Incorporation of GIS in Calculation of Cost Index for Highway Construction

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Abstract
This study demonstrates that LBP can be applied independently to a highway construction project using a GIS. LBP has previously been utilized for highway construction projects, but only as a complement to other approaches. Several digital technologies are currently being used to plan and schedule highway construction projects. It will be simpler to keep track of, comprehend, and execute plans and timetables with greater precision and comprehension if there is a single platform for all of the data. This article uses a literature review and a national survey of questionnaires to find out how HCCIs are currently calculated and used. For the purpose of calculating HCCI, construction item bundles are constructed using item level and categorical market baskets. The Fisher index is the indexing formula that is utilized by state DOTs the most frequently, as stated by the FHWA and the IMF (IMF). Despite the large number of people who could benefit from HCCIs, there are few current users in state DOTs.

1. INTRODUCTION

Activities that are completed at multiple locations on a construction project are known as repetitive construction. Projects that cover a large area and are carried out repeatedly are referred to as repetitive linear projects. Tunnels, trains, pipelines, and motorways are all examples of linear projects. These projects are similar to manufacturing assembly lines, but instead of moving the product along a predetermined path, workers and equipment move along the project's length as it is built to complete the tasks. Crew members are accountable for completing a particular project as a whole. When a crew completes its task in a location, that location becomes accessible to the next team. Highways and other linear projects have fewer activities than building projects, but their design is important for keeping workers motivated. Long periods of inactivity by crews are extremely harmful to such machinery. the most significant task, LBP shifts the focus of planning away from activities and toward places. The objective is to monitor workers' movement between the various locations where the project is being worked on. There are distinct tasks and amounts associated with each site. Until the project is finished, crews working on a particular project move from one site to another.

When all of an area's responsibilities have been accomplished, it is deemed "complete." This method may reduce design flaws, project delivery risk, and total manufacturing costs for future fiscal years. Accurate construction cost projection in the early stages of project planning and programming is essential. If the construction costs are underestimated, the project will be reduced in scope, canceled, or the owner will need to seek additional funding. Overestimating construction costs limits the number of projects that can be completed simultaneously. Nonetheless, it is

challenging to calculate early costs because the project's scope has not yet been fully defined. Estimating becomes more difficult when the construction market is volatile. Successful contract awards were included in the FHWA's Bid Price Index (BPI), which was used to generate NHCCI, a more accurate reflection of the current highway construction market conditions (FHWA, 2014). Numerous state transportation departments (DOTs) have accepted suggestions from the Federal Highway Administration (FHWA) (HCCIs) in order to create and maintain their own cost index data.

According to White and Erickson (2011), state DOTs' current market conditions and purchasing power can be determined using indicators like the HCCI index. By looking at patterns from the past, future market conditions can be predicted. The HCCI can be used as an early warning system for future price changes. HCCIs can be used to keep track of construction costs, and the amount currently spent building roads can be fixed (FHWA 2014a). PIERCE and others 2012) used material-specific cost indexes for price adjustment clauses, and Dodier (2014) suggested using HCCI's historical trend to set gasoline tax rates. HCCIs can also be used to evaluate the effects of natural disasters on the construction industry (Cheng and Wilmot, 2009).

Despite their relevance and potential application areas, many state DOTs have complained about a lack of direction in the development and updating of their state-level HCCIs (Walters and Yeh, 2012). The methods they use to calculate HCCI are constantly being improved. The researchers want to discover and document the current methods for calculating and implementing health care cost containment initiatives (HCCIs) using published research and a wide-ranging questionnaire.
“CostIndexingTheories” The cost indices can only be created by combining data from two distinct time periods. An index is typically constructed using data from the base year and unit prices from the current year (International Monetary Fund, 2010). This indexing formula is known as the Lapsers index.

These two indices are considered to be "twins" in the theory (IMF 2010). By averaging their results, the most accurate estimater for the same concept can be compared. To put it another way, the twins' positive and negative biases are eliminated by averaging. However, there are a number of ways to determine the average of these two indices. The geometric mean of the two indices previously mentioned can be multiplied by the following formula to determine the Fisher index:
Some people prefer to use Fisher and Walsh indices, which take into account both past and present prices and quantities, as an alternative. The prices and quantities of both eras are handled in the same way by superior indexes (IMF 2010)

<table>
<tr><td colspan="6">Complete highway project (100 km)</td><td>Level 1</td></tr>
<tr><td colspan="3">Highway segment awarded to contractor A (50 km)</td><td colspan="3">Highway segment awarded to contractor B (50 km)</td><td>Level 2</td></tr>
<tr><td>15 km</td><td>15 km</td><td>20 km</td><td>20 km</td><td>15 km</td><td>15 km</td><td>Level 3</td></tr>
<tr><td colspan="6">Each 100 m segment of highway with estimated quantities, construction material, and crew requirements</td><td>Level 4</td></tr>
</table>

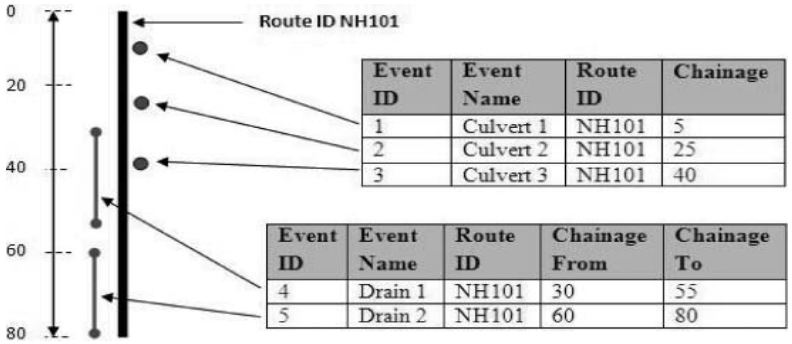
Fig.1 Locationbreakdownstructure(LBS)atdifferentlevels

2. LITERATURE REVIEW

Because they are both network-based methods, CPM and the Program Evaluation and Review Technique (PERT) are frequently utilized in highway project planning. Planners have a lot of animosity toward these approaches (Herbsman, 1987; NCHRP 2000). The difficulty of maintaining crew continuity, the difficulty of employing various crew strategies, and the fact that task production rates are unavailable at any given time during the project execution are some of the primary limitations of these methods.

Bar charts are one of the most effective methods for organizing smaller projects. Being able to prepare and comprehend them quickly and easily has distinct advantages. As a result, they face a significant challenge when it comes to resource and time management: However, while the graphical representation of crucial production information is simpler to visualize, location-based scheduling and network-based approaches require more time and effort to develop. It may also be helpful in identifying spatial and temporal conflicts between various activities. It is possible to plan for long-term developments like highways with this information. In addition, location-based scheduling charts include information such as lead time, synchronization, concurrency, work in progress, sequence and direction, interfering trades, and buffers. Traditionally, the first step in highway construction planning is to estimate the total amount of work required throughout the project. Quantities are calculated using design drawings created with CAD-based technologies. The numbers are stored and calculated using spreadsheets like this one made with Microsoft Excel. Equipment, labor, and materials are all included in this. You can learn about the materials, labor, and tools that will be used to complete specific jobs from the design documentation. In the same spreadsheet, all of the current prices for materials, labor, and equipment are recorded. Although this is not always the case, the size of the equipment is typically determined by its availability and the circumstances on the job site. Work durations are typically estimated using normal production rates, regardless of the equipment used. It is possible to calculate job durations and costs for a specific time unit. According to Hassanein & Moselhi (2004), in order to speed up the completion of each component, the project may be divided into smaller sections based on physical obstacles like mountains, valleys, and rivers or the number of personnel that can be assigned to multiple regions at once. Depending on the tasks that need to be completed in each section, CPM or Gantt charts are created using software like Primavera or Microsoft Project. Parts of LBP are used in general in highway construction planning. The reliability and consistency of the final plans and schedules may improve if the LBP method is used more frequently. You will be able to estimate the amount of labor required for each section with greater accuracy if you begin by dividing the highway into smaller sections. For instance, as a result, the tasks that need to be completed in each phase will be easier to identify and define. Based on the unique qualities of each crew member, different combinations can be chosen for different segments. Multiple production rates may be assigned to distinct segments in order to provide a more accurate estimate of the amount of time required to complete a given activity. Contractors can be paid in accordance with the actual location of their work with the help of location-based cost estimates. This method of payment guarantees that each job will be finished at each location. A review of the literature reveals that, in contrast to other systems like CPM or PERT, location-based planning has few studies and no computer implementation. As a result, complete sites may be overlooked during the final evaluation of long-distance projects. Few studies have used case studies to demonstrate that linear projects like roads are better suited to the linear scheduling approach. There are very few studies on highway

construction that specifically focus on earthwork; The majority of them are focused solely on building construction. Additionally, research reveals that various phases of building planning have investigated the GIS's potential for investigation. Project management, cost estimation, and schedule visualization are just a few of the many uses for GIS data management in the construction industry. A standalone GIS-based planning and scheduling tool has not been the subject of previous research. This study focuses on the LBP approach for highway construction using GIS.



Event ID	Event Name	Route ID	Chainage
1	Culvert 1	NH101	5
2	Culvert 2	NH101	25
3	Culvert 3	NH101	40

Event ID	Event Name	Route ID	Chainage From	Chainage To
4	Drain 1	NH101	30	55
5	Drain 2	NH101	60	80

Fig.2 Route and event features

3. PROPOSED SYSTEM

Georeferenced data can be retrieved and managed with the help of a geodatabase, which is a relational database management system (RDBMS). A lot of visual data is stored in feature classes. Utilizing feature classes, features are grouped according to their nature and function (point, line, or polygon). Culverts were represented by simple points in the point feature class, whereas pavement layers, side drains, and breast walls were all represented by lines. The properties of each and every graphic element are linked dynamically and stored in tables. A feature table is immediately generated whenever new features are added to a feature class. A unique object identification number, which can be found in each row of the feature table, is how objects are identified.

Using ArcGIS, the highway alignment has been transformed from a line feature into a route feature. A route is any line that can be measured along its entire length. A series of events along the route resulted in the proper placement of numerous highway construction pieces along the route feature. A "event" is any event that occurs along a route, whether at a single point or along a continuous line. A point event is only defined by its location, whereas a line event is described by its beginning and ending positions. As an illustration, Route ID-NH101, for instance, has 80 chainage at the end and zero chainage at the beginning. On the road NH101, all three points and two lines are positioned in their proper places. A point or a line event is used to represent drains and culverts, respectively. The tables that are displayed are automatically generated when events are defined. These tables contain event and route data. As long as certain bid elements make up a sufficient portion of the overall building expenditures, they can be used directly without being divided into other categories. Because it will provide the indexing formula with data that is more finely grained, this approach can be referred to as an "item level market basket." Marshall hot-mix base and wear course stones, Marshall hot-mix base course, class B concrete, reinforcing steel bars, and type 1 guardrail are the components that make up the Highway Condition Classification Index (HCCI) of the West Virginia Department of Transportation.

For the HCCI to accurately represent changes in the construction industry and construction prices, it is necessary to select the appropriate construction materials. Ten participants stated that the HCCI

was calculated using goods that were bid on more frequently. The quantity and unit price of each item or category must be known for two consecutive periods. If a product's price and quantity are uncommon in one era, the analysis should either remove that product or use prices from historical data from earlier periods. Using any of these approaches, calculating the HCCI takes a lot of work. State DOTs use elements that are frequently used to avoid dealing with missing values. According to Collins and Pritchard (2013), the Ohio Department of Transportation uses a missing-ness factor that they developed and applied in order to determine whether or not something occurs frequently enough to be included in the HCCI calculation. The HCCI computation process has also been automated with SAS® software by the Ohio Department of Transportation.

If only the most common ones are chosen, larger, less common things may be overlooked. It is possible to use data from previous periods when data for those items are not available for a specific item period because the DOTs of six states take the higher expenses into account even when they are rarely used. In a similar vein, the total cost of building a house may be affected by the prices of variable items.

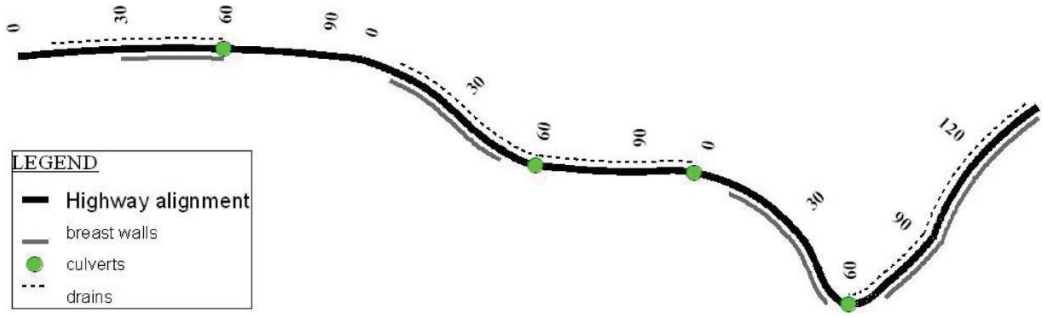


Fig.3 The route of the highway and the components of construction are situated in accordance with the chain of command

However, if the objects in question aren't very big or infrequent, then incorporating them would only add unnecessary complexity. Only one responder (Tennessee Department of Transportation) considered volatility to be an important element in determining market basket

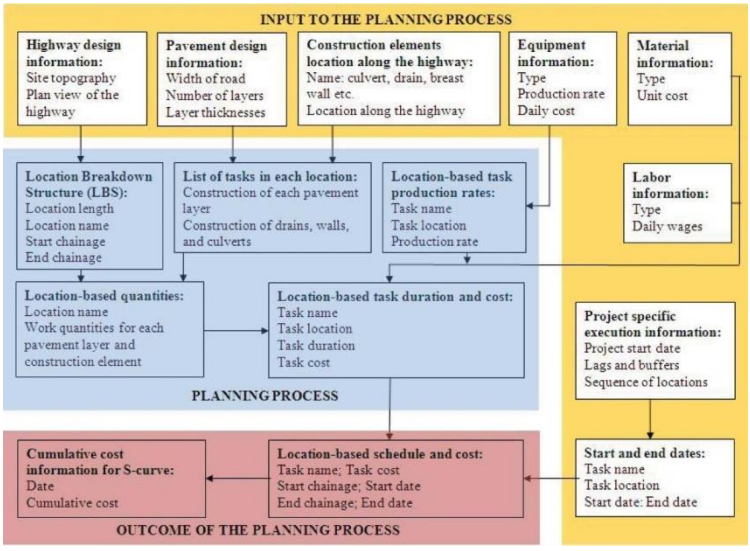


Fig.4 Proposed Methodology

5.CONCLUSION

An HCCI (Highway Construction Cost Index) greatly facilitates preliminary cost estimations for the planning and budgeting stages. The FHWA and state DOTs calculate HCCIs in order to monitor the national and state construction markets. There are two ways to generate an itemized list of construction materials for the HCCI calculation: a market basket with categories and b an item-level market basket Because it lets more items be included, the categorised market basket is being used by more people to calculate HCCI. State transportation departments frequently refer to the Fisher index as an "ideal" index due to its excellent indexing formula. Items can be added or removed, and their weights can be changed over time, thanks to the chained Fisher index. State DOTs must manually cleanse and transform the data they collect in order to calculate HCCI. Automating data transformation, cleansing, and HCCI calculation is essential. Among other applications, HCCIs can be used to estimate costs, convert current dollars into a constant dollar, track market conditions, and determine the fuel tax rate. However, it has been determined that the scope of the current applications is limited

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