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Function Based Condition Indexing of Aging Infrastructure

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One of the main challenges that the civil engineering profession facing today is the effective sustainment of aging infrastructure due to global slowdown of economy. However a systematic evaluation of the health of the infrastructure and its performance under various time bound conditions such as, natural hazards, raising population downstream of a dam, interdependence of other infrastructure etc., will enable us to allocate the limited funds in an efficient manner. This systematic approach of evaluating the infrastructure can be termed as Condition Indexing (CI).

A condition indexing (CI) system is a methodology or set of rules that may be used to systematically define the physical condition of a facility or network of related facilities. The output of a CI system is a quantitative condition index, or a number, typically between "0" and "100". The lowest possible index (CI = 0) represents the "worst" condition possible for the facility. The highest possible index (CI = 100) represents the "best," or ideal, condition.

A variety of CI systems have been implemented by state and federal agencies in the US responsible for managing complex infrastructure networks made up of numerous facilities or structures. Notable CI applications include, for example, those developed by the U.S. Army Corps of Engineers (USACE) for managing paved road networks, shore protection structures, and earth dams (e.g., Andersen and Torrey, 1995; Andersen et al., 1999a, 1999b, 2001).

In each of these cases, a rational ranking procedure is used to quantify the physical condition of the individual components comprising the larger, more-complex system. Qualitative and quantitative parameters are defined that may be observed and recorded during site inspections (e.g., corrosion of the guy wires of a tower, cracking of soil around the foundation, leaks in a dam, etc). Each component is assigned a quantitative value based on these observations to represent the physical condition of that particular component and is then weighted to capture the relative importance of that component to the overall health and performance of the structure. Weighted condition values for all of the system components are summed to generate an overall condition index for the facility.

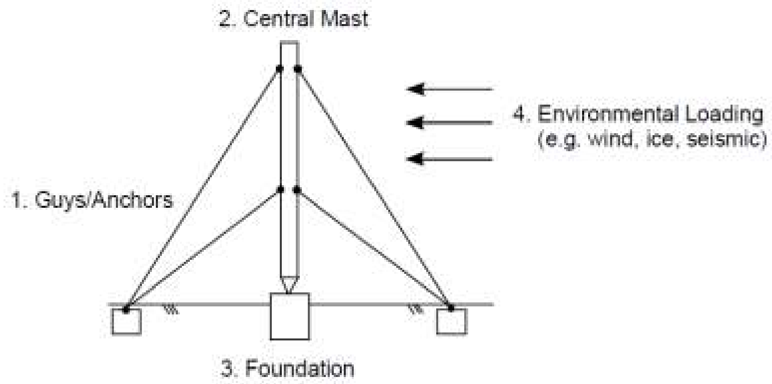
Overall condition may also be weighted by the severity of anticipated environmental loads at the structure's location (e.g., seismic, wind, ice) and by the relative importance of that particular structure in the performance of the overall network (e.g., the number of communication channels linked to a particular radio tower, purposes served by a dam like recreation, irrigation, power, water supply, etc). The output from the CI system is a numerical value that reflects the structure's level of deterioration or loss of functionality, which may in turn be used as a rational basis for recommended action and a corresponding basis for the managing agency to allocate funds for repair, evaluation, maintenance, and rehabilitation (REMR) activities.

What steps to follow in developing a CI system?

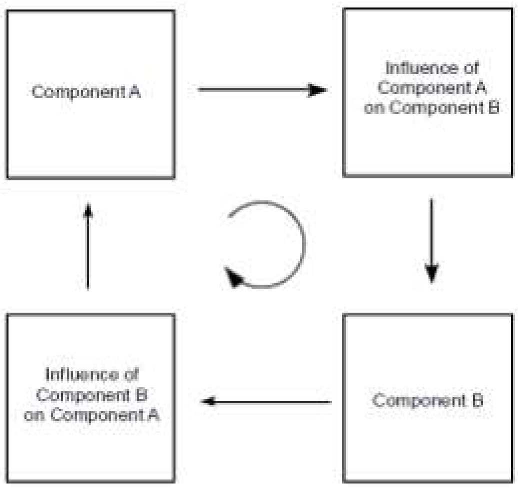
Although numerous types of CI systems exist (e.g., Hudson, 1992), many adopt the same general approach - The structure one wishes to assess (e.g., a communications tower) is sub-divided into several subunits (e.g., central mast, foundation, guy wires); the condition of each subunit is rated; and the subunit ratings are combined in a rational and systematic manner to compute an overall condition of the structure as a whole.

Andersen and Torrey (1995) describe several steps required to develop a "function-based" conditioning indexing system. A simplified synthesis of those steps is given below:

1) Identify the functional components of the system. An example of communication tower network is given below:



2) Develop a component interaction matrix (see figure below).



3) Code the interaction matrix to represent the strength of each interaction.

4) Define ranges between ideal and failed conditions for each component. The table below can be used a general guide in defining ranges:

Condition Index	Condition Description
85 – 100	Excellent: No noticeable deviation from ideal condition
70 – 84	Very Good: Only slight deviations from the ideal condition are evident
55 – 69	Good: Some deviation from the ideal condition evident but function is not significantly affected
40 – 54	Fair: Moderate deviation from the ideal condition evident but function is adequate
25 – 39	Poor: Serious deviation from ideal condition in at least some portion of the component; function is inadequate
10 – 24	Very Poor: Extensive deviation from ideal condition: Component is barely functional
0 – 9	Failed: All or a potion of component is missing or has failed

5) Develop weighting factors and formulate condition index scalar.

How to use a CI System!

Procedures for conducting a condition assessment using the proposed CI system may be summarized as follows:

1) Rank the physical condition of each principal component from 0 to 100 based on the observed deviation from ideal conditions. Generally ideal conditions are predefined best case scenarios. This produces definite numbers from 0 to 100 for various components.

2) Compute the overall CI of the structure by applying weighting factors using equation developed by including various weighting factors and condition of identified components. An example of a similar equation developed for communication towers is given below:

$$CI_{gt} = CI_{gc}(0.31) + CI_{ga}(0.19) + CI_{cm}(0.31) + CI_{fd}(0.19)$$

3) Correlate the overall CI to a qualitative description and recommended action. An example of CI scale and recommend action is given in table below:

Condition Index	Condition Description	Recommended Action
85 – 100	Excellent: No noticeable defects; some ageing or wear may be visible	Immediate action is not warranted
70 – 84	Very Good: Only minor deterioration or defects are evident	
55 – 69	Good: Some deterioration or defects but function is not significantly affected.	Economic analysis of repair alternatives is recommended to determine appropriate action
40 – 54	Fair: Moderate deterioration but function is adequate	
25 – 39	Poor: Serious deterioration and function is inadequate	Detailed evaluation is required to determine the need for repair, rehabilitation, or reconstruction. Safety evaluation is recommended.
10 – 24	Very Poor: Extensive deterioration; barely functional	
0 – 9	Failed: No longer functional	

4) Develop CI for all the assets in an infrastructure system and allocate the available funds as per the CI of the asset.

5) Organize an electronic database describing conditions and physical properties of each asset and its CI.

In conclusion a function based condition indexing of various infrastructure systems is an important tool to efficiently assess:

- The condition of a structure;
- Identify critical structures, and;
- Can easily apply this technique to various facilities (pavements, bridges, culverts, dams etc) and gives a level playing field in allocation of funds.

References

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