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Transit Asset Management Working Group

Using Asset Criticality to Make More Informed Decisions in a Transit Agency

Abstract: This *Recommended Practice* introduces key concepts in asset criticality, provides worked examples for determining asset criticality using three different methods, and presents a framework for preparing for and performing a criticality assessment.

Keywords: transit asset management, asset criticality, MAP-21

Summary: All transit agencies are required to make decisions about their assets. Decisions range from long-term strategic decisions, such as capital replacements or extensions, to short-term operational decisions, such as prioritizing unplanned maintenance or taking an asset out of service. Determining the criticality of its assets can help an agency understand their relative importance, thereby helping prioritize decisions and work activities more effectively and consistently.

Scope and purpose: The scope of this paper is limited to asset criticality concepts and methods. Its purpose is to describe recommended practices for transit agencies to consider when determining the criticality of their assets.

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Introduction

This introduction is not part of APTA RP-xxx-00x-21, "Using Asset Criticality to Make More Informed Decisions in a Transit Agency."

APTA recommends the use of this document by:

- individuals or organizations that operate transit systems;
- individuals or organizations that contract with others for the operation of transit systems; and
- individuals or organizations that influence how transit systems are operated (including but not limited to consultants, designers and contractors).

Note on alternate practices

Individual transit agencies may modify the practices in this standard to accommodate their specific equipment and mode of operation. APTA recognizes that some transit systems may have unique operating environments that make strict compliance with every provision of this standard impossible. As a result, certain transit agencies may need to implement the standards and practices herein in ways that are more or less restrictive than this document prescribes. Transit agencies may develop alternates to APTA standards so long as the alternates are based on a safe operating history and are described and documented in the agency's safety program plan (or another document that is referenced in the system safety program plan).

Documentation of alternate practices shall:

- identify the specific APTA transit safety standard requirements that cannot be met;
- state why each of these requirements cannot be met;
- describe the alternate methods used; and
- describe and substantiate how the alternate methods do not compromise safety and provide a level of safety equivalent to the practices in the APTA safety standard (operating histories or hazard analysis findings may be used to substantiate this claim).

Using Asset Criticality to Make More Informed Decisions in a Transit Agency

1. Introduction

All asset-intensive organizations are required to make decisions about their assets. Decisions range from long-term strategic decisions, such as capital replacements or extensions, to short-term operational decisions, such as prioritizing unplanned maintenance or taking an asset out of service. Making informed asset decisions relies upon having access to information of a sufficient quality, along with the processes, tools and methods to use that information to support decision-making.

Understanding the criticality of assets is an example of a useful input that can support more informed asset decision-making. Determining asset criticality can help an agency understand which assets are more deserving of attention and which will return the greatest value to the organization when compared with the effort expended, thereby helping agencies to prioritize decisions and work activities more effectively and consistently.

This paper introduces some key concepts in asset criticality, provides some worked examples for determining criticality using three different methods, and presents a framework for preparing for and performing a criticality assessment.

2. Key concepts for asset criticality

ISO 55000[1] defines a critical asset as one that has the "potential to significantly impact the achievement of the organization's objectives." Put simply, criticality is a way of understanding the relative importance of an asset to an organization.

While it is common for organizations to use the consequence of failure as a means for determining the criticality of their assets, this is just one potential method (see Section 3). By considering the ISO 55000 definition given above, agencies can place potential methods in context and examine some broader concepts behind criticality.

The ISO 55000 definition emphasizes the agency's objectives as the reference point for determining asset criticality. Without an understanding of what the organization is trying to achieve, it is challenging to determine what is truly critical and therefore where the organization should prioritize its limited resources. Before embarking on a determination of asset criticality, the organization should first consider its objectives and the decisions or questions that are trying to be addressed, as this will guide it to the appropriate criticality method.

Table 1 provides some common transit agency objectives and examples of decisions or questions related to those objectives and potential criticality methods that can help.

1. The International Standards Organization 55000:2014 standard for Asset Management.

TABLE 1
Example Decisions Supported by Asset Criticality

Objective	Given our limited resources…	Resulting asset criticality question	Potential criticality method[2]
Safety	For which assets is it most critical that we focus our efforts on maintaining or improving safety?	Which assets have the highest potential for impacting safety should they fail?	Consequence of failure on safety or risk of failure on safety
Levels of service (LOS)	For which assets is it most critical that we focus our efforts on ensuring that we meet our desired LOS?	Which assets have the highest potential for impacting service should they fail?	Consequence of failure on LOS or risk of failure on LOS
Cost reduction	For which assets is it most critical that we streamline our maintenance practices?	Which assets account for the greatest proportion of maintenance costs?	Maintenance cost
Operational performance	For which assets is it most critical that we define operational contingency plans?	Which assets have a high operational consequence of failure (but a low likelihood)?	Consequence of failure
Life cycle cost reduction	For which assets is it most critical that we focus our life cycle cost reduction efforts?	Which assets account for the greatest proportion of life cycle costs?	Total cost of ownership
Environmental	For which assets is it most critical that we focus our greenhouse gas reduction efforts?	Which assets produce the most carbon dioxide through their life cycle?	CO_2 emissions

It follows that the same asset can have different levels of criticality based on the context through which it is viewed. For example:

- Signal equipment on a railroad can be considered critical to both safety and operational performance (i.e., should it fail, both will be significantly impacted[3]).
- An elevator might be considered critical from a LOS perspective if it were the only elevator serving a station (i.e., LOS at the station may be dependent on that elevator working), but not necessarily critical from a safety perspective.
- An asset that is relatively much more costly to maintain compared with others but with relatively low CO_2 emissions may be highly critical for an organization seeking opportunities for reducing its maintenance costs; however, it is unlikely to be considered critical when seeking opportunities to reduce CO_2 emissions.

Another important asset criticality concept is relativity. When seeking to understand which assets are critical, it simplifies things greatly to consider their relative, rather than absolute, criticality. This means determining if asset A is more or less critical than asset B, but not quantifying by how much.

3. Asset criticality methods

The method employed to determine asset criticality should be based on the decision being made and be tied to the objective(s) being considered (see above). Two common methods are described below, along with a third method based on total cost of ownership. These do not constitute all possible methods for determining asset

2. Criticality methods for consequence of failure, risk of failure and total cost of ownership are described further in Section 3.
3. Noting that signal equipment is designed to "fail-safe," which mitigates the safety impact arising from a failure.

criticality, and agencies should carefully consider a range of potential methods appropriate for the decisions they are trying to make.

3.1 Method 1: Asset criticality based on consequence of failure

Under this criticality method, the potential failure modes of the assets are identified, along with the consequences of those failures against the objectives of the organization.

Table 2 presents criticality scores for two different assets (elevators A and B), which are derived by considering the consequences of each suffering different failure modes against three notional agency objectives of safety, LOS and cost reduction. In this example, the consequence of failure is derived using subject matter expert (SME) judgment and given a rating from 1 to 5 (where 1 is lowest consequence). A more advanced approach to this method would be to use historical data to quantify the consequences of failure, using consistent "units" of consequence (ideally expressed in monetary terms) to enable improved cross-asset comparison.

Average consequence scores by failure mode and by objective are derived, with an overall consequence score derived through addition. A more sophisticated approach might include weighting each agency objective and using those to derive weighted averages totals by failure mode.

TABLE 2
Asset Criticality Based on Consequence of Failure

Elevator A Sole elevator at a busy station, subject to third-party maintenance contract		**Safety**	**Level of Service**	**Cost Reduction**	**Average Consequence by Failure Mode**
Failure mode	Cable snap, elevator falls	**5** Could result in serious injury or fatality	**4** Will be out of service for a month, with no other elevators at the busy location	**4** Requires expensive repairs and safety checks	4.33
	Doors fail	**1** Customers may experience discomfort should they become entrapped, but not a major impact on safety	**2** Will be out of service for a day while third-party maintainers arrive, with no other elevators at the busy location	**2** Requires expensive third-party maintenance call	1.67
Average consequence by objective		**3.00**	**3.00**	**3.00**	**3.00**

TABLE 2
Asset Criticality Based on Consequence of Failure

Elevator B One of three elevators at a moderately busy station, maintained by agency staff		**Safety**	**Level of Service**	**Cost Reduction**	**Average Consequence by Failure Mode**
Failure mode	Cable snap, elevator falls	**5** Could result in serious injury or fatality	**2** Will be out of service for a month, but other elevators exist at the location	**4** Requires expensive repairs and safety checks	**3.67**
	Doors fail	**1** Customers may experience discomfort should they become entrapped, but not a major impact on safety	**1** Will be out of service for an hour, but other elevators exist at the location	**1** Fix can be performed by local maintenance crew	**1.00**
Average consequence by objective		**3.00**	**1.50**	**2.50**	**2.33**

The results above are placed in an Asset Criticality Ranking table:

TABLE 3
Method 1 Asset Criticality Ranking

	Safety	**Level of Service**	**Cost Reduction**	**Overall**
Elevator A	3.00	3.00	3.00	3.83
Elevator B	3.00	1.50	2.50	2.33

How does an agency use this consequence of failure criticality score once derived?

- If it were seeking to prioritize work to reduce the consequence of failure on safety, this analysis suggests there is no difference in rank between the two elevators (both 3.00)
- If it were seeking to prioritize work to maintain or improve its levels of service, this analysis suggests elevator A should be ranked above (i.e., is more critical than) elevator B (3.00 versus 1.50). Armed with this knowledge, the agency could increase the spare parts availability to reduce the length of time it is out of service (i.e., reducing the consequence of the failure by reducing its length), or even installing an additional elevator in the station (i.e., reducing the consequence of the failure by providing operational redundancy). In the latter example, care must be taken to weigh the life cycle cost of the new elevator against the benefits gained.
- If it were seeking to prioritize work to reduce its costs, this analysis suggests elevator A should also be ranked above elevator B (3.00 versus 2.50) for this objective, and the agency could, for example, explore whether moving the maintenance of the elevator in-house may reduce costs by avoiding a potentially more expensive third-party maintenance contract.
- If it were seeking to prioritize work across both elevators to reduce the consequence of cables snapping, this analysis suggests elevator A should be ranked above elevator B (4.33 versus 3.67). For example, it may prioritize cable replacement or inspection work at this elevator.

- If it were seeking to prioritize work across both elevators to reduce the consequence of door failure, this analysis suggests elevator A should be ranked above elevator B (1.67 versus 1.00). For example, it may prioritize door preventive maintenance work at this elevator.
- If it were seeking to determine where it should place most emphasis in terms of optimization of work to reduce the overall consequence of both failure modes, it might rank elevator A over elevator B, as its total consequence of failure score is higher (3.00 versus 2.33).

Extending this assessment across all asset types would enable the agency to make cross-asset type comparisons, by identifying the asset types with a high consequence on, for example, levels of service and considering potential programmatic responses.

3.2 Method 2: Asset criticality based on risk of failure

While consequence of failure is perhaps the most common approach to asset criticality, some organizations elect to take a risk-based[4] approach, as an asset that fails regularly may have a bigger impact overall than a very reliable asset with a more highly consequential failure. This method builds upon the previous approach by introducing the likelihood of each failure mode occurring, in addition to its consequence.

In the notional example here, likelihood is determined by asking SMEs to use their asset knowledge and judgment to rate each failure mode on a 1-to-5 scale, where 1 is "very unlikely" and 5 is "very likely." A more sophisticated approach might be to use historical failure rate data for each failure mode to derive a probability for each. Notice that the likelihood of each failure mode was judged by the SMEs to be different for each elevator due to operating context and their knowledge of its failure history (i.e., the doors on elevator B have historically failed much more frequently than on elevator A, so the SMEs judge its likelihood of future failure to be very likely (5), compared with unlikely (2) for elevator A.

Once likelihood is introduced, in **Table 4** below, the risk of failure can be determined by multiplying the previously determined consequence of each failure mode by its likelihood. This gives a risk of failure by objective, by failure mode and a total overall risk-based criticality score.

TABLE 4
Asset Criticality Based on Risk of Failure

Elevator A		Safety	Level of Service	Cost Reduction	Average Consequence by Failure Mode	Likelihood	Average Risk by Failure Mode
Failure mode	Cable snap, elevator falls	5	4	4	**4.33**	1	**4.33**
	Doors fail	1	2	2	**1.67**	2	**3.33**
Average consequence by objective		**3.00**	**3.00**	**3.00**	**3.00**	**Total average risk score**	
Risk by objective		**3.50**	**4.00**	**4.00**	**3.83**		

4. Risk is determined by consequence times likelihood.

TABLE 4
Asset Criticality Based on Risk of Failure

Elevator B		Safety	Level of Service	Cost Reduction	Average Consequence by Failure Mode	Likelihood	Average Risk by Failure Mode
Failure mode	Cable snap, elevator falls	5	2	4	**3.67**	1	**3.67**
	Doors fail	1	1	1	**1.00**	5	**5.00**
Average consequence by objective		**3.00**	**1.50**	**2.50**	**2.33**	**Total average risk score**	
Average risk by objective		**5.00**	**3.50**	**4.50**	**4.33**		

The results above are placed in an Asset Criticality Ranking table:

TABLE 5
Method 2 Asset Criticality Ranking

	Safety	Level of Service	Cost Reduction	Overall
Elevator A	3.50	4.00	4.00	3.83
Elevator B	5.00	3.50	4.50	4.33

In this example, although the consequence of each failure remains the same as with method 1, the introduction of different likelihood scores for each asset changes which elevator is considered more critical. Now B is more critical because although it has lower consequences of failure, its likelihood of failing is greater than A, and so its overall risk value is greater.

How does the agency use this risk of failure criticality score once derived?

- If it were seeking to prioritize work to reduce safety risks, this analysis would suggest elevator B should be ranked above (i.e., is more critical than) elevator A (3.50 versus 5.00).
- If it were seeking to prioritize work to reduce its risk to levels of service, this analysis would suggest elevator A should be ranked above (i.e., is more critical than) elevator B (4.00 versus 3.50).
- If it were seeking to prioritize work to reduce its costs, this analysis suggests elevator B should be ranked above elevator A (4.00 versus 4.50) for this objective.
- If it were seeking to prioritize work across both elevators to reduce the risk of cables snapping, this analysis suggests elevator A should be ranked above elevator B (4.33 versus 3.67).
- If it were seeking to prioritize work across both elevators to reduce the risk of door failure, this analysis suggests elevator B should be ranked above elevator A (3.33 versus 5.00).
- If it was seeking to determine where it should place most emphasis in terms of optimization of work to reduce the overall risk arising from both failure modes, it might rank elevator B over elevator A, as its total risk of failure score is higher (3.83 versus 4.33).

3.3 Method 3: Asset criticality based on total cost of ownership

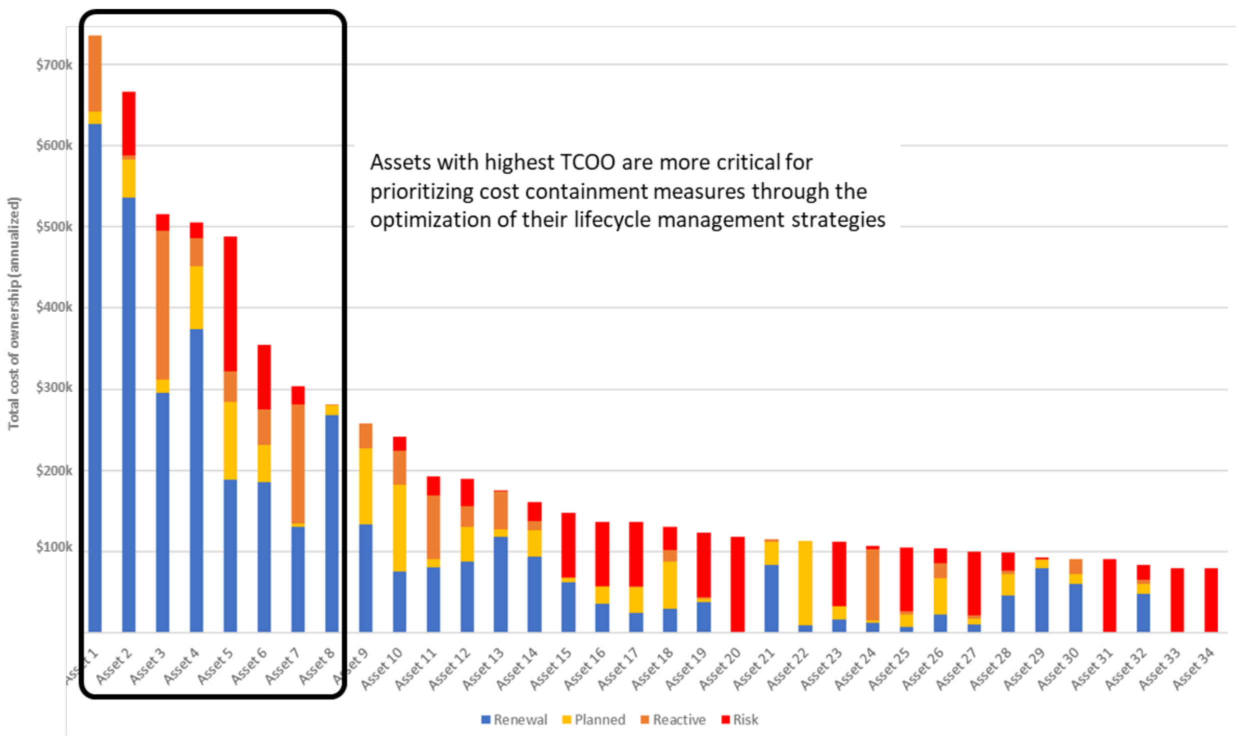
A third criticality method based on total cost of ownership is provided here for comparison purposes.

Under this method, the organization uses historical capital, maintenance and risk data to determine the annualized total cost of ownership (TCOO) for each asset, where TCOO is the combination of anticipated ongoing renewal (i.e., replacement/refurbishment) costs, planned (i.e., preventive) and reactive (i.e., corrective) maintenance costs and "risk cost" (i.e., cost arising from asset risks being realized over the course of its lifetime).

By determining the TCOO for each asset, the organization can rank them in order from highest to lowest, with the assets with the highest TCOO being the ones that account for the greatest proportion of costs borne by the agency. If the organization has an objective to lower its overall costs, the assets with the greater TCOO may be deemed more critical for prioritizing where it focuses its cost-cutting efforts—that is, there is potentially greater opportunity for achieving cost savings by focusing the optimization of life cycle management strategies on those assets that contribute most to TCOO.

In **Figure 1**, for example, assets 1 and 2 have the greatest proportion of renewal costs. This may be appropriate for the assets in question, but perhaps the organization can explore alternative life cycle strategies for the assets that lower the ongoing renewal costs (such as extending the renewal frequency), thus reducing the TCOO of those two assets.

FIGURE 1
Determining Criticality Using Total Cost of Ownership



3.4 Example of methods used at U.S. transit agencies

Table 6 provides a few specific examples of how asset criticality has been determined and used by transit agencies in the U.S.

TABLE 6
Examples of Criticality Methods at U.S. Transit Agencies

Agency	Method used	Description
Sound Transit	Risk of failure	Performed risk of failure criticality assessment across its major asset classes. The assessment did not consider specific risk to specific objectives, instead considering broad consequence of failure to the agency. The purpose of the assessment was to introduce and socialize the concept of criticality among the agency and support broad decision-making.
New York City Transit Department of Subways	Risk of failure	Piloted criticality assessment for a subset of its elevators using risk of failure, using an unweighted average of risk against the MTA's strategic objectives. The purpose of the criticality assessment was to pilot and test an approach that could support capital prioritization.
MARTA	Consequence of failure	Performed criticality assessment based on consequence of failure to safety, to determine "life safety" critical systems and the assets within those systems. The purpose of the assessment was to support capital investment prioritization.
Maryland MTA	Consequence of failure	MDOT MTA has developed a methodology for assessing criticality for revenue vehicles and facilities as part of an Asset Management System Pilot at the Eastern Bus Division. MDOT MTA is in the process of implementing this across the entire bus mode and then will focus on implementing the methodology agency-wide. Criticality is part of an overall approach to assessing condition and a risk-based approach to asset management. • Bus vehicle criticality considers the severity of impact to transit service if the bus were to fail unexpectedly. Bus criticality is assessed on a 1-to-5 scale with 1 the most critical and 5 the least critical. Because MDOT MTA rotates its bus fleet across different routes to ensure equitable public transportation across its diverse service areas, the approach for assessing the criticality of buses considers two weighted factors: service capacity and environment. • Facilities criticality considers the severity of impact to transit service if the systems were to fail unexpectedly. Facilities criticality is also assessed on a 1-to-5 scale with 1 the most critical and 5 the least critical. To assess criticality, each asset is scored on a 1-to-5 scale to indicate the consequence of failure, with 1 the most severe impact or highest consequence and 5 insignificant/low impact or lowest consequence. • An overall criticality score is calculated based on a weighted average of the criteria scores.

4. Framework for determining asset criticality

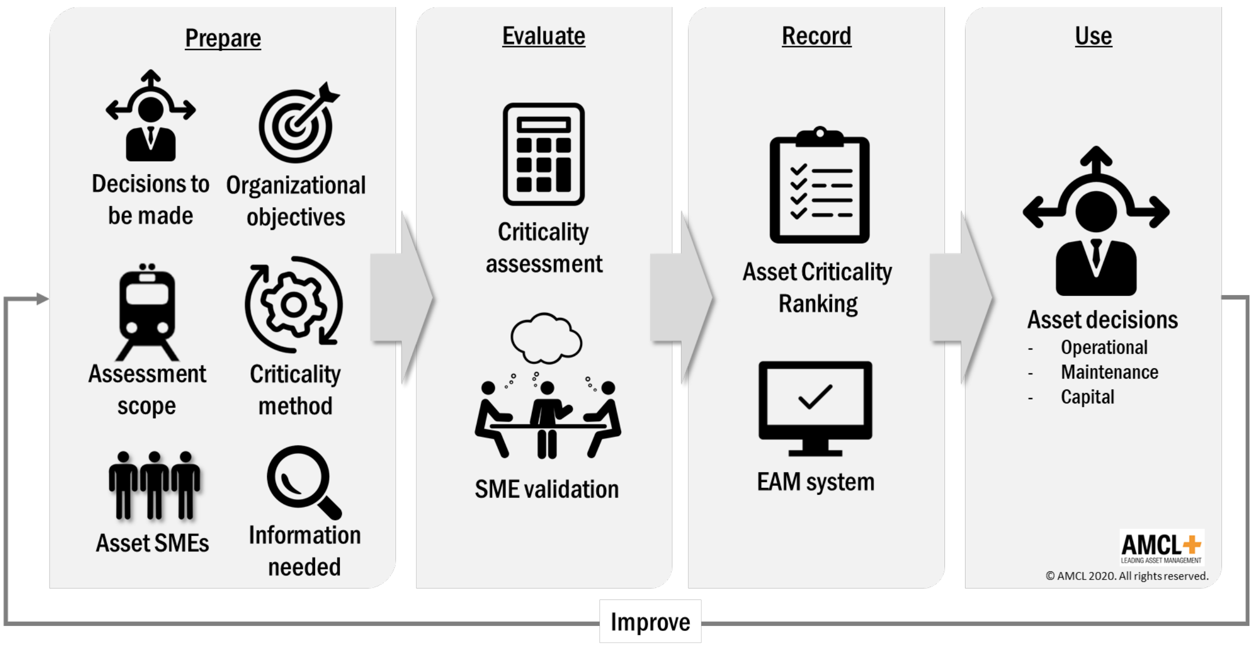
This section presents a potential framework for determining asset criticality, comprising five steps:

1. **Prepare:** Consider the decisions to be supported by the criticality assessment, ensure clarity on organizational objectives, agree on scope of assets to be assessed, select the appropriate criticality method, identify SMEs with expert knowledge of the assets, and gather information needed to support the chosen method.
2. **Evaluate:** Assess the criticality of the assets, using the defined method and available data, and validate with SMEs as necessary.
3. **Record:** Store and control the criticality assessment outcome such that it can be used to support decision-making.
4. **Use:** Support asset-related decisions with the criticality assessment results.

5. **Improve:** Based on the experience of using the criticality assessment outcome to support decision-making, identify and apply improvements to the methodology or data for future criticality assessments.

This is summarized in **Figure 2**, with more detail provided for each step in the following sub-sections:

FIGURE 2
Determining and Using Asset Criticality



4.1 Prepare

Before embarking on a criticality assessment, it is recommended that agencies identify the decisions or questions to be supported by the criticality assessment and gain clarity on the objectives of the organization.

Once these are clearly understood, the agency should agree on the method for determining criticality that is appropriate for the decision being made. Common criticality methods include consequence of failure and risk of failure, but care should be taken to consider other methods that might provide a better fit for the decision or question being asked (see **Table 1** for examples).

Once the method is identified, the agency should next agree on the assets in scope for the criticality assessment, which will be tied to the decisions being made. Should all asset classes be included, or just a subset? At what level of the asset hierarchy should the criticality assessment occur—for example, at the system, asset or component level? Should types of assets be assessed or specific assets? The bigger the scope, the more effort is required to complete the assessment, and this effort should be balanced against the expected value. Should the scope of the asset extend across multiple asset classes, the selected method should support the determination of criticality across different asset classes.

Finally, identify the SMEs for the assets subject to the assessment, and collate and review what data is available based on what is required for the chosen method.

4.2 Evaluate

Once an agency has understood its objectives, articulated its decision, selected the appropriate criticality method, confirmed the assessment scope, collected the available data and identified its SMEs, it can evaluate asset criticality. The assessment approach will vary based on the method, but all should involve discussion and validation with SMEs, as this will encourage engagement, buy-in and trust from the wider business for the resulting outcomes. One potential approach is to perform the assessment based on available data before holding SME workshops to review and validate the data used, the results it gave and any assumptions used: do they make sense? Do we need to fine-tune the analysis before using the results to support decision-making? Care should be taken to be organized and effective for the SME meetings, to respect their time.

Although it is normally preferable to use data to drive decision-making, it is not essential when determining asset criticality. Agencies should use data where it is available, but should data be missing, criticality could still be determined using SME judgment and assumptions; agencies should just accept that the resulting asset ranking maybe less robust than one based on data.

A practical example is given here: The GM of an agency has recently announced customer experience to be an important priority, and the agency is using consequence of failure to determine the criticality of elevators for the purpose of prioritizing work that may improve customer experience:

- Should it have access to passenger counts at stations, it could use these to numerically determine the relative consequence of an elevator failing at each station (the greater the station throughput, arguably the greater the consequence to customer experience of an elevator failing), and therefore rank the criticality of its elevators.
- Alternatively, it could use the duty cycle (e.g., frequency of usage) for each elevator to determine consequence, whereby an elevator that gets used infrequently may have less consequence should it fail than a corresponding elevator that is used more frequently.
- Without historical passenger count data, however, the agency could still rank the elevators based on consequences of failure to customer experience, by using expert judgment and assumptions of which stations are normally busiest, while factoring in the number of elevators in the station (or within a certain distance of the station) that might provide operational redundancy should one fail.

Both approaches yield an asset criticality outcome, but the first is more data-driven and hence arguably its results are more robust.

4.3 Record

Once the criticality assessment has been performed, the results should be recorded, controlled and consistently available across the agency to avoid multiple groups having different criticality rankings for the same asset–decision pairings.

Most commonly, criticality assessment results are recorded in two places:

- **Asset Criticality Ranking (ACR).** The ACR simply lists an agency’s assets (or asset classes) in relative order, ranked from most critical to least critical. It typically takes the form of a spreadsheet or Word document.
- **Enterprise Asset Management (EAM) system.** EAM systems can be configured to include criticality fields against each asset record (or asset class).

4.4 Use

Once an agency understands the relative criticality of its assets, it can use this information to support asset-related decision-making, including maintenance, capital and operational decisions. For example, an asset deemed highly critical to ensuring that service levels are met may warrant the following:

- more frequent or targeted application of condition monitoring or inspections
- a greater availability of certain spares
- more frequent capital replacement or renewal
- adjustments to operational usage patterns or enhanced operator training

It should be stressed that criticality will not give an agency "the answer" and should simply be viewed as another useful input to well-rounded decision-making.

Finally, agencies should consider how criticality information can be best positioned in the decision-making life cycle at the agency. For example, should consideration of criticality be a mandatory requirement for decision-making, or optional?

4.5 Improve

Based on the experience of using the criticality assessment outcome to support decision-making, identify and apply improvements to the method or data for future assessments, and rerun the assessment as new data becomes available, or as new decisions are required. For example:

- Moving from a criticality assessment based largely on SME judgment and limited data to a more data-driven assessment, should the anticipated benefits of doing so justify the cost of collecting better data.
- Develop a roadmap for how criticality can be matured and embedded into the organization's decision-making processes. For example, in year one, perform a pilot to test the method and gain buy-in; in years two and three roll out the method across all asset classes using a judgment-based approach; and in years four and five move from judgment-based to data-driven.

Be aware that as the agency uses criticality scores to make decisions and enact improvements, the criticality scores themselves might change. For example, using a consequence of failure approach to rank assets most critical to achieving operational performance might lead to maintenance or operational improvements to the most critical assets (i.e., to reduce the consequence of their failure), which in turn reduces their criticality.

Related APTA standards

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References

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Definitions

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Abbreviations and acronyms

ACR Asset Criticality Ranking
EAM Enterprise Asset Management
LOS level of service
NATSA North American Transportation Services Association
SME subject matter expert
TCOO total cost of ownership

Document history

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