Heavy Rail Transit Station Physical Condition Index: An initial framework

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Synopsis

This paper presents a proposed Condition Index for Heavy Rail Transit stations. Based upon existing indices used in bridge and pavement management, the index is designed to help transit agencies in management of their physical assets. The proposed index examines with physical components of the transit station and utilizes a 10-point scoring method. Results of a field test on an operational system are discussed along with opportunities for further research and improvement of the index

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Sound funding of transportation infrastructure is a crucial part of any transportation agency. In addition to funding infrastructure improvements, most transit agencies in the United States are responsible for maintaining and operating their respective transit systems. This has led to several of them facing severe budget crises over the past few years, including the Metropolitan Atlanta Rapid Transit Authority (MARTA) and the Pittsburgh Port Authority (The T). While the U.S. federal government provides funding for major capital investments such as provision of rolling stock and funds for new construction, the U.S. Department of Transportation (USDOT) through the Federal Transit Administration (FTA) provides no operational funding for major urban public transit agencies, leaving operational funding to be provided for by state or local funds. This leads to examples such as MARTA where the authority has plenty of resources available for capital improvement projects, since the 1% locally collected sales tax must be split at least 45% for operating revenues and up to 55% for capital revenues according to Georgia law. Therefore, financial crisis at MARTA and at other agencies around the U.S. is in reality a crisis about operating funds.

Part of the solution for as system like MARTA could be increasing overall transit ridership, particularly on the rail system which has lower operating costs per passenger mile at $1.49 for heavy rail versus $2.14 for bus. A critical part of this strategy of increasing rail system ridership will be making sure that the transit passenger experience in the rail station itself contributes to the overall transit trip attractiveness. In other words, physically, the transit station should be in good condition. Intelligent use of available capital funds to improve those stations whose physical condition discourages passengers from riding will help MARTA gain the most new riders for their investment.

With this point in mind, the next logical question is “Which stations are in poor physical condition?”

One way to determine which stations deserve attention for whether they can improve their physical condition and connectivity is development of a Transit Station Physical Condition Index (TSPCI) that presents a network level analysis of the rail stations.

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After conclusions, please insert: endnotes, references, acknowledgements and appendices.

DETERMINATION OF FRAMEWORK

A review of existing literature revealed that a number of condition indices are already in use, particularly for evaluating bridge and pavement systems. One of the most common indices in use in the United States is the Pavement Condition Index (PCI). This index calls for a physical examination of the pavement and a general evaluation of the pavement condition through visual observation. The result is a single number result that allows for a network level examination of pavement condition throughout a roadway network. While this type of examination can provide a good snap-shot of where to invest resources to improve pavement condition, it is independent of other practices such as examining life-cycle costs and reliability assessments. While the proposed TSPCI in practice performs the same function as the PCI, it is envisioned as part of a larger process.

Incorporation of an index into a life-cycle cost approach is useful since the index can be used to help in formulating when to repair a particular piece of infrastructure or determining when infrastructure has reached the end of its useful life. Created a TSPCI that could easily be incorporated into another analysis process such as a life-cycle cost analysis or reliability assessment enhances the usefulness and value of the TSPCI by providing an agency not only with a snapshot of their current infrastructure condition, but also a tool that can be used to help better manage their assets. Ideally, the TSPCI should form an integral part of what Shen and Grivas (1996) define as a Decision Support System (DSS). A DSS is defined as a system that “incorporates both data and knowledge that can improve the effectiveness of the decision and the efficiency of the whole decision process”. An infrastructure preservation DSS consists of two major parts – a database that provides overall information at the network level and a knowledge base that provides assistance at the project level. A condition index is well suited to providing as basis for creating the database part of the DSS. Therefore, one goal of the TSPCI is not only to provide an overview of the transit station condition, but to also provide a database that can be used to develop an overall DSS to help a transit agency better maintain and preserve its valuable infrastructure assets.

The overall framework of the TSPCI consists of building a database of information regarding the physical condition of the stations obtained through physical observation. That information is quantified based upon measures discussed below. Those quantified numbers are then aggregated into a single condition index number. Therefore, the TSPCI is an aggregate collection of visual observations. While this leads to some variability based upon the observer, the TSPCI is designed to limit this variability by limiting the number of choices available for the observer to describe the transit station condition. Figure 1 illustrates the overall process of determining the TSPCI.

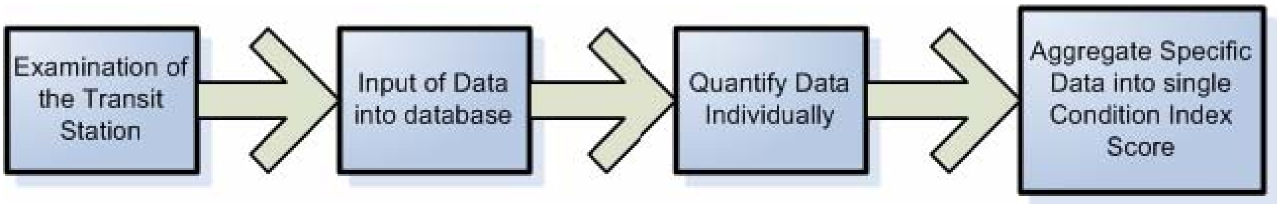

Figure 1: Overall process for determining the Transit Station Physical Condition Index

Figure 1 shows the progress from the initial field evaluation of the transit station into the input of the required data elements into an accessible database. Afterwards, each of the elements in the database is quantified by some predetermined factor such as a condition of the facility or type of material used with the quantities bused based upon an external measure that relates to the importance of the database element. Finally, the quantified data are aggregated into a single number that becomes the Condition Index Score.

Additionally, the initial condition index database should contain additional information that may not be completely necessary for the network analysis, but is useful as part of the overall DSS. For example, as Mohammadi, Guralnick, and Yan (1995) note, to fully use a network analysis it is necessary to be able to identify what specific deficiencies exist in the facility so that a project level decision can be made once the network analysis has revealed which facilities merit closer inspection. For example, suppose use of the TSPCI identifies three stations that warrant closer inspection. A basic TSPCI would reveal only that each station has flooring in poor condition with no information on what type of flooring is there and therefore would require a further inspection to provide information about why the flooring is in poor condition. However, a TSPCI that incorporates what kind of floor is present in the station – say two of the stations have tile floors and the other station has a concrete floor – now a decision maker knows to send tile repair experts to the first two stations and a concrete repair team to the third station. By incorporating additional information during the additional physical examination, a decision maker is able to make a project level decision immediately after the network level analysis reveals where there are problems. Taking into account the role of the condition index as part of a larger DSS led to the development of the specific elements of the index discussed below.

SPECIFIC ELEMENTS OF THE PROPOSED HEAVY RAIL STATION PHYSICAL CONDITION INDEX

What are elements of a good condition index?

Before discussing the specific elements of this index, it is important to develop an idea of what is the role of a good index outside of the context of providing a database for a DSS and providing an network level analysis. For example, it is entirely possibly to develop a condition index that allows for a network level analysis and contains a useful database, but is of little practical use or measures something other than physical condition. There are three necessary elements to a useful condition index:

Differentiability
Repeatability
Relevance

Differentiability is defined as the ability of the condition index to identify differences between the different elements being evaluated. For example, a condition index that identifies every element in good condition or in which every element receives the same score is of little practical use since it is impossible to identify where resources should be expended. There are useful condition index should produce a range of values that allow the elements to be placed in different categories.

Repeatability refers to two things. First, a good condition index should produce the same results if used by two different evaluators. Therefore, a good condition index should eliminate qualitative decisions based upon the evaluator's opinions. If this is not possible, then a condition index should seek to minimize the number of qualitative decisions an evaluator will have to make. The second part of repeatability is the ability of the condition index to be used again over time to compare changes over time. In other words, the condition index should not include any measures that are outside the control of the element's owner that will automatically change over time such as factors dependent on the weather the day the condition index was conducted.

Relevance is defined as whether the condition index is actually useful for evaluating what it says it evaluates. In other words, a condition index should provide some idea of the actual condition of an element. For example, a TSPCI that included factors such as frequency of train service, number of people using the station per day or average passenger waiting time but does not include factors such as whether elevators are working or the condition of the ceiling is not a relevant condition index. While these example factors might provide useful information in another context, the example factors provide no information of the condition of the transit station and therefore are not relevant to a Transit Station ***Physical Condition*** Index.

A proposed heavy rail condition index

The specific elements of the index for a heavy rail TSPCI consists of two different types of elements – those present in all stations and those elements that may or not be present in all stations. Specifically, if a station is not a subway (or underground) station, then it may or may not have a roof or walls. Figure 2 below illustrates the specific elements examined in the proposed physical condition index that is placed into a database field. There are two main types of elements examine in the index: those elements that require some judgment on the part of the evaluator – such as roof type and condition – and those elements that require the evaluator to input a specific value with no judgment required by the evaluator – such as the total number of escalators and the number of operational escalators. While it would be desirable to include only those elements that do not require evaluator judgment, leaving out elements such as roof condition would severely limit the usefulness of the TSPCI. As Figure 2 indicates, the type of material used for certain fields is required in direct anticipation the TSPCI will form part of an overall DSS as discussed previously.

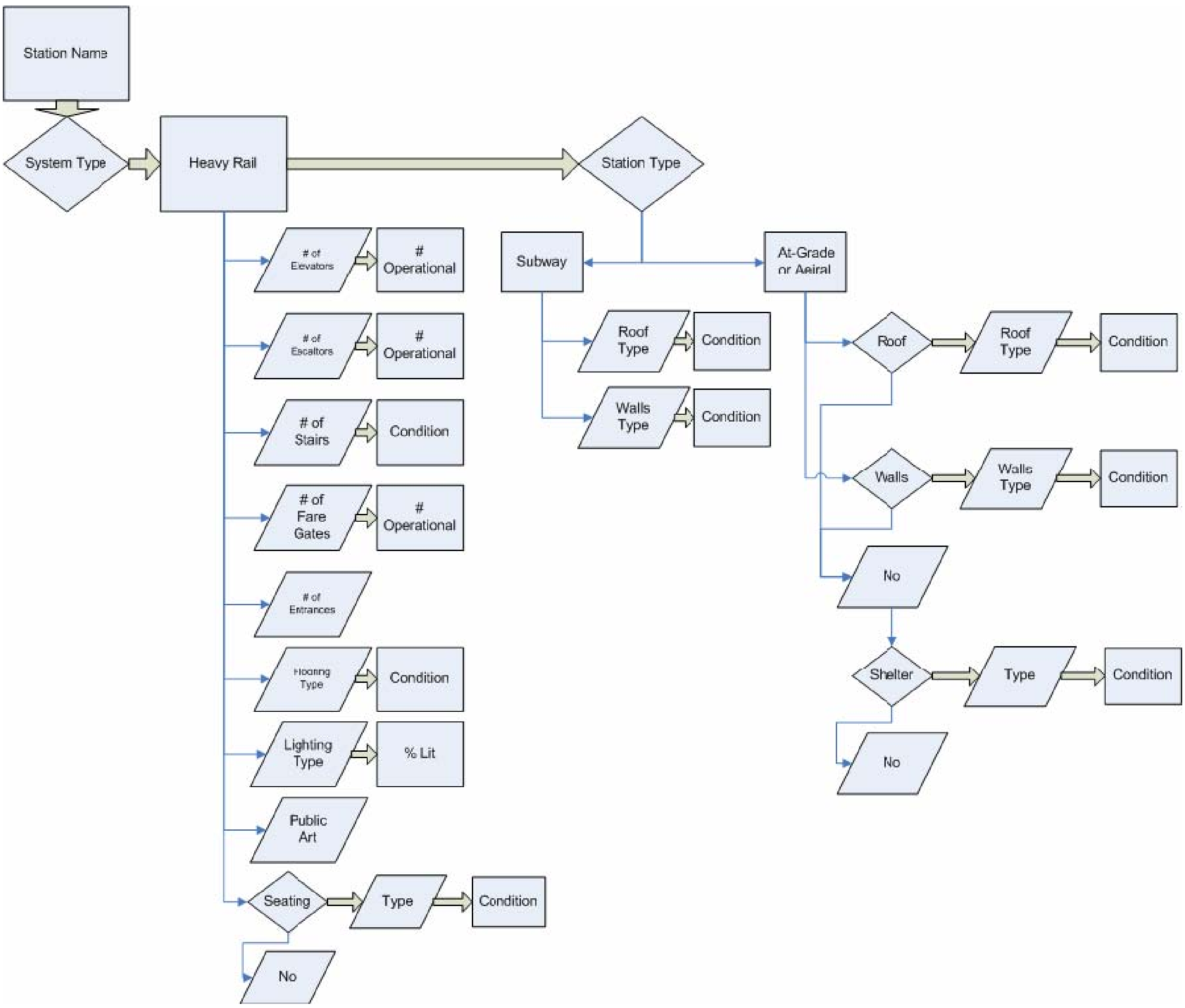

Figure 2: Specific Elements of the Proposed Heavy Rail Transit Station Physical Condition Index

Recognizing that many elements such as floors may incorporate several materials (i.e., concrete with tile inlay), evaluators are instructed that the main material used, such as concrete in the example, is the material to place in the “Type” field. A predefined list of allowable materials, usually the most frequently used construction materials, are allowed to be placed in the “Type” field. For example, predefined values for the “Flooring Type” field are: Concrete, Tile, Brick, Stone, Wood, Metal, and Other. In addition for “Type,” the evaluator must also input the condition of the facility. In order to minimize variability between evaluators, the “Condition” field is limited to three values – “Good”, “Fair”, and “Poor” – each of which is clearly defined.

“Good” – Excellent physical condition with few signs of wear such as cracks, water stains, etc. Overall the facility is in an almost like new condition that enhances the overall transit riding experience

“Fair” – Adequate physical condition, but showing some signs of wear such as visible and noticeable cracking, presence of graffiti, noticeable water-stains, etc. Overall, the facility is able to perform its function, but is showing its age or great use. The facility does not positively or negatively influence the transit riding experience.

“Poor” – The facility is in poor physical condition such as major leaks in a roof, major cracking on a concrete or tile floor that could cause transit customers to trip, unusable seating, etc. Overall, the facility severely diminishes the transit riding experience.

Providing a pre-defined list of acceptable types of facilities and defining the allowable “Condition” field values will reduce the qualitative judgments of the evaluator and thereby increase the repeatability of the TSPCI. The system type field currently allows for the input of other types of systems of the heavy rail in anticipation that physical standards similar to these developed for heavy rail systems will be developed for other system types.

Scoring

Each of the fields used for scoring are directly related to the physical condition of the station in recognition of the principle of relevance. The other information collected is used once the overall TSPCI for the network has been developed. There are ten (10) fields used for scoring the condition of the transit station. They are:

# of Operational Elevators
# of Operational Escalators
# of Operational Fare Gates
% of Operational Lighting
Presence of Public Art
Condition of Stairs
Condition of Floor
Condition of Seating
Condition of Roof
Condition of Walls (or other vertical shelter)

The first three items receive a score of 1 if 75% or more of those facilities are operational (i.e. 3 out of 4 elevators work), a score of 0.5 if between 50% and 75% of those facilities are operational (i.e. 2 out of 4 elevators), and a score of 0 if less than 50% of these facilities are operational (i.e. 3 out of 10 fare gates). There are three values that can be placed in the “Lighting” field – 90%, 75%, or <75% - and these values correspond to a score of 1, 0.5, and 0 respectively. The presence of public art receives a score of 1 if art is present and 0 otherwise. For the last five (5) items, the score is determined by condition. A “Good” condition rating receives a score of 1. A “Fair” condition rating receives a score of 0.5. A “Poor” condition rating receives a score of 0.

The score of each of these fields is added together to produce a number between 1 and 10 and that result is the Transit Station Physical Condition Index Result.

TEST RESULTS

In order to test the usefulness of the TSPCI, a field test of eight stations on the MARTA heavy rail system in Atlanta was conducted. The stations were located throughout the MARTA rail system. For field test a Mobile DB® database was developed. This software operates on the Palm OS® utilized in many handheld computers including the Tungsten T® used in this field test. A total of twenty-five (25) fields that replicate the desired elements on the Heavy Rail Transit Station Physical Condition Index presented in Figure 2 were used in the database. Since the Mobile DB software limits a user to twenty (20) fields, two separate databases were used that were merged into one MS Access® Database.

Once the stations were visited and the observations entered into the handheld computer, the data was transferred to an MS Access database constructed with the same field present in the Mobile DB database. The next step was to develop the Condition Index Score fore each of the field test stations. Table 1 below presents the scores for each of the stations along with the station name and type.

Tab 1: Initial Field Test Results for TSPCI

Field	Station 1 Results	Station 2 Results	Station 3 Results	Station 4 Results	Station 5 Results	Station 6 Results	Station 7 Results
Station Name	Midtown	Arts Center	Buckhead	Five Points	West Lake	East Point	Inman Park/ Reynolds-town
Station Type	Subway	Subway	At-Grade	Subway	At-Grade	At-Grade	At-Grade
# of Operational Elevators	1	1	1	1	1	1	1
# of Operational Escalators	1	1	1	1	0	1	0
# of Operational Fare Gates	0.5	0.5	1	0	1	1	0
% of Lighting Working	1	1	1	1	0.5	1	1
Public Art	1	1	1	1	0	1	1
Condition of Stairs	1	1	1	1	1	1	1
Condition of Floor	1	1	1	0.5	1	1	1
Condition of Seating	1	1	1	1	1	1	0.5
Condition of Roof	1	1	1	0.5	0.5	1	1
Condition of Walls/Shelter	1	1	1	0.5	1	1	1
Overall TSPCI Score	9.5	9.5	10	7.5	7	10	7.5

As Table 1 shows, it is possible to develop an overall Condition Index Number using the framework and process laid out previously. The next section will discuss whether this TSPCI is useful and areas for improvement and enhancement.

COMMENTS ON THE OVERALL EFFECTIVENESS OF THE TSPCI AND NEXT STEPS

The initial field test reveals that it is possible to create a TSPCI Score and the TSPCI can be used to differentiate between stations. While the scores are high, they do identify that West Lake, Five Points, and Inman Park are worth examining for physical improvements. Since heavy rail stations represent significant public investments and are some of the most heavily patronized areas of a transit system, a base heavy rail TSPCI should ideally be set to a level of around 7.5 or 8 or higher. The next step is to examine the rest of the MARTA rail system and see if the TSPCI can provide useful system wide information.

While the TSPCI did provide differentiation between the stations, another way to increase the differentiation between would be to have the score based upon not only the condition of an element (i.e. seating or flooring) but also to have a weighted score based upon the maintenance costs of the materials (i.e. maintenance of a tile floor vs. maintenance of a concrete floor). This additional differentiation may be useful to some agencies that place a high priority on reduction on maintenance costs.

During the evaluation it was noticed that MARTA had recently installed new lighting that the malfunctioning fare gate equipment negatively impacted several TSPCI scores. Intriguingly, MARTA is in the midst of a station rehabilitation program and the installation of new fare equipment – two activities that suggest that the TSPCI can correctly identify deficiencies in station condition in ways that will be useful to transit agencies.

There are also two additional next steps that should be taken to increase the ease of use for the TSPCI. First is the automation of the TSPCI so that an initial score can be developed either as the data is collected in the field or once the data is downloaded into Access. This requires development of a coordinated programming effort whose scope was simply beyond the time constraints of this project. The field data collection device would only allow the evaluator to enter the specific pre-defined field presented in the form of a drop-down menu or checkbox. Next, the data would either be stored on the handheld itself if a direct connection to the main computer is available – such as through a serial port or Bluetooth access – or on a removable memory card to enable the field data to be loaded directly onto the main computer.

An additional step would be to include another measure of physical design that is important ridership and convenience of a transit station – the connectivity and accessibility of the station. This would be a set of additional fields to measure whether the transit station provides adequate connections to transfer services such as bus or other rail services, whether movement throughout the station is intuitive or confusing for riders, and whether the access / egress points of the station are convenient to riders' origins and destinations. Combined with the TSPCI, a physical connectivity index would provide a transit agency with a powerful tool to gauge their stations from a rider's perspective from a point of view of both from an attractiveness of the station itself and the usefulness of the station. A physical connectivity index could rely upon the standards set by the Transit Quality of Service Standards and Passenger Information Guidance Systems – both developed as part of the Transit Cooperative Research Program (TCRP) of the United States Federal Transit Administration.

The refined index, including the more detailed definition of qualitative elements, the improved mobile data collection, and integration with a connectivity index will yield two results. First, transit agency will have a tool to easily evaluate the condition of their heavy rail stations on a routine basis providing an ability to monitor the maintenance needs of different stations and identify stations where resources can be used more effectively. Additionally, with the software publicly available as freeware and compatible with existing mainstream computer programs, transit advocacy groups such as Citizens for Progressive Transit (CPT) in Atlanta or Citizen's Taking Action (CTA) in Chicago, have a tool to independently evaluate transit station condition and potentially create public support for increasing transit agency resources

Finally, the development of this TSPCI for heavy rail stations could serve as an initial framework for developing condition indices for commuter rail stations, light stations, Automated Guideway Transit (AGT) stations, and potentially expanded to include bus services as well. While those indices will be based upon the specific requirements and characteristics of each mode, a comprehensive set of indices could help major transit agencies more adequately utilize their increasingly scare resources.

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