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Tools to Support Prevention through Design (PtD) Processes in Water Utility Facilities

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Background

Applied Safety and Ergonomics, Inc. (ASE) performed a multi-year research project for the Water Research Foundation with the primary objective being to "develop a tool to support PtD initiatives by demonstrating value to organizations."

Following a review of barriers to PtD processes identified earlier in this project, the ASE research team concluded that the primary project objective could be met by a set of tools that has the following characteristics.

1. Broadly applicable to the water industry; i.e., for utilities of all sizes
2. Capable of facilitating comparisons of alternative designs
3. Provide guidance for designers of water facilities
4. Enable cost/benefit analysis of features aimed at mitigating injury risk
5. Sophisticated enough to be credible for large organizations with mature engineering processes, yet simple enough to be used by small utilities with limited engineering resources.

With input from participating water utilities and engineering organizations, five priority groups were identified that included tasks with the potential for serious injury or death, and which impose the greatest ongoing operating costs associated with maintaining safe operations.

1. Confined spaces
2. Electrical work
3. Elevated work
4. Chemical processes
5. Materials handling

For each priority task group, specific facility attributes were identified that drive the cost associated with performing a job including:

- Labor required to perform the task "safely"; i.e., within compliance
- Equipment - availability, rent, capital cost, maintenance and inspection, etc.
- PPE requirements

- Permit requirements
- Requirements for developing specific safe work plans
- Set-up and tear-down work associated with performing the task
- Training required to maintain task capability
- Supervision to assure safe procedures are followed
- Equipment or process downtime resulting from the need to work on de-energized systems
- Residual injury cost as measured in expected injury costs if safe method is followed. (Note: Injuries may still occur even when appropriate safety measures are followed. This component recognizes this residual risk. It does not account for injuries stemming from inadequate or failed safety systems.)

The ongoing operating costs associated with performing tasks within the five groups are directly related to facility design features. For example, servicing an elevated valve is generally less costly if the work is performed from a fixed maintenance platform than if performed from portable ladders or manlift.

Three prototype tools have been developed to support and drive PtD initiatives. A Task Categorization Model, or TCM, identifies facility features or task characteristics that affect the ongoing costs of performing tasks and thereby provides guidance to facility planners on how to lower operating costs. The other two tools use the TCM as their foundation. The Relative Ongoing Cost of Safe Operations Model (ROCSO) is a tool for comparing alternative designs and task methods within the each of the five task groups. As the name implies, it is based on assessments of relative ongoing costs among competing designs. The Total Ongoing Cost of Safe Operations Model (TOCSO) is a tool that aims to account for ongoing costs in a more comprehensive manner. Output from applying the TOCSO model may be used for cost/benefit analyses and for justifying capital improvements.

The following is an outline for each of these tools, including objectives and intended uses, a brief description, input data to be gathered or specified by the user, and output or results from tool application.

Task Categorization Model (TCM)

Objectives and Intended Uses

- Provide guidance to both facility designers and SHE professionals on how to make water facilities with low safety related operating costs
- Facilitate assessments of ongoing operating costs that result from water facility design features
- Enable managers and SHE practitioners to evaluate alternative facility features and processes.
- Provide a base for more sophisticated quantitative PtD metrics.
- Provide a baseline tool that can be used by all organizations without the need for specialized safety or engineering skills.

Description

The Task Categorization Model (TCM) identifies common tasks performed within each of the five priority task groups for water utilities; e.g., vault entry is a task within confined spaces.

Features of the facility or attributes of task performance that instill ongoing safety related costs to perform work are identified for each of these tasks. Combinations of these features and attributes are then categorized by level of ongoing costs that must be incurred by the organization to assure safe operations.

In the TCM model, three categories are defined by the facility features and task performance methods, but may be summarized as follows:

A. *Lower Ongoing Costs* –Tasks in this category require no special equipment, training, or PPE and can be performed by an individual without special supervision and with minimal injury risk.
B. *Medium Ongoing Costs* – Tasks in this category generally require little or no special equipment, only minimal PPE, and no supervisory permits or assistance.
C. *Higher Ongoing Costs* - Tasks in this category typically require active safety controls. Multiple workers and specialized or portable equipment may be required to perform work safely. PPE beyond safety glasses and hearing protection may be required. Tasks may require permits and direct supervision.

A TCM matrix is created by listing the common tasks in a vertical column, and the three Ongoing Cost category levels across the top. Category attributes are described in cells for each task. Using the TCM, the analyst can assign a "Category" rating to any of the identified common tasks based on their water facility design and operating procedures. If the task attributes most closely follow those of Category B but has one or more attributes of Category C, the task is assigned to Category C. Similarly, one attribute in Category B could result in a task being downgraded from Category A to B.

Note that Category C attributes are generally consistent with guidelines for hazard control specified in applicable regulations and consensus standards. If tasks are performed that do not meet Category C requirements, the utility may be operating outside of compliance with these standards and may be viewed as operating in "Category D conditions". In many situations, Category D conditions may be viewed as unacceptable. With the possible exception of the Manual Material Handling task group, serious injuries and fatalities in water facilities are believed to occur when tasks are performed using Category D conditions, and rarely if Category A, B, or C conditions are fully met.

Tool Inputs

Organizations using the TCM must first identify their tasks that fall into one of the five priority task groups. They then determine the safety controls that will be required to perform the tasks safely, and estimate the number of times the tasks are performed annually.

Tool Output

The tool can be used to either categorize building features, or to categorize common tasks. For example, a site might conduct an assessment and identify 20 Category A confined spaces, 80 that fall into Category B, and 30 that are classified as Category C. Alternatively, the site might identify 32 tasks requiring work at elevation, including 15 that are Category C tasks. Such assessments can easily be converted to performance goals aimed at reducing ongoing costs through plant improvements. The TCM provides designers and managers with a roadmap for improving efficiency in safe operations.

ROCSO (Relative Ongoing Cost of Safe Operations) Model

Objectives and Intended Uses

- Incorporate all the features and benefits of the TCM
- Incorporate task frequency, a critical factor in assessing cost/benefit for capital expenditure planning.
- Provide a quantitative method for rating existing facilities or comparing design alternatives within task groups without requiring extensive financial analysis or cost estimates.
- Provide a decision tool that can be used by managers and SHE practitioners with limited engineering skills.

Description

The ROCSO Model is a tool to help assess the relative on-going costs of safely performing tasks. The model is being developed for the same five groups of tasks previously identified. The tool is intended to help consider alternative task strategies within task groups. It is NOT designed to enable comparisons across task groups; i.e., it does not facilitate comparison of a confined space task change with a change in an electrical task.

The ROCSO Model assigns a quantitative value or score to each cell in a matrix of specific tasks and 3 category levels; i.e., the TCM Model. Category levels reflect the characteristics of the task that affect the cost of performing the task safely under the conditions specified. The method and conditions that afford the lowest on-going cost for performing a task are assigned to Category A, and all Category A scores are set at the value of 1.0. ROCSO scores for Categories B and C are multipliers that reflect the cost associated with safe task performance when performed under the conditions in those respective categories, as compared to the benchmark cost of performing the task under Category A conditions. That is, a task with a Category B score of 2.0 costs the utility twice as much to perform safely under Category B conditions as it would under Category A conditions. Note that assigned scores are independent of frequency of performance.

It is assumed that appropriate scores for the three categories will vary among the five priority task groups, and will likely not be uniform across all water utilities. That is, a scoring matrix such as those shown below may be developed by and for each organization. (Values shown are arbitrary, with the exception of those for Category A which are always set at 1.0.) The numbers in the scoring matrix assign numerical values or scores to columns and cells in the TCM.

	Category A	Category B	Category C
Confined Spaces	1	2	10
Electrical Work	1	1.3	3
Elevated Work	1	1.8	2.8
Chemical Processes	1	2	6
Materials Handling	1	3	8

Example 1. Hypothetical ROCSO Score Table

ELEVATED TASKS	Category A	Category B	Category C
Inspection and other light work	1.0	1.3	1.9
Lubricating valves, pumps, etc.	1.0	1.3	2.0
Change out valve, pump, etc.	1.0	1.4	2.1
Climb onto tank	1.0	2.2	4.2
Repair in place	1.0	1.3	2.3
Install piping	1.0	1.4	2.1
Add chemical	1.0	1.4	2.6

Example 2. Hypothetical ROCSO Score Table for Elevated Work

Frequency may be introduced to the model through the use of a multiplier. It is suggested that the frequency multiplier simply be the estimated number of times that the task is performed on an annual basis. The ROCSO score for a task may simply be calculated as:

Annual ROCSO Score = Task Category Score x *# of task performances / year.*

Tool Inputs

Before an organization can use the ROCSO model, it must establish its own ROCSO Score Table as shown above. (If such a table is agreed upon by utility managers and engineers, the ROCSO model will likely be sufficiently robust to be used as a credible quantitative decision tool.) To use the model, the utility first identifies tasks that fall into the five priority task groups, as was done with the TCM model. Next, the organization assigns each of the identified tasks to a Category, based on the TCM criteria. It is also suggested that task frequency be determined or estimated. Finally, if the ROCSO model is to be used for approximations of cost/benefit analyses, an organization needs to establish dollar values for performing all identified tasks under Category A conditions. It may be appropriate to establish these benchmark costs concurrent with development of the ROCSO score table.

Tool Output

The ROCSO Model is intended for the following applications:

- compare the relative advantages and costs of different task strategies within a task group
- provide a quantitative, relative value assessment of existing or planned facility features against alternatives

- facilitate tracking of utility progress in efforts to reduce ongoing costs related to safety compliance and risk management
- objectively and quantitatively assess the cost-effectiveness of facilities and operations to enable safe operations.

The ROCSO Model is NOT suited for comparing alternatives across task groups or for supporting capital cost justification based solely on expected operating costs.

Two simple equations provide quantitative values that can be used to compare design alternatives, prioritize capital improvement projects, assess improvement opportunities, and set ROCSO goals for the facility as a leading performance metric.

Annual ROCSO Score = Task ROCSO Score x *# of task performances / year*, and

Annual ROCSO Cost = (Category A Estimated Cost) x *(Annual ROCSO Score)*

Note that eliminating a high hazard activity altogether yields a ROCSO value of zero, since the task no longer exists.

If one wants to assess zones or entire facilities, annual ROCSO task scores or costs can simply be summed for the applicable task group and operations contained therein to arrive at an Overall ROCSO Score or Cost. If diverse facilities, zones, or designs are to be compared, the analyst can divide the Overall ROCSO score by the number of tasks included to yield an Average ROCSO score.

TOCSO (Total Ongoing Cost of Safe Operations) Model

Objectives and Intended Uses

- Incorporate all the features and benefits of the TCM
- Incorporate task frequency and financial costs
- Provide a quantitative method for rating existing facilities or comparing design alternatives either within or across task groups
- Provide a tool for estimating operating costs that can be used for cost benefit analysis, and which is more robust than the ROCSO model. It may be especially useful for budgeting training, supervision, and administrative time.
- The tool must be sufficiently detailed and comprehensive to have credibility with senior leaders in large organizations, yet simple enough to be used without extensive training.

Description

The Total Ongoing Cost of Safe Operations Model (TOCSO) is a more sophisticated scoring model that affords more detailed analysis but also requires more preparatory work. The application of this model is similar to that for the ROCSO model. The assessment begins with use of the TCM, a score is assigned for each task, and a facility score can be computed in a manner similar to the ROCSO procedure. The difference lies in how values are assigned to TCM cell conditions. Instead of simply estimating a Category A score and then applying multipliers for

Category B and C conditions, a pre-determined cost value is established for each cell within the TCM. The result is a more complete and rigorous valuation method.

The TOCSO model involves a series of equations that can easily be programmed as an Excel spreadsheet. As with the ROCSO model, preliminary work to establish baseline values for several parameters allows for straightforward and repeated application of the model to a variety of operations and designs.

The basic TOCSO model equation is as follows:

Annual Task TOCSO Cost = (D + O) x *F*, where

D = Direct Cost expressed in dollars
O = Overhead Cost expressed dollars
F = Frequency, i.e., the number of times per year the task is expected to be performed

D = (L x C) + E + S + P + W, where

L = dollar value of expected total labor hours to perform the task safely with the conditions given in the TCM cell, including supervisory time. (*Note: Supervisory time should be estimated as the amount of time required to reasonably ensure that safe procedures are properly executed at each task performance. This may be substantially more than the amount of supervisory labor that is normally allocated. Labor hour estimates should also include time spent retrieving items such as PPE, ladders, air monitoring instruments, and other items that serve a safety purpose or which effect worker safety.)*
C = assigned PPE constant between 1.0 and 3.0: e.g., C = 1.0 for no PPE, C = 3.0 for full face or cartridge respirator and other PPE that significantly affects worker comfort or productivity (*Note: C can be applied to some or all members of a crew performing a task as applicable to arrive at an equivalent burdened labor factor*.)
E = equipment cost per use, e.g., rental, acquisition (e.g., annualized depreciation value), storage allocation, allocated maintenance cost / use, including PPE cost
S = dollar value of set-up and tear down labor hours, such as setting up barriers, scaffolding, shoring, etc.
P = dollar value of labor hours involved in securing permits for PRCS entries, hot work, etc.
W = dollar value of time and costs engaged in developing task specific work plans

O = T + I, where

T = training time and cost value in dollars, with training time calculated as follows: *Training time = (# of training hours required to enable the task to be performed safely* x *2) / estimated # of applications for the trained skill per year*. The 2x multiplier accounts for trainer and supervisor costs associated with training / retraining and coaching.
I = fully loaded value of expected injury costs per task performance or exposure, calculated as follows: *Expected injury costs = expected Workers Compensation values per exposure for operating under each set of conditions* x *indirect cost multiplier.*

Example: Assume that a facility performs 100 Category C elevated work tasks of a certain type each year. Historically, the facility has experienced one serious fall performing this type of task every two years. Expected direct injury cost (workers comp) for these injuries is approximately $5000. Assuming an indirect cost multiplier of 3.0, or $2.00 of indirect cost for every $1.00 of WC, the fully loaded expected injury value for this type of task in Category C would be calculated as follows: I = ($5000/incident x 0.5 incidents/yr. x 3.0) / 100 tasks/yr. = $75 / task performance.)

Note that by using a simple dollar / hour conversion factor, the currency used as the basis for cost estimates can be either dollars or labor hours, accommodating those utilities that need to justify projects in terms of labor savings.

Tool Inputs

Prior to using the TOCSO model, an organization will need to determine the following input values:

1. An assumed labor cost rate, so that labor hours can be readily converted to dollars, and vice versa.
2. An estimate of the total direct and supervisory labor hours required to perform each of the relevant tasks under each of the applicable conditions listed in the TCM model; i.e., a labor hour estimate for each applicable cell in the TCM model. Once developed, this table becomes a primary reference table that can be linked to, and pre-populate, much of an Excel Worksheet.
3. PPE burden constants, if using values other than those suggested above.
4. A list of commonly accessed/used/leased equipment used for the various tasks in the TCM table, along with an estimated cost per use for each applicable cell in the TCM.
5. An estimate of set-up and tear down hours for each applicable TCM cell.
6. An estimate of the time required to secure safe work permits.
7. An estimate of the expected labor hours involved in developing and acquiring specific work plans.
8. An estimate of training hours required to perform each identified task in a manner as described by the criteria in the TCM.
9. Data from injuries sustained while performing tasks within the TCM model, including Workers Compensation costs
10. An assumed ratio of direct / indirect injury costs.

The above inputs are used to create a TOCSO Master Table that identifies an equivalent cost per task performance for each cell in the TCM. That is, each applicable cell should have a value calculated as:

$$\textit{Task TOCSO Cost per performance} = D + O.$$

If this Master Table is created in a spreadsheet, simple macros can be used to pull values from referent variable tables as applicable for the site's conditions and resources. For example, a boom lift may be needed for some elevated work tasks, but not for others, and this approach allows flexibility in applying equipment costs. The TOCSO Master Table can be automatically updated whenever new values are entered in the referent variable tables, and it is suggested that referent table values be updated annually.

Tool Output

As with the ROCSO model, a simple equation provides quantitative values that can be used to compare design alternatives, prioritize capital improvement projects, assess improvement opportunities, and set TOCSO goals for the facility.

Annual Task TOCSO Cost = Task TOCSO Score x *# of task performances / year*.

Again, eliminating a high hazard activity altogether yields a TOCSO value of zero, since the task no longer exists.

If one wants to assess zones or entire facilities, Task TOCSO Costs can simply be summed for the applicable operations to arrive at an Overall TOCSO Cost. If diverse facilities, zones, or designs are to be compared, the analyst can divide the Overall TOCSO Cost by the number of tasks included to yield an Average TOCSO cost.

Because cost components are individually determined, TOCSO model values should be more accurate than ROCSO model estimates, and therefore more credible with financial analysts. Model outputs can be used directly for cost/benefit analyses of alternative designs and processes. Once the TOCSO Master Table has been set-up, use of this model is essentially the same as applying the ROCSO model.