncertainty, for example: influent flows and mass loads, SRT, SVI, overflow rates, denitrification rates and the design of the process air system.

E.2.2.2 Detailed design and construction

During detailed design for conventional design–bid–build projects, risks are mostly assumed by the designer/engineer who has to follow through the concepts of the preliminary design while preparing contract documents that can be built from. The owner does accept some risk accepting the design criteria presented in the preliminary design report, type of equipment that is provided, and operational procedures.

The development of tight contract documents and specifications is essential for the successful management of risk during construction. Reliability and redundancy standards are also used to reduce the risk of failure due to individual unit processes being out of service either due to mechanical failure or maintenance. The EPA and some states have developed standards based on the sensitivity of the receiving stream and the criticality of each unit process or piece of equipment. Typical requirements include:

- A minimum of two aeration basins of equal volume;
- Multiple pumps that can pump peak flows with the largest pump out of service; or
- Multiple units with the capacity to treat a certain percentage of design flows.

In the design–bid–build approach, no flexibility is given to the contractor to change the amount of redundant equipment, so the risk of adequate reliability falls upon the owner when the plant goes into operation.

E.2.2.3 Operation

Design–bid–build places all the operational risks upon the owner. There are some initial risks to the designer/engineer that the process design will perform as predicted, but once the plant resumes normal operation after the project is completed, the designer/engineer and contractor are no longer involved.

E.2.3 Design−build contracts

E.2.3.1 Preliminary design

In the design−build contract types, there may be an emphasis at the preliminary design stage to introduce additional risk in the design, which will be borne onto the owner during facility operations, in order to reduce construction costs. The following sources of uncertainty during preliminary design were identified earlier in this chapter:

- Variability in influent flows and loads;
- Selection of effluent design criteria;
- Selection of aerobic solids retention time;
- Selection of design sludge volume index (SVI);
- Denitrification rates;
- Considerations in the design of the process air system.

Examples of potential items which would introduce more risk to the owner would include a reduction in aerobic SRT (thereby reducing the aerobic bioreactor volume), use of a lower SVI (thereby reducing clarifier sizing), and a reduction in process air requirements (which would decrease blower or mechanical surface aerator size, compressed air pipe size (if applicable), and number of diffusers (if applicable)).

A second source of risk that is addressed in this stage that could be shifted to the owner during design would be the cost to operate the facility. Examples of potential items that could potentially provide capital cost savings during construction but increase operational costs include the use of chemical phosphorus removal in lieu of biological phosphorus removal and use of aeration systems that are not as efficient (mechanical aerators or course bubble diffused air).

Development of a strong design criteria package

To prevent undesirable items in the delivered plant, it is critical in a design−build project to have a detailed contract−design basis package that is used to specify the owner's goals for the project. However, the design package should consider a design change path for the contractor to allow them to propose cost savings ideas in a structured and thought-out manner.

At this stage of the design process, the owner will (most likely) hold a contract with a third-party engineer who is responsible for preparing a design criteria package, which may include a preliminary design of the facility along with minimum standards the facility must be designed around (the 'owner's engineer'). This will include design criteria for process mechanical, structural, electrical, instrumentation, HVAC (heating ventilation and air conditioning) and plumbing, and architectural codes and standards.

The development of a strong design criteria package by the third-party engineer can specify minimum requirements for items above such as minimum aerobic SRT, minimum clarifier solids/hydraulic loading rates, or standard oxygen requirements to prevent the design from becoming overly aggressive and making the owner more risk adverse during operations to save money during design and construction. In order to realise the benefits of this approach however, that is, reduced costs and risks to the owner, careful consideration is needed in the development of the design package to balance the true minimum requirements and the costs of being overly conservative.

E.2.3.2 Detailed design and construction

In the case of a design–build contract, the owner mitigates project risk by having both the designer/engineer and the contractor under one contract. This eliminates the so-called 'finger pointing' during the construction process. It also, however, provides the owner less control over the aspects of the project unless these items are specified in the design criteria package, which typically accompanies a design–build proposal. In this case, the owner is taking on risk by not having as much control over day-to-day decisions (such as ensuring that a specific manufacturer of a unit is provided) as long as the contract requirements are met and the price to perform the work remains the same. For example, the design–build may use alternative manufacturers or materials of construction as long as the minimum specified requirements in the design criteria package are met.

In design–build, the risks during detailed design and construction lie entirely with the design–build team to determine the level of design drawings needed to proceed to construction. There is some flexibility in this approach since it is possible to change the design during construction, if needed, to address issues that were not originally considered. In the traditional design–bid–build approach such changes normally result in additional change orders from the contractor that add to project costs.

The design–build contractor is fully responsible for the costs of the project, so the contract must be clear about where the project risks are and the limits on those risks. The goal of the approach would be to best allocate risks to where they are best handled, either at the owner level, or at the design–build level. Since it is not possible to have a 'perfect' contract, the design/builder will normally require supervision by the owner/owner's engineer to ensure that the intent of the contract is met.

Communication

Design–build eliminates some of the design–bid–build risks related to communication between the engineer and the contractor but makes the communication between the owner/their consultant and the design/builder critical. The owner and their consultant have less control over the product at this stage than is normal in a design–bid–build delivery, so communications need to be held in light of the contract language, which reduces the ability of the owner/owner's engineer to influence the design.

E.2.3.3 Operation

As in design–bid–build, the risks during operation are almost entirely upon the owner upon commencement of normal operation.

E.2.4 Design–build–operate contracts

E.2.4.1 Preliminary design

Addressing risk at this stage of the design process would be the same as for design–build systems. One advantage of this delivery form is mitigation of the concerns stated previously for the design–build contract. The designer–builder–operator will now be required to operate and comply with effluent criteria as well as pay for costs associated with operating the plant and maintaining the equipment. The benefit of this type of contract include transfer of most of the project risk to the contractor and having them responsible for the operations allows that bidder to develop what they feel is an optimum balance of risk and cost of the project.

E.2.4.2 Detailed design and construction

Most major DBO contractors have sophisticated risk analysis tools that can be used to balance the initial capital costs versus the predicted operational costs later. These tools range from as simple as applying contingencies and safety factors based on experience, to full Monte-Carlo risk analysis tools that can be used to estimate the cost impacts of various approaches. The tools consider process risks, design risks, construction risks, and operational risks versus the likelihood of their occurrence and the probable costs of the risks.

E.2.4.3 Operation

The design−build−operate (DBO) contract has significant risks related to long-term operational costs for the contractor, as compared to the owner doing operations. The DBO contract stipulates a cost for given loading conditions and what happens if conditions change, so the contractor is fully responsible for operation of the plant within the contracted loading and effluent conditions. Owners typically have more flexibility in their budgets for meeting changing conditions, within certain limits. The DBO does not eliminate cost risk to the owner should loading or effluent conditions vary from the contracted values.

E.3 CURRENT PRACTICE IN OTHER COUNTRIES

E.3.1 Questionnaire

The approaches engineers take during design vary depending on their geographic location. This is a result of the varying regional water situation and the legislative and contractual environment. In the following section, the approaches used by engineers in a selected number of countries across the world is presented. A questionnaire was sent to practicing engineers that included questions covering a variety of topics that capture the way designs are approached and the way risk is apportioned and handled. The questionnaire included the following questions related to design and risk:

(1) What is the prevalent type of contract delivery mechanism (Design (D), Design−Build (DB), Design−Build−Operate (DBO), Design−Build−Own−Operate (DBOO); if several, give percentages)?
(2) What are the most common types of design projects (green-field, replacement of an entire plant, upgrade of plant; give percentage range of capital cost of plant being replaced, give percentages for the three categories)?
(3) What information is included in the ‘Requests for proposal’ (RFP) prepared by the client (load projections, effluent requirements, configuration, industry standards to be used (e.g., ATV-131, 2000)? How much is predetermined, using which type of methods and which information (e.g., city master plans)?
(4) What is the typical design strategy of the engineering consultants (guidelines vs. mechanistic models, steady state vs. dynamic, calibration of models, performing of additional experiments on-site, safety factors used or parameter sets in models)?
(5) What is typically the design level at submission (level of completion of process design)?
(6) What are the typical bid selection criteria (including weighting) (e.g., cost, technical merit, …)?
(7) Are post-audits performed (how is success/failure of a design defined)?
(8) What is the way that risk is typically apportioned (insurance – risk premiums)?

E.3.2 United Kingdom

Question	Response
Type of contract delivery mechanism	D DB
Type of design	*Anglian:* green field (<5%); new plant (<10%); upgrades (85%) *United Utilities:* green field (<2%); new plant (<5%); upgrades (>90%) *Severn Trent:* green field (<2%); new plant (<1%); upgrades (>95%)
Requests for proposal as prepared by the client	Internal design guidelines (alternative design guidelines implemented on occasion). Basis for design: flow and concentration Several of the water companies prepare designs internally.
Design strategy of engineering consultant	Team-based approach: engineering options listed and then eliminated. Remaining options investigated and proposals prepared. Presentation to programme board: questions asked, costs presented and process options discussed. Programme board approves proposal, or sends it back for more study. Water company and consultants work as a team start-to-finish on proposal. No bidding process: the consultants are part of a framework agreement, so RFPs as typically done in USA are not really applicable. The contractor agrees to provide an upgrade for a fixed amount of money. If the design runs over budget, then the water company will attempt to save the money on a different project. Costs debated internally. Hydraulics are always modelled (sometimes even with a physical model). Activated sludge plants might be modelled, but not always (steady-state typically, sometime dynamic). Safety factors: not specifically used, rather the design is sized to give an effluent concentration that is some percentage of the requirement (e.g., for a 10 mg/L effluent consent, the design will be sized to give an effluent of 3 mg/L). Conservative design parameters are used (e.g., conservative SVI, OTE, high max flow and loads). Pilot plants used for biological phosphorus removal trials and new innovative technologies.
Design level at submission	See above. Same team structure is used from project start to finish.
Selection criteria in bidding procedure	Capital cost Total life cost evaluated secondarily (Capital + Operational) For the Framework agreement: Contractor experience, financial stability, health and safety record and reputation.
Post-audit	Very little. Lessons learnt are incorporated into future projects. *Severn Trent* allocates budget to post project activities. Models used are not typically re-checked.
Risk spreading	Risk shared contractually with the contractors but in reality, the water companies assume the ultimate risk (contractor could be sued if negligent issue with delivery, design, etc.)

E.3.3 The Netherlands

Question	Response
Type of contract delivery mechanism	D (87%) New, more innovative contracts (risk-based approach, more risk in contracts, let market define solution). Recently some projects were done with 'innovative bidding', that was solution free (no design, only the problem was submitted). This appeared to put (too) much risk to the market and also led to non-optimal designs and a poor cooperation during construction (due to legal issues). Currently, there is a tendency towards working with framework contracts. In these contracts, a party or consortium is selected to cooperate and organise the different project phases, from performance/design specs to pre-design and construction.
Type of design	Plant upgrades (biology and secondary clarifiers).
Requests for proposal as prepared by the client	Design requested from 3 to 5 companies Design specifications: load projection and effluent requirements Standards: STOWA Guidelines on N-removal (HAS method), P-removal (Scheer method), bulking sludge guidelines, final clarifier design guidelines
Design strategy of engineering consultant	Activated sludge part design based on the ATV-131 (2000) guideline. The design approach includes: – Simple mechanistic model for nitrogen removal – Steady-state simulations – Influent fractionation (focus on determining biodegradable COD and volatile fatty acids, the latter for the Scheer Bio-P model) – Influent loading targets
Design level at submission	Preliminary design for the selection of the consultant and the design Detailed design for the final submission
Selection criteria in bidding procedure	Best elements from each of the four () preliminary designs. Detailed design. Tender for the construction. Quality and cost
Post-audit	Performance within the defined effluent requirements. Evaluation period. Technological evaluation.
Risk spreading	Typically, none, however, new design delivery methods are currently being tested.

E.3.4 Switzerland

Question	Response
Type of contract delivery mechanism	D: 90% (Assumption) DB: 10% (Assumption)
Type of design	Upgrades (biology, secondary clarifiers): 50% Re-dimensioning of primary clarifiers: 50%
Requests for proposal as prepared by the client	Effluent requirements, seldom load projections. No industry standards like ATV-131 (2000), but an orientation towards standards is desirable. State-of-the-art technology expected, but effluent requirements do not orient themselves on the best available technology.
Design strategy of engineering consultant	Mechanistic models: often combined with experience and guidelines. Steady state Safety factors
Design level at submission	Competition at the design stage very seldom (e.g., WWTP Bern or Zurich). Competition for building is price based. Winner usually proposes some modification to the original design during construction.
Selection criteria	Investment cost Technical merit Flexibility for further adaptations Yearly costs (includes personal, operation costs and value conservation) Acceptance by population (e.g., sludge treatment).
Post-audit	Compliance with effluent criteria after one year of operation
Risk spreading	None

E.3.5 Czech Republic

Question	Response
Type of contract delivery mechanism	D: 80%, DB:20% The design is almost always undertaken by a 'Project Company' which composes the design and project drawings. Some Project Companies may use an external expert/consultant for design. Together they compose the project management team. The Construction Company (usually the tender winner) must take on the project, check it and take responsibility for the delivery, including the guaranteed performance/effluent parameters. In rare occasions, the Project Company is the tender winner and will subcontract a Construction Company. In smaller projects where technology cost is high, the Technology Delivery Company may win the tender instead of a Construction Company.
Type of design	Small WWTP $<$2000 PE – 95% greenfield Medium WWTP 2000 – 100 000 PE – 99% upgrade Large WWTP $>$100 000 PE – 100% upgrade
Requests for proposal as prepared by the client	RFPs include load projections and effluent requirements. The design must comply with city master plans. No restriction is placed on technology selection however, the design must comply with best available technology given by legislation, the effluent standards and the Czech norms.
Design strategy of engineering consultant	ATV-131 (2000) guideline are often used. Compliance with Czech norms is required (norms include parameters such as load, SRT, HRT in reactors, etc.). Mechanistic models are used mostly in steady state. Dynamics are accounted for by applying 'irregularity coefficients' (e.g., for aeration system design). Irregularity coefficients reflect and correct for the real dynamic behaviour of the plant. Czech norms include several. For example: – hourly, daily, weekly, monthly irregularity coefficients – oxygenation capacity irregularity coefficient (different for small, medium and large WWTP can substitute a dynamic model with daily flow and load fluctuations). Standard modelling procedure: (1) Model calibration if data are available (if not, conservative values are used). On-site experiments are rarely required for model calibration. (2) Steady-state design (of several alternatives) leads to selection of one final alternatives. Steady-state design usually performed with more conservative parameters than what was used in the calibration model. (3) Dynamic design (parameters from calibration used). For industrial plants, lab or pilot-scale experiments are performed (in 10–20% of cases). Applying new technologies usually requires pilot testing.
Design level at submission	Tender documentation with basic plant design needed for cost calculation (technology information, basic process design, configuration, volume, air design, reactor depth, etc.)

Question	Response
Selection criteria	Merit: Compliance with effluent standards, city plan, … Cost (90% weight) References, guaranties (5% weight) Technical equipment quality (5% weight) Environmental criteria have been newly (2021) added to the selection process however, there is no experience yet on how they will be implemented.
Post-audit	For projects which are partially funded from external sources, local, state or EU funds (grant-in-aid projects), there often (not always) exist additional criteria that must be met after the plant is finished. For example, the load capacity reached at a specific time. Grant-in-aid projects are audited after a trial period (usually 1 year). Plant capacity must be justified by proving that the plant is loaded to certain percentage of design capacity (usually 80%) and must comply with effluent standards.
Risk spreading	Client requires insurance of the contracted Co., together with other usual conditions for contract (financial, technical equipment, experiences, etc.).

E.3.6 South Korea

Question	Response
Type of contract	Turn-Key: 30−50% Separate contracts for DB, then operated by local governments: 50−70%
Type of design	Greenfield: about 30% Replacement of an entire plant: almost 0% Upgrades: 70%, as nutrients effluent quality is getting tougher
Requests for proposal as prepared by the client	Only load projections and effluent requirements.
Design strategy of engineering consultant	Design guidelines with safety factors.
Design level at submission	Complete process design
Selection criteria	Cost: 30% Technical merit: 60% Company's status (financial, previous records, stability…)
Post-audit	One- or two-years' successful operation (meeting effluent requirements).
Risk spreading	No insurance

E.3.7 South America

Question	Response
Type of contract	This varies enormously between countries. For example, municipal treatment plants in Brazil (run by government operators) are most likely D, whereas municipal treatment plants in Chile (being privatised) are mostly DBO. It also varies from municipal/industrial/mining/etc. treatment plants.
Type of design	Industrial treatment plant projects are evenly distributed between green-field and plant upgrades For municipal plants, there are quite a few greenfield sites in countries with low coverage (Peru, Ecuador). In countries with high coverage (Chile) plants are mostly upgrades.
Requests for proposal as prepared by the client	Varies by country. Projects funded by international financial institution, e.g., the World Bank, generally have load projections and effluent requirements (mostly concentrations). Local design standards are often cited in the request for proposals. Very few indicate design guidelines or standards to be used (e.g., ATV-131, 2000).
Design strategy of engineering consultant	Established consulting firms use dynamic modelling. However, there is a small number of these large, established firms. Most consultants use Excel spreadsheets with the Metcalf & Eddy steady-state equations. For larger plants (over 1 m^3/s capacity), established consulting firms tend to be hired. For smaller plants, Excel-based design prevails.
Design level at submission	Varies by country. Turn-key dominant in industrial applications, that is, the client 'buys' a plant from an equipment supplier that sells them the whole package (similar to a DBOT). Municipal plants are tendered with a preliminary process design. Bidders complete process design and execute detail design, construction and initial operation.
Selection criteria	Technical merit and cost. However, the primary selection criterion is cost. A few of the large utilities (two or three) are starting to give more weight to technical merit. Industrial clients: no defined standards, but mostly they pick companies they trust to work with and then look for lowest price. Little attention paid to life-cycle costs (present value including CapEx and OpEx). CapEx only dominates in both the municipal and industrial markets.
Post-audit	Rarely done. If design achieves quality criteria at start-up, then it is considered successful. Testing and auditing are not required. Some effort is put into evaluating the performance of the electrical and mechanical equipment.
Risk spreading	Through insurance.

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