SHIFT 2020

Workgroup Summary and Recommendations

11/30/2018

Summary of the analysis and recommendations of the SHIFT 2020 Workgroup and Technical Advisors

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SHIFT 2020 Workgroup Summary - FINAL

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Executive Summary

In 2016, Gov. Matt Bevin directed the Kentucky Transportation Cabinet (KYTC) to develop a process to better allocate the Commonwealth's limited transportation funds. The Strategic Highway Investment Formula for Tomorrow (SHIFT) was the result -- a data-driven, objective approach to compare capital improvement projects and prioritize transportation spending.

SHIFT helps reduce overprogramming and provides a clear road map for construction in the coming years. The formula applies to all transportation funding that is not prioritized by other means, such as maintenance work, local government projects and dedicated federal projects.

KYTC staff developed SHIFT over the summer of 2016 and used the model to prioritize projects in the 2018 Highway plan. In June of 2018, the Kentucky Transportation Cabinet convened another workgroup to plan for SHIFT 2020. This group consisted of 17 members representing several areas inside the cabinet and key external stakeholders; State Highway Engineers Office, Program management, Maintenance, Highway Safety Improvement Program, Planning, Highway Design, Districts, MPOs, and ADDs. There were also about 40 KYTC staff and KTC staff involved as technical advisors.

The group met twice a month June through November 2018. The goal of the workgroup was to systematically examine the 2018 SHIFT process and look for ways to improve the system for 2020.

Feedback was also gathered from an advisory group that included representatives of the General Assembly, Kentucky League of Cities, Kentucky Association of Counties and Kentucky Judge-Executives Association. This group met on September 27th, 2018 at the Transportation Cabinet.

The following is a summary of the workgroup recommendations for SHIFT 2020.

Safety:

Crash History:

The crash history criteria was evaluated by a research study through the Kentucky Transportation Center. The research team for the crash history component of SHIFT evaluated the 2018 SHIFT crash history component and developed a new methodology to rank the safety needs of the 2020 SHIFT projects. For the current year of SHIFT, the research team suggests replacing the 2018 SHIFT formulas with a new metric that is backed by the most current safety analysis guidelines available. The new metric is known as excess expected crashes (EEC).

EEC is based on a crash prediction model, which takes the guesswork out of the safety analysis. To be more specific, the crash prediction model estimates the number of crashes one might expect on road segment with a given traffic volume and length. The research team has developed state-specific crash prediction models for various roadway types with similar geometrics based on traffic volume and roadway characteristics. Out of these models comes the EEC. EEC is a value that represents the difference in segment's current crashes to the crashes that would be expected on a segment of that type and length. So, EEC simply suggests the number of excess crashes a segment is experiencing compared to others of its type.

All 2020 SHIFT projects will be ranked based on the EEC of the individual projects. The project with highest EEC will receive the maximum score for the safety component of SHIFT, with all successive projects receiving incrementally lower scores.

Roadway Characteristics:

The Roadway Characteristics component of the SHIFT scoring process evaluates how well a particular roadway segment's physical characteristics conform to values that would generally be expected for the type of roadway being evaluated. Roadway characteristics that are evaluated may include lane width, lateral clearance, geometric-constrained speed, and median type, depending on the type of roadway. Roadways are categorized by functional classification and area type, and target values for each characteristic are established, generally based on common geometric practices for roadways in that category. Each roadway segment is assigned points based on how much each characteristic deviates from the target value, with larger deviations resulting in more points being assigned. The points assigned for each characteristic are then combined into a composite score which can range from zero to 100.

Congestion:

The congestion criteria was evaluated by a research study through the Kentucky Transportation Center. The study involved analyzing field measured HERE speed data to evaluate congestion. For SHIFT 2020, the recommended measure of congestion is vehicle hours of delay (VHD). Delay is defined as the excess time a traveler spends on a trip over the time that would be required in uncongested conditions. VHD is the total delay experienced by all vehicles traveling on a section of highway during the analysis period.

VHD is chosen as the measure of congestion for the following reasons:

- It is a direct and consistent measurement of highway user delay, whereas VSF is a surrogate measure of operating condition.
- It can be estimated for any analysis period, not just peak period, if data are available. For example, an agency can define the analysis period to be a typical weekday or a whole year. Conversely, VSF reflects average peak hour condition; it does not account for congestion outside the peak hour.
- It is generated from measured speed data. Such data are available and deemed adequate for most state maintained roads in Kentucky. This largely bypasses the traditional approach of capacity analysis, which is limited for planning level applications.

After the percentile score for each project is obtained, an adjustment factor based on functional classification is applied to reflect the strategic importance of highways.

Economic Growth

Economic Competitiveness:

The Economic Competitiveness score is calculated for the Statewide (primarily interstate and parkway NHS) SHIFT project group and receives a 10 percent weighting. The formula is made up of two components:

1.) Cumulative number of job-years of employment created over a 10-year period; and

2.) Percent change in the county economy over a 10-year period

These two components are derived from TREDIS model runs and summed to arrive at a final Economic Competitiveness score.

Accessibility / Connectivity:

The Accessibility / Connectivity score is calculated for the Regional SHIFT project group and receives a 10 percent weighting. Accessibility/Connectivity is measured using facility type upgrades, county tier designations indicating levels of distress, and a facility's average daily traffic. This component quantifies the importance of improving access to rural and less-affluent areas while improving interconnectivity of the network to help improve economic conditions. Accessibility/Connectivity is measured using the travel time savings of facility type upgrades, and county tier designations indicating levels of distress, and a facility's average daily traffic.

Freight:

The Freight portion of the SHIFT formula is calculated for the statewide and regional scoring criteria. The freight section makes up 10 percent of the SHIFT Score. Upon reviewing all possible data sources for modifications, the freight committee decided that only three changes were possible to implement at this time. The reasons most of the other items could not be incorporated range from lack of data to inability to apply any new measure fairly to all possible freight projects. The three changes to the freight formula that were recommended and approved are:

- Separation of Single and Combo Unit trucks and different weights at the statewide and regional levels
- Incorporation of truck reliability ratio into the formula
- Addition of Coal Haul routes as a fifth tier, whereas previously there were only four.

Benefit / Cost:

The Benefit / Cost component is a compilation of 3 sub measures: Safety Benefits, Travel Time Savings Benefits and Project Cost. The Safety Benefit calculation was updated with refinements to the 2018 Safety Benefit Factors (SBF) scores and their associated improvement types. There are now 32 Improvement Types with Kentucky specific SBFs. The Travel Time Savings calculation was improved with updates to the Kentucky Statewide Travel Demand Model for modeled projects and also to the HCM formulas for non-modeled projects. Stantec analyzed the two travel time savings methods, modeled vs non- modeled, and recommended steps to take to make the two approaches more comparable. The project cost calculation method will stay the same as in 2018.

A final change from 2018 was to split the two halves of the benefit / cost equation and weight them equally. Now the Travel Time Savings Benefits and the Safety Benefits each contribute ½ of the overall points for the measure.

Asset Management

The idea behind a SHIFT score for existing assets is to capture the value added for projects that address bridges or pavement sections in poor condition. Funding SHIFT projects where Good conditions exist is not fiscally responsible. To measure this value functions determining the condition of the bridge and pavement in within the project area were developed. The team felt that the SHIFT bridge measure evaluated the bridges effectively and recommended no changes. The team recommended adding Pavement Distress Index to the current pavement formula to aid in evaluating pavement conditions.

SHIFT Flags (Missing Criteria)

The Missing Criteria team, later known as the SHIFT Flags team, recommends the following items be implemented into the SHIFT process:

- Incorporate additional informational flags into CHAF, with a maximum of two being able to be selected for each project.
- A comment field should also be incorporated to provide additional context or hyperlinks to relevant documentation.
- Flags should accompany the project on all documentation leading up to the assembly of the recommended highway plan. After this point, flags should fall away.

Detailed Component Summaries

Safety:

Crash History:

Safety Part 1

Crash History Formulas

Statewide: 15% **Regional: 15%***

Statewide Score = 15% X Crash History Safety Measure (CHSM)

Regional Score = 15%* X Crash History Safety Measure (CHSM)

$$CHSM = (\sum EECs)_{\dagger scaled}$$

Measure	Description	Summary Method All crash data summarized over 5 yrs. 2013-2017	Source
EEC	Excess Expected Crashes	Expected Crashes – Predicted Crashes	Crash Database HIS

* Standard Regional % listing. Regions may adjust priorities by up or down by 5% with a minimum of 5% in any individual criteria.

† Scaled - The percentile rank of the value. Converts value to score of 0 to 100.

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The Safety - crash history criteria was evaluated by a research study through the Kentucky Transportation Center. The Safety – Crash History Team was tasked with evaluating the 2018 SHIFT safety components and suggesting improvements to the ranking methodology that reflect the most current and nationally accepted data-driven methods to evaluate safety. In doing such, the team used the Highway Safety Manual (HSM) as a guide to both evaluate the 2018 SHIFT safety component, and to develop a new method of evaluating safety for the 2020 SHIFT cycle.

Analysis of 2018 SHIFT Safety – Crash History Component

Previously, the safety component was calculated using a combination of three safety measures; critical rate factor (CRF), crash frequency (CF), and crash density over a segment length (CD*L).

CRF is a measure that compares a segments crash rate to a crash rate that is considered critical, or much greater than the average crash rate for a segment of that roadway type. However, recent research has shown that CRF is not the most accurate or reliable method to compare a segment's crash performance to segments of a similar type. CRF relies on the assumption that crashes and traffic volume have a linear relationship, which is not always true. Regression to the mean bias is not addressed with CRF either, meaning CRF does not account for temporal fluctuation in crashes.

CF is simply the total number of crashes a location experiences in five years. This measure does not account for regression to the mean either. It also produces a length bias because longer segments will have more space available to accumulate crashes.

CD*L is an attempt to distinguish each SHIFT project based on its roadway type. The average crash density (crashes per mile) for each roadway type (interstate, parkway, urban multilane, rural two lane, etc.) was calculated. For each SHIFT project, the average crash density for that project's roadway type was multiplied by the length of the project to achieve the CD*L measure. This measure is supposed to represent the average number of crashes that could be expected on a roadway of the same type and length of the SHIFT project. This factor also creates a length bias, as longer SHIFT projects will have a higher CD*L score. This measure does not accurately reflect the number of crashes that should be expected on a roadway because factors other than roadway type and length influence crash occurrence, such as roadway geometry and traffic volume.

The three components for each project were scaled from 0-100 based on how their magnitudes ranked in comparison to all other SHIFT projects. The scaled values of the three components were combined for each SHIFT project to create a single safety score. The scaled components were weighted differently based on the length of a project. If the project was less than or equal to 0.2 miles, the project was considered an intersection. If the project was greater than 0.2 miles in length, the project was considered a segment. The following equations show how the three components were weighted to create a combined safety score for segments and intersections:

Segment (L>0.2): = 0.25*((CD*L)†scaled) + 0.25*(CRF † scaled) + 0.50*(CF †scaled)

Intersection (L<=0.2): = 0.5*(CF †scaled) + 0.5*(CRF †scaled)

The weighting of each of the three components shown in the equations above is arbitrary and also contributes to a length bias. In both the segment and intersection equations, CF contributes 50% of a projects score. As discussed, CF is influence by the length of a project, and longer projects tend to have higher crash totals.

2020 SHIFT Safety- Crash History Component

The HSM promotes the use of safety performance functions (SPFs) to model crash frequency based on traffic volume and length of homogeneous roadway segments. SPFs are typically modeled using negative binomial regression, which is a more accurate representation of the relationship between crashes and traffic volumes than the assumed linear relationship with CRF. The estimated number of crashes calculated by an SPF represents the number of crashes one might expect on an average length of road with a given traffic volume. The functional form of an SPF is as follows:

SPF Crashes=L*e^a*AADT^b*AF

Where,

SPF Crashes = crash prediction

L = Length of segment

AADT = annual average daily traffic

a & b = regression coefficients

AF = adjustment factor (if needed)

If a road segment does not identically match the base conditions of the homogenous roadway segments used to calibrate the SPF, then an adjustment factor (AF) must be applied to the SPF's crash prediction to account for the difference in roadway characteristics. For example, an SPF was developed from a dataset of rural two-lane roads that all had nine-foot lanes and three-foot shoulders. However, the SPF is used to predict crashes on a rural two-lane road with nine-foot lanes and two-foot shoulders. To account for the decrease in safety associated with reducing shoulder width by one foot, the SPF should be multiplied by an appropriate AF that reflects the increase in crashes that would be expected.

Furthermore, the HSM recommends the use of the empirical Bayes (EB) method, which combats regression to the mean by combining the SPF crash prediction for a segment with the historical crash data of that segment. The two crash measures are balanced using a weight parameter that is a function of how well the SPF model represents the dataset from which it was correlated. If the SPF has poor correlation, the weight parameter places more emphasis on the historic crash data, and vice versa. The EB method uses the following formula:

EB Expected Crashes=w*SPF Crashes +(1-w)*Historic Crashes

Where,

w = weight (based on over dispersion parameter from calibrated SPF)

SPF Crashes = predicted crashes on a segment from SPF

Historic Crashes = total historic crashes on a segment

The difference between EB expected crashes and SPF predicted crashes is a measure known as excess expected crashes (EEC). EEC quantifies the number of crashes occurring at a location more than what would be expected. EEC is positive when more crashes are occurring than expected and negative when fewer crashes are occurring than expected. The following graphic shows a visual representation of the relationship between SPF predicted crashes, historic crashes, EB expected crashes, and EEC.

For the 2020 SHIFT cycle, EEC will be used as a standalone measure to replace the three measures that were used in conjunction to evaluate safety in the 2018 SHIFT cycle. EEC is a more statistically rigorous metric to evaluate safety because it follows current HSM guidelines, accounts for regression to the mean bias, and reduces length bias.

Instead of using the CD*L measure to distinguish between crash patterns on different roadway types, the safety team developed a new SPF for each roadway type for the 2020 SHIFT cycle. Individualized SPFs for each roadway type are used to calculate crash predictions, EB estimates, and EECs for projects for only roadways of that type. This method more accurately captures the differences in crash patterns on differing roadway types than a simple crash density average (CD*L). The Safety Team developed SPFs for the following roadway types: ramps, intersections, rural two-lanes, rural interstates/parkways, rural multilane divided highways, rural multilane undivided highways, urban two-lanes, urban interstates/parkways, urban multilane divided highways, and urban multilane undivided highways.

All 2020 SHIFT projects will be ranked based on the EEC of each project. The project with the highest EEC will receive the maximum number of safety points toward the overall SHIFT score based on the weight of the safety component. Each successive project will receive a lower score, with the amount of score reduction being linear and based on the total number of projects in the 2020 SHIFT cycle. In some instances, projects may have an EEC an order of magnitude higher than the next highest ranking project, even though their SHIFT safety scores will be close in magnitude due to the linear nature of the scoring process. The safety scores for these projects will come with a warning that their EEC is much greater than the next highest SHIFT project.

See Appendix A – SPFs for a listing of all the Safety Performance Functions

Roadway Characteristics:

Safety Score 2020 Part 2

Roadway Characteristics(RC) Formulas

Statewide: 10% **Regional: 5%**

Statewide Score = Urban or Rural Roadway Characteristics Safety Measure * 10%:

Regional Score = Urban or Rural Roadway Characteristics Safety Measure * 5%:

Measure	Description	Source
Urban Freeway: $0.25P_{S,avg}+0.25P_{S,min}+0.25P_L+0.25P_C^{\dagger}$ (Scaled)	$P_{S,avg}$: Average points awarded for geometric constrained speed	HIS
Rural Freeway: $0.3P_{S,avg}+0.2P_{S,min}+0.25P_L+0.25P_C^{\dagger}$ (Scaled)	$P_{S,min}$: Minimum points awarded for geometric constrained speed	HIS
Urban Arterial: $0.25P_{S,avg}+0.25P_{S,min}+0.25P_L+0.25P_M^{\dagger}$ (Scaled)	P_L: Points awarded for lane width	
Rural Arterial: $0.3P_{S,avg}+0.1P_{S,min}+0.1P_{S,ratio}+0.2P_L+0.3P_C^{\dagger}$ (Scaled)	P_c: Points awarded for lateral clearance	HIS
Urban Collector/Local: $0.25P_{S,avg}+0.25P_{S,min}+0.5P_L^{\dagger}$ (Scaled)	P_M: Points awarded for median type & width	HIS
Rural Collector/Local: $0.2P_{S,avg}+0.2P_{S,min}+0.1P_{S,ratio}+0.2P_L+0.3P_C^{\dagger}$ (Scaled)	$P_{S,ratio}$: Points awarded for S_{min}/S_{avg}	HIS

†Scaled - The percentile rank of the value. Convert s value to score of 0 to 100.

The Roadway Characteristics component of the SHIFT scoring process evaluates how well a particular roadway segment's physical characteristics conform to values that would generally be expected for the type of roadway being evaluated. Roadway characteristics that are evaluated may include lane width, lateral clearance, geometric-constrained speed, and median type, depending on the type of roadway. Roadways are categorized by functional classification and area type, and target values for each characteristic are established, generally based on common geometric practices for roadways in that category. Each roadway segment is assigned points based on how much each characteristic deviates from the target value, with larger deviations resulting in more points being assigned. The points assigned for each characteristic are then combined into a composite score which can range from zero to 100.

Several changes were made from the process used for the 2018 Six-Year Highway Plan:

- Equations for awarding points for geometric-constrained speed were changed from linear equations to elliptical equations. This change was made to allow an increasing number of points to be awarded for decreasingly favorable values of geometric-constrained speed up to a theoretical worst-probable value, while still allowing a high number of points to be awarded for very unfavorable (although not necessarily worst-probable) values.

- Equations for awarding points for lane width were adjusted, and some changes were made to the functional classification groups that use each equation.
- Shoulder width was replaced with lateral clearance, defined as the sum of the right shoulder, bike lane, and parking lane widths.
- New area type classifications were used to determine how projects are scored. Some areas that are classified as “rural” by the Census Bureau are actually small communities where a high-speed road design would not necessarily be desirable, while some roads in urban areas are intended for higher speeds than would typically be expected in a dense urban environment. Therefore, roads were classified as Urban/Low-Speed or Rural/High-Speed, instead of simply Urban or Rural, for scoring purposes.
- New characteristics were introduced, including median/center turn lane type and width (for Urban/Low-Speed principal and minor arterials) and the ratio between the minimum and average geometric-constrained speed (for Rural/High-Speed roadways, excluding freeways).
- Data on superelevation and vertical curvature based on pavement scans collected by the Division of Maintenance using Mandli software is expected to be available. Geometric-constrained speed calculations were refined to take into account superelevation and crest vertical curve attributes, if and when the data becomes available. Sag vertical curves were not included in the calculations: In 2016, FHWA released a Notice in the Federal Register that sag vertical curvature was no longer considered one of the controlling criteria for design. As noted in the NCHRP Report 783, stopping sight distance (SSD) has little impact on the safety and operations at sag vertical curves under daytime conditions when the driver can see beyond the sag vertical curve, or at night, when vehicle taillights and headlights make another vehicle on the road ahead visible in or beyond a sag vertical curve. KYTC common practices reflect FHWA’s exclusion of sag vertical curves as geometric criteria so that more emphasis could be placed on roadway geometry that can have a greater impact on roadway safety.

<u>Functional Classification</u>

In the documentation that follows, the following abbreviations are used to denote functional classification and area type:

Fwy: Freeway; includes Interstates, Parkways, and Other Freeways (Classes 1 and 2)

PrinArt: Principal Arterial (Class 3)

MinArt: Minor Arterial (Class 4)

MajColl: Major Collector (Class 5)

MinColl: Minor Collector (Class 6)

Loc: Local (Class 7)

R: Rural/High-Speed: The road being evaluated is predominantly outside any Census-defined urban cluster or FHWA-adjusted urban area boundary, or the predominant posted speed limit is 55 miles per hour or higher, or the functional classification is Class 1 or Class 2.

U: Urban/Low-Speed: The road being evaluated is predominantly located within a Census-defined urban cluster or FHWA-adjusted urban area boundary, or the predominant posted speed limit is 35 miles per hour or lower, and the functional classification is not Class 1 or Class 2. (This classification may be manually reset to Rural/High-Speed if the initial Urban/Low-Speed classification was solely a result of the posted speed limit and it is determined that the area is truly rural and a high-speed design is appropriate.)

Geometric-Constrained Speed

The following variables are required to estimate geometric-constrained speed:

e: Superelevation at the midpoint of a horizontal curve, as a percentage

d: The lower of degree of curve reported in HIS, or 0.1; if unavailable or no curve is reported, assume d=0.1

f: Side friction factor, determined based on the roadway category as follows:

Fwy: 0.10

R PrinArt/R MinArt: 0.12

U PrinArt/R MajColl/R MinColl: 0.14

U MinArt/U MajColl/R Loc: 0.17

U MinColl/U Loc: 0.20

G1,G2: The grades connected by a vertical curve, as percentages; if unavailable or no vertical curve is reported, assume G1=G2=0%

L_V: Length of vertical curve, in feet

L_i: Length of evaluation section i. Road is divided into evaluation sections such that each section has constant values of horizontal and vertical curvature.

S_i: Estimated geometric-constrained speed for evaluation section i, in miles per hour

S_T: Target geometric-constrained speed in miles per hour, based on the roadway category as follows:

Fwy: 70 mph

R PrinArt/R MinArt: 60 mph

U PrinArt/R MajColl/R MinColl: 50 mph

U MinArt/U MajColl/R Loc: 40 mph

U MinColl/U Loc: 30 mph

For each evaluation section i:

If vertical curve data is available:

Calculate vertical geometric-constrained speed, S_V, from the following equation, which is based on AASHTO guidance for the design speed of crest (G1>G2) vertical curves:

If G1>G2, S_V = minimum(10.9*[L_V/abs(G2-G1)]$^{0.34}$,S_T)

Otherwise S_V=S_T

If vertical curve data is not available:

S_V=S_T

If superelevation data is available:

Calculate horizontal geometric-constrained speed, S_H, from the formula:

S_H = minimum(293*(f+0.01*e)$^{1/2}$*d$^{-1/2}$,S_T)

If superelevation data is not available:

Estimate horizontal geometric-constrained speed, S_H, from the formula:

S_H = minimum(111.89*d$^{-0.437}$,S_T)

Estimate the overall geometric-constrained speed for evaluation section i as the minimum of the horizontal and vertical geometric-constrained speed:

S_i=minimum(S_H,S_V)

Based on the calculated geometric-constrained speeds for each section, calculate the length-weighted average and minimum values of geometric-constrained speed, and the ratio of the minimum to average geometric-constrained speed, for the overall section of roadway being analyzed:

$S_{avg} = \Sigma(L_i*S_i) / \Sigma L_i$

S_{min} = minimum(S_i)

$S_{ratio} = S_{min}/S_{avg}$

Assign points, $P_{S,avg}$ and $P_{S,min}$, based on S_{avg} and S_{min}, respectively, using the following equations depending on functional classification, where S represents S_{avg} or S_{min} and P_S represents $P_{S,avg}$ when calculated using $S=S_{avg}$ or $P_{S,min}$ when calculated using $S=S_{min}$:

Fwy:

If $S \leq 30$, $P_S=100$; If $S \geq 70$, $P_S=0$; Otherwise, $P_S=200*\text{sqrt}[1-(S-30)^2*3/6{,}400]-100$

R PrinArt/R MinArt:

If $S \leq 15$, $P_S=100$; If $S \geq 60$, $P_S=0$; Otherwise, $P_S=200*\text{sqrt}[1-(S-15)^2/2{,}700]-100$

U PrinArt/R MajColl/R MinColl:

If $S \geq 50$, $P_S=0$; Otherwise, $P_S=200*\text{sqrt}(1-S^2*3/10{,}000)-100$

U MinArt/U MajColl/R Loc:

If $S \geq 40$, $P_S=0$; Otherwise, $P_S= 200*\text{sqrt}(1-S^2*3/6{,}400)-100$

U MinColl/U Loc:

If $S \geq 30$, $P_S=0$; Otherwise, $P_S=200*\text{sqrt}(1-S^2/1{,}200)-100$

Assign points, $P_{S,ratio}$, based on the ratio of minimum speed to average speed:

$P_{S,ratio} = 100 – 100*S_{ratio}$ *(This equation should result in values ranging from 0 to 100.)*

Lane Width

The following data is required to assign points for lane width:

LANES: Number of through lanes reported in HIS; predominant value; if unavailable, assume N=2

LANEWID: Lane width reported in HIS; length-weighted average value; if unavailable, assume LANEWID=12

TYPEOP: Type of operation reported in HIS (1 for one-way, 2 for two-way); predominant value; if unavailable, assume TYPEOP=2.

Calculate an effective average lane width, L:

If LANES < 2, L = LANEWID / TYPEOP; otherwise L = LANEWID

Assign points, P_L, for lane width using the following equations depending on functional classification:

Fwy:

P_L=minimum(maximum(600-50*L,0),100)

R PrinArt/R MinArt/U PrinArt:

P_L=minimum(maximum(733-66.7*L,0),100)

R MajColl/R MinColl/U MinArt/U MajColl/U MinColl:

P_L=minimum(maximum(550-50*L,0),100)

R Loc/U Loc:

P_L=minimum(maximum(333-33.3*L,0),100)

Median Type & Width (only for U PrinArt and U MinArt)

The following data is required to assign points for median type and width:

TYPEROAD: Type of road reported in HIS (C for couplet, D for divided highway, U for undivided highway); predominant value; if unavailable, assume TYPEROAD=U

MEDTYPE: Median type reported in HIS (1 for concrete barrier, 2 for guardrail barrier, 3 for other positive barrier, 4 for raised non-mountable, 5 for raised mountable, 6 for flush, 7 for depressed, 8 for none); predominant value; if unavailable, assume MEDTYPE=8

MD_BARR: Median barrier reported in HIS (1 for concrete, 2 for guardrail, 3 for cable, 4 for delineator post, 5 for other, 6 for none, 7 for earthed); predominant value; if unavailable, assume MD_BARR=6

L_i: Length of evaluation section i. Road is divided into evaluation sections such that each section has constant values of AUXLNWID and MEDWID (defined below).

$MEDWID_i$: Median width reported in HIS for evaluation section i; if unavailable, assume MEDWID=0

X_SECT: Indicates the location of an auxiliary lane. For median type & width, only consider CL (Cardinal Left) and M (Middle/Median).

$AUXLNWID_i$: Auxiliary lane width reported in HIS for evaluation section i, **only for X_SECT=CL or M.** If multiple auxiliary lanes exist at the same location, use the sum of their widths.

Assign points for median type and width, P_M, as follows:

If TYPEROAD=C, or MEDTYPE=1,2,3,4, or 7, or MD_BARR=1,2,3,5, or 7: P_M=0

Otherwise, if MD_BARR=4: P_M=25

Otherwise: Calculate a length-weighted average effective median width, $MEDWID_{avg}$, and points for median type and width, P_M, as follows:

$MEDWID_{avg} = \Sigma[\text{minimum}(\text{maximum}(AUXLNWID_i, MEDWID_i),14)*L_i]/\Sigma L_i$

$P_M = 100 - 75*MEDWID_{avg}/14$ *(This equation should result in values ranging from 25 to 100.)*

Lateral Clearance (only for U Fwy and Rural/High-Speed facilities)

The following data is required to assign points for lateral clearance:

L_i: Length of evaluation section i. Road is divided into evaluation sections such that each section has constant values of AUXLN, AUXLNWID and SHLDWID (defined below).

X_SECT: Indicates the location of the shoulder or auxiliary lane. For Lateral Clearance, only consider CR (Cardinal Right).

$SHLDWID_i$: Shoulder width reported in HIS for evaluation section i **only for X_SECT=CR**

AUXLANE: Auxiliary lane type reported in HIS. For Lateral Clearance, only consider types 2 (Parking) and 6 (Bicycle) since other lane types are for general-purpose travel.

$AUXLNWID_i$: Auxiliary lane width reported in HIS for evaluation section i **only for AUXLANE=2 or 6 and X_SECT=CR.** If multiple auxiliary lanes exist at the same location, use the sum of their widths.

Calculate a length-weighted average lateral clearance, C, and points for lateral clearance, P_C, as follows:

$C = \Sigma[\text{minimum}(AUXLNWID_i + SHLDWID_i,8)*L_i]/\Sigma L_i$

$P_C = 100 - 12.5*C$ *(This equation should result in values ranging from 0 to 100.)*

Composite Score

Several principles were established for assigning weights to the various component scores for different roadway types. Average speed was given more emphasis for freeways and Rural/High-Speed arterials since those roadways tend to serve longer-distance trips. Urban/Low-Speed roadways (except freeways) were not given points for lateral clearance since they generally have lower speeds and more restricted right-of-way. Instead, points were assigned for median type and width for urban arterials, since those types of roadways often experience congestion and safety issues where left turns to and from entrances and side streets are not adequately controlled. Based on those principles, a composite score is calculated using the following equations, depending on functional classification and area type:

Fwy: P= $P=0.3P_{S,avg}+0.2P_{S,min}+0.25P_L+0.25P_C$

U PrinArt/U MinArt: $P=0.25P_{S,avg}+0.25P_{S,min}+0.25P_L+0.25P_M$

U MajColl/U MinColl/U Loc: $P=0.25P_{S,avg}+0.25P_{S,min}+0.5P_L$

R PrinArt/R MinArt: $P=0.3P_{S,avg}+0.1P_{S,min}+0.1P_{S,ratio}+0.2P_L+0.3P_C$

R MajColl/R MinColl/R Loc: $P=0.2P_{S,avg}+0.2P_{S,min}+0.1P_{S,ratio}+0.2P_L+0.3P_C$

Potential Changes for Future Iterations

Incorporating a measure of roadside hazard into SHIFT was considered, and some conceptual ideas were generated, but they were unable to be implemented for the current iteration. KYTC's current stance is that resources should not be devoted to collect data if the data's only use would be to support SHIFT. Zegeer's 7-point rating method, which is a qualitative indicator of the level of roadside hazard, was initially considered, but it doesn't appear that this data is currently being collected for other purposes. However, it was determined that U.S. Road Assessment Program Star Ratings, which is a more quantitative measure of roadside hazard than Zegeer's 7-point rating method, along with related data, has been collected for a significant portion of two-lane rural roadways for the Highway Safety Improvement Program (HSIP). Star Ratings range from 1 to 5, with 1 being the least desirable. The data collection process is described in the Kentucky Transportation Center Research Report *Quantifying Roadside Assessment for Highway Safety* (2017). Before using this data for SHIFT, it would need to be determined how well the current data covers existing SHIFT projects, and if the data can be expanded and updated in the future, if necessary.

If it was determined that it would be feasible to incorporate the Star Ratings or related data into SHIFT, a new equation might be added to the Roadway Characteristics measure to award points based on roadside hazard, as measured by the Star Rating:

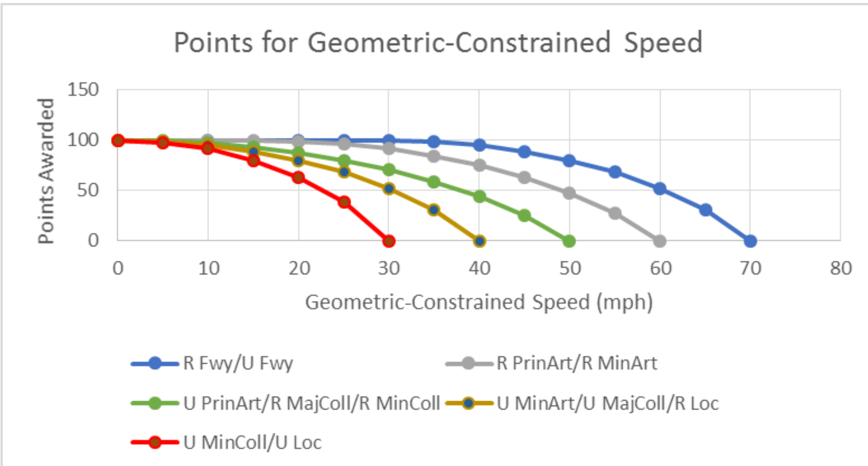
$P_H = 125 - 25*SR$, where SR is the Star Rating

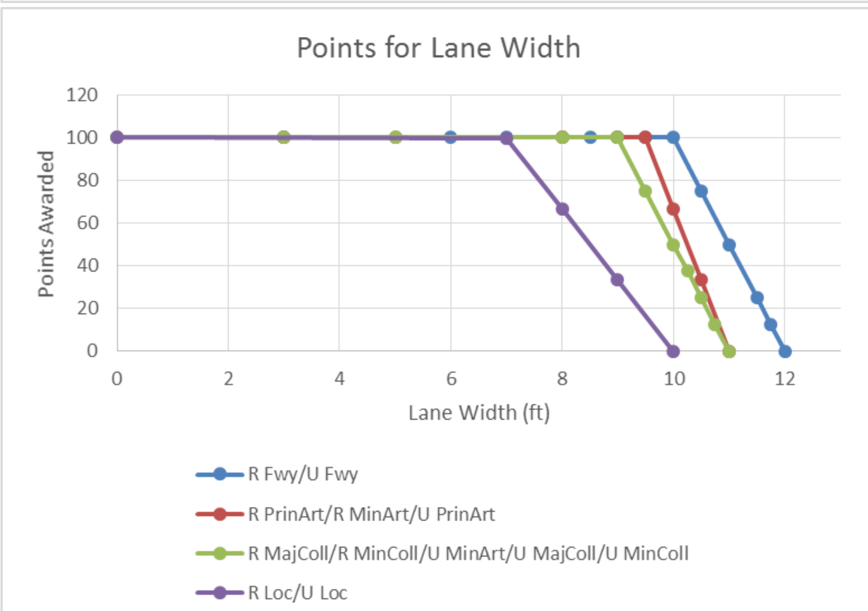
These points would likely only be applicable to rural non-freeway facilities. Since Star Ratings take shoulder width (which is often a major component of clearance) into consideration, it might be advisable to award points for either clearance or Star Rating, but not both. Therefore, the composite equations for rural non-freeway facilities might be modified as follows:

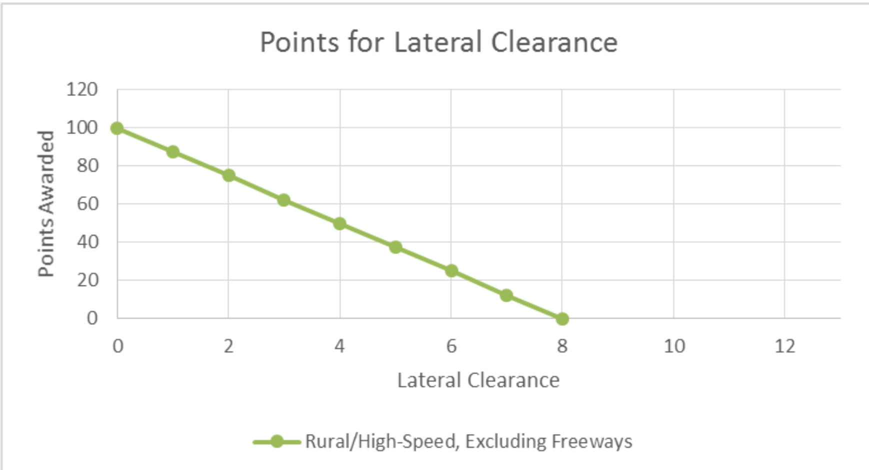
R PrinArt/R MinArt: $P=0.3P_{S,avg}+0.1P_{S,min}+0.1P_{S,ratio}+0.2P_L+0.3\text{maximum}(P_C,P_H)$

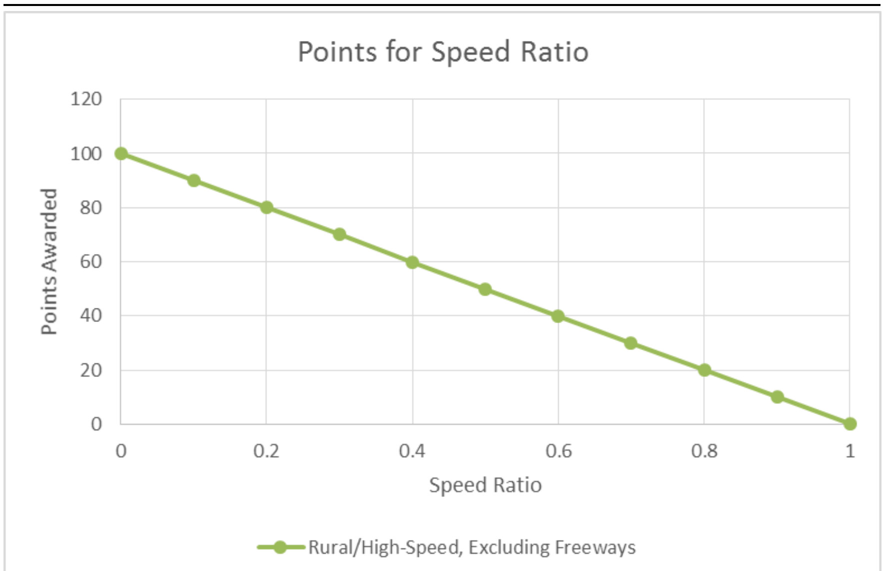
R MajColl/R MinColl/R Loc: $P=0.2P_{S,avg}+0.2P_{S,min}+0.1P_{S,ratio}+0.2P_L+0.3\text{maximum}(P_C,P_H)$

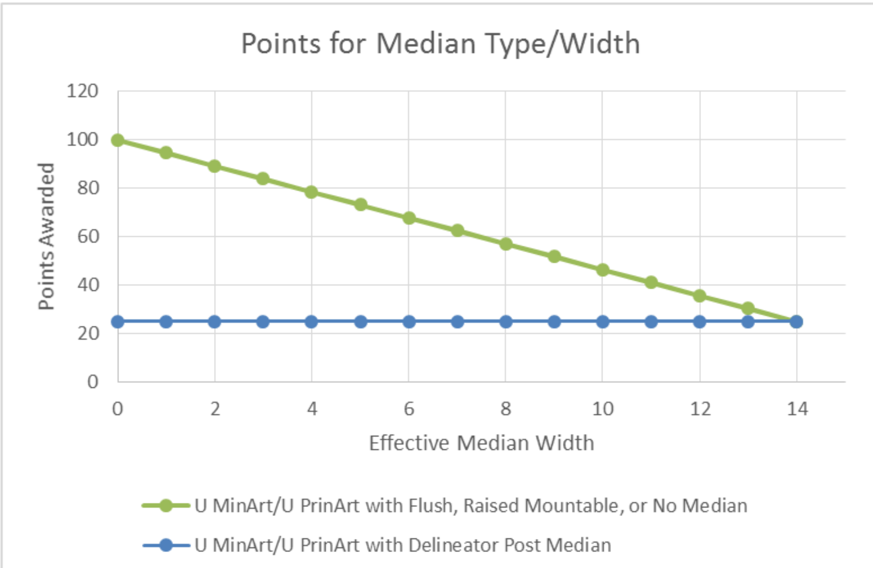
<u>Plots of Points Awarded for Select Values of Various Characteristics</u>



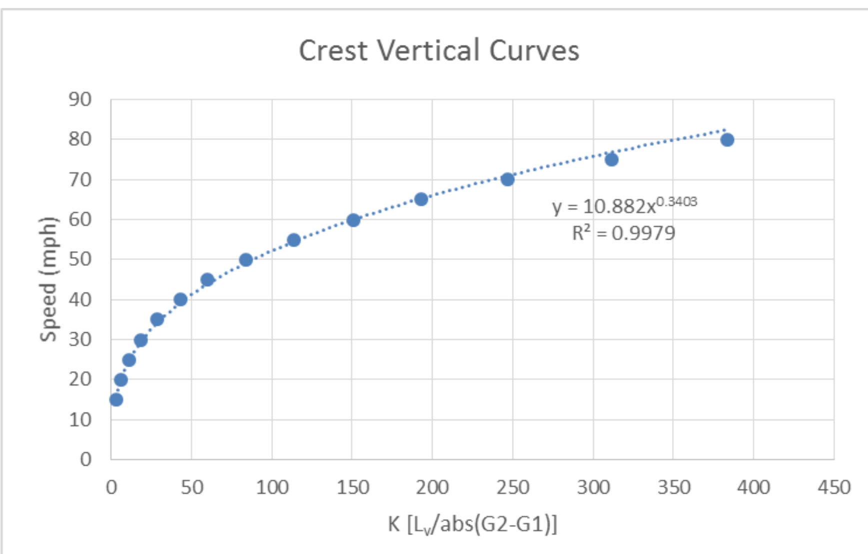


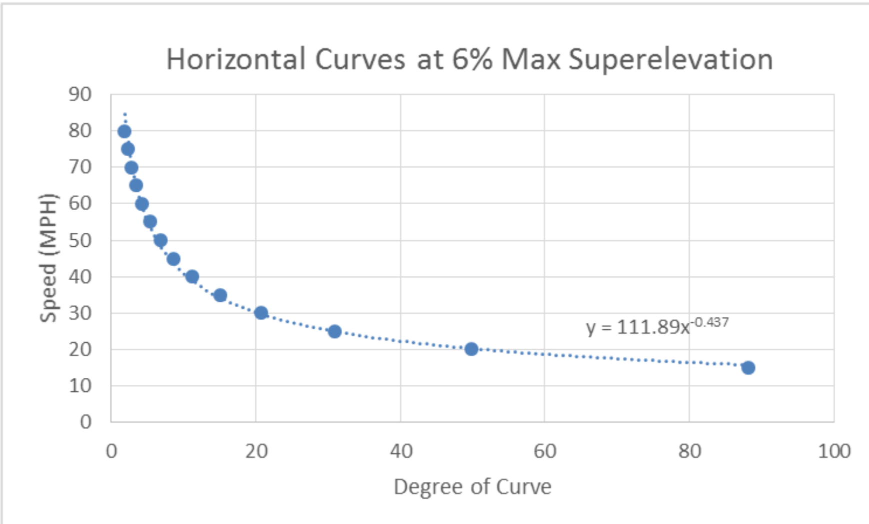

Points for Lateral Clearance
Points Awarded
120
100
80
60
40
20
0
0
2
4
6
8
10
12
Lateral Clearance
Rural/High-Speed, Excluding Freeways


Points for Speed Ratio
Points Awarded
120
100
80
60
40
20
0
0
0.2
0.4
0.6
0.8
1
Speed Ratio
Rural/High-Speed, Excluding Freeways



Equations to Estimate Geometric-Constrained Speed




Horizontal Curves at 6% Max Superelevation
Speed (MPH)
Degree of Curve
y = 111.89x-0.437
0
10
20
30
40
50
60
70
80
90
0
20
40
60
80
100

Congestion

Congestion Score 2020

Congestion Formulas

Statewide: 20% **Regional: 10%**

Statewide Score = 20% * Congestion Measure (CM) :

Regional Score = 10% * Congestion Measure (CM) :

Functional Class	Congestion Measure
Interstates	$(VHD)_{Scaled}$
Other Freeway	95% $(VHD)_{Scaled}$
Other Principal	90% $(VHD)_{Scaled}$
Minor Arterial	85% $(VHD)_{Scaled}$
Major Collector	80% $(VHD)_{Scaled}$
Minor Collector	75% $(VHD)_{Scaled}$
Local Road	70% $(VHD)_{Scaled}$

Measure	Description	Summary Method	Source
VHD	Vehicle Hours of Delay	Sum of Vehicle Hours of Delay during weekdays 6am – 8pm along the project length.	2015 -2017 HERE link-referenced speed data or HERS-ST speed model

†Scaled - The percentile rank of the value. Converts value to score of 0 to 100.

The congestion criteria was evaluated by a research study through the Kentucky Transportation Center. This summarizes research on development of the data and methodology to quantify congestion for project selection and systemic network evaluation. The goal is to update the measure of congestion for SHIFT2020.

The SHIFT2018 considers volume-to-service flow ratio (VSF) and annual average daily traffic (AADT) as two components of the congestion measure. Their relative importance varies for statewide and regional projects. The formula used in SHIFT2018 is shown in Figure 1.

Statewide: 20% Regional: 10%

Statewide Score = 20% * Congestion Measure (CM) :

CM = 0.6 * (VSF –scaled) + 0.4 * (DHV-scaled)

Regional Score = 10% * Congestion Measure (CM) :

CM = 0.8 * (VSF –scaled) + 0.2 * (DHV -scaled)

Measure	Description	Summary Method	Source
VSF	Volume to Service Flow. †Scaled VSF used in calculations	Length Weighted Avg	HIS
DHV	Design Hourly Volume = K*AADT †Scaled DHV used in calculations. K: Design Hour Factor AADT: Annualized Average Daily Traffic	 Length Weighted Avg Length Weighted Avg	 TRADAS TRADAS

†Scaled - The percentile rank of the value. Converts value to score of 0 to 100.

Figure 1 SHIFT 2018 Formula

VSF is a traditional measure of service quality and has been widely used by agencies. It has several limitations when used to measure congestion. VSF reflects condition during peak hour but does not account for congestion beyond that. The value of VSF is not a consistent representation of the level of service across all facility types. For example, on two-lane highways, service quality deteriorates well before volume approaches capacity. Further, VSF relies on the knowledge of peak capacity, which requires a number of data items that may not be available for all facilities, especially for ramps.

Basic Approach

Previous studies have established the value of third-party probe speed data in generating performance measures at corridor, regional, and statewide levels. The basic approach of the SHIFT2020 update is to use these speed data wherever they are available and deemed adequate. After the speed data is integrated with KYTC's highway information system (HIS) data set, various travel time-based performance measures can be developed.

For roadways lacking adequate speed data, the speed model in the Highway Economic Requirement System – State Version (HERS-ST) is adapted to estimate hourly speed. HERS-ST is a benefit-cost analysis tool for highway investment programs and policies. It uses highway inventory data in the standard HPMS (i.e., Highway Performance Monitoring System) format. The detailed methodology can be found in HERS-ST Technical Documentation. Major adaptions to the HERS-ST speed model include:

- Calibrated free-flow speed model using measured speed data;
- Incorporated zero-volume delay for signal- and stop sign-controlled facilities;
- Incorporated lane width adjustment factor for rural one/two-lane roads to account for the impact of narrow lanes; and
- Expanded the methodology to estimate hourly speed.

Data Sources

Major data sources include (1) historical speed data acquired from a third-party data provider, HERE Technologies, Inc., and (2) roadway geometric condition and usage data extracted from KYTC's Highway Information System (HIS).

Speed Data

Archived speed data for 2015-2017 on all Kentucky roadways were acquired from HERE Technologies, Inc. The speeds are referenced to HERE 2017Q3 map links, and available in 5-min and 60-min epochs for each day of the year. Further, speeds are available for all vehicles, cars only, and trucks only.

Due to limited probe vehicle data on some roads in Kentucky, especially rural low-volume roads, speed data were not available for all segments in all time periods. Data adequacy analysis was performed using a bootstrap sampling method. Results indicate that if speed data are available for at least 10% of the time epochs in the analysis period, they are representative of the true operating condition.

HIS Data

KYTC's HIS extract provides key data items required for estimating speed using the adapted HERS-ST speed model. The traditional methodologies require a number of data items on roadway geometric condition and usage.

Measures of Congestion

Various performance measures have been developed through studies at the national and state levels. This section lists several commonly used measures that can be developed for Kentucky highways.

Delay is frequently used as a measure of congestion. It is defined as the excess time a traveler experiences on a trip over the time that would be required in uncongested conditions. A threshold value of speed that separates the congested and uncongested conditions must be determined before delay can be estimated. This threshold value is referred to as "reference speed" in this document.

Setting Reference Speeds

When speed falls below the reference speed, the roadway is deemed congested. Several methods of setting reference speeds are tested using 2015-2017 data. Based on data adequacy evaluation and the feedback from the SHIFT2020 workgroup and KYTC's congestion focus group, the recommended reference speeds for Kentucky roadways are set below and capped at the speed limit.

Freeways: The 85^{th} percentile speed of all speed data

Non-freeways: The average speed during weekday daytime (6am-8pm)

Performance Measures

After setting the reference speed, a number of performance measures can be calculated. Several variations of delay that can be used as the primary measures of congestion are defined below. Other measures, such as travel time index, travel time reliability index, cost of congestion, and unreliable travel time, can also be estimated.

Vehicle Hours of Delay (VHD) Delay is the extra time spent traversing a segment beyond the reference travel time. Individual vehicular delay for the i^{th} hour (D_i) is defined as:

$$D_i = \frac{L}{S_i} - \frac{L}{RS}$$

in which, L = Segment Length, S_i = Average Speed for the i^{th} hour, RS = Reference Speed.

Vehicle hours of delay for the i^{th} hour (VHD_i) can be estimated as:

$$VHD_i = V_i \times D_i$$

in which V_i = Volume for the i^{th} hour.

Total vehicle hours of delay (VHD) for a typical weekday during 6am-8pm (i.e., the 14-hour daytime period) can be estimated as:

$$VHD = \sum_i VHD_i$$

VHD reflects the total delay experienced by all vehicles traversing a segment of highway.

Vehicle Hours of Delay per Mile (VHDPM) VHDPM reflects vehicle hours of delay per unit length (e.g., 1 mile) of a segment. It can be calculated as:

$$VHDPM = \frac{VHD}{L}$$

Average Hours of Delay (AHD) AHD measures the delay experienced by a vehicle traveling one mile on a segment. It is the ratio of total VHD to vehicle miles traveled (VMT) over the same time frame, as defined below:

$$AHD = \frac{VHD}{VMT}$$

and

$$VMT = \sum_i V_i \times L$$

It is recommended that VHD be used in ranking projects, of which project lengths have been pre-determined. VHDPM and AHD are more suitable for system-wide screening to identify bottleneck.

Ramp Performance Measures

Probe speed data are available and adequate for almost all ramps in Kentucky. Therefore, delay can be estimated when ramp volume data are available. In rare cases where ramp speed needs to be estimated, the methodology presented in the Highway Capacity Manual (HCM) 6th Edition can be adopted for assessing the operational conditions on ramps.

For projects involving interchanges or ramps, it is recommended that project mapping be expanded to include the portion of the connecting roadway that may be subject to the impact of queue spillover.

Project Ranking Formula

To prioritize projects, Vehicle Hours of Delay (VHD) is the recommended measure of congestion. To reflect the priority of highway types, a functional classification (FC) adjustment factor (f) is applied to the scaled VHD. The factors are shown in Table 1.

Table 1 Functional Classification Adjustment Factor

FC	1	2	3	4	5	6	7
Adj. Factor (f)	1	0.95	0.9	0.85	0.8	0.75	0.7

Congestion Measure (CM) = $VHD_{\text{-Scaled}} * f$

Statewide Score = 20% * CM

Regional Score = 10% *CM

Economic Growth:

The Kentucky Transportation Cabinet (KYTC) has been charged with developing a data driven process to prioritize and program federal and state funded highway improvement projects. An important part of this process is an economic development component. Similar to North Carolina, our model contains two criteria that attempt to capture economic impacts: Economic Competitiveness and Accessibility/Connectivity. Economic Competitiveness uses an economic model, TREDIS, to quantify the economic benefit a project is anticipated to provide over a span of 10 years. Economic Competiveness estimates the number of long-term jobs created and the percent change in value added by a project. Accessibility/Connectivity quantifies the importance of improving access to rural and less-affluent areas while improving interconnectivity of the network to help improve economic conditions. Accessibility/Connectivity is measured using facility type upgrades, county tier designations indicating levels of distress, and a facility's average daily traffic.

Economic Competiveness:

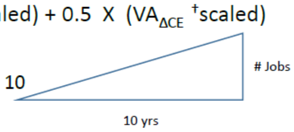
Economic Growth Part 1 Statewide

Economic Competitiveness Formula
Statewide: 10%

Statewide Score = 10% X Economic Competitiveness Measure (ECM):

$$ECM = 0.5 \times (Yrs\_Emp_{10yr}\ {}^{\dagger}scaled) + 0.5 \times (VA_{\Delta CE}\ {}^{\dagger}scaled)$$

$$Yrs\_Emp_{10yr} = (\#\_Jobs\ {}^{\dagger}scaled) \times 1/2 \times 10$$



Measure	Description	Source
Yrs_Emp_{10yr}	Cumulative # of years of employment created over a 10 year period 2017 - 2026	TREDIS
$VA_{\Delta CE}$	Value Added, % change in County Economy over 10 yr. period 2017- 2026	TREDIS
#_Jobs	# Jobs created over 10 year period 2017 - 2026	TREDIS

KYTC has worked with representatives from the Kentucky Cabinet for Economic Development (CED), Kentucky State Data Center (KSDC), and met with Economic Impact Modeling companies: TREDIS and REMI to help define these criteria.

The Economic Competitiveness score is calculated for the Statewide (primarily interstate and parkway NHS) SHIFT project group and receives a 10 percent weighting. The formula is made up of two components:

1.) cumulative number of job-years of employment created over a 10-year period; and

2.) percent change in the county economy over a 10-year period

These two components are derived from TREDIS model runs and summed to arrive at a final Economic Competitiveness score.

North Carolina made a change this year to their Economic Development scores by replacing “number jobs increase” with “percent jobs increase” in their scoring formula. We examined this potential change for Kentucky and looked at the following:

The “number jobs increase” method favors the urban areas that attract larger employers. The “percent jobs increase” method favors the economically disadvantaged areas since they are comparing their increase in jobs to a smaller total number than what is found in the more densely populated urban areas. Since the Economic Competitiveness formula is applied only to Statewide projects (primarily interstates and parkways on the NHS), then it would make sense to favor “number jobs increase” recognizing the workgroup’s intent to give a higher score to those projects that would tend to drive the economy. A “hybrid” approach was also considered that uses the higher of the two scores based on “number jobs increase” and “percent jobs increase”. The hybrid method tends to help a few projects with high “percent jobs increase” while only minimally lowering the scores for those projects with high “number jobs increase”. That slight score reduction to the economy-driving projects in the “hybrid” method does not accumulate until well down the list where projects don’t tend to make the cut for Highway Plan consideration anyway. Testing out the hybrid method on a sample set of 20 projects resulted in no change to any project rankings. Given these considerations, the workgroup recommends keeping the SHIFT 2017 “numbers increase” method for calculating economic competitiveness scores.

Consideration of Project Costs

The workgroup also considered whether or not to add project cost as a TREDIS input for the Economic Competitiveness score. Given that project cost is already considered in the Benefit-Cost analysis in SHIFT and given the differences in precision for different projects and different project phases, the work group recommends maintaining the exclusion of cost from the Economic Competitiveness scoring element moving into SHIFT 2018.

Absolute Value of TTS vs. Zero value of TTS

In SHIFT 2017, 177 projects were modeled to look at travel time savings (TTS) over a 10-year period. Of those 177 projects, 26 resulted in negative TTS. 35 percent of the 26 projects were related to building a new route or interchange and 38 percent were related to reconstruction. Of those 26 projects, 15 had very low negative results that effectively round to zero. For the remaining 11 projects with negative TTS, those results might be explained by the project attracting traffic from other routes. Some argue that the increase in travel time (negative TTS) would result in bringing growth to the area and be considered beneficial from an economic standpoint. For this to reflect in the scoring would require the result to be converted to a positive value. The most direct and obvious way to achieve this would be to take the absolute value of the TTS. For 92 of the projects, the TTS was nearly zero. These projects would contribute no economic benefit in either TTS or attracting growth. While absolute valuing the TTS was favored by some work group members, others considered it counterintuitive. The negative TTS for some projects might be attributed to attracting traffic from other routes, however, this has not been proven. It was also found that coding errors for some consultant modeled projects contributed to negative travel time savings. Without a complete understanding of a negative result, it is difficult to recommend just changing the sign from negative to positive. Such an approach might even be considered manipulative. Therefore, it is the work group's recommendation that projects with negative travel time savings that don't round to zero be referred back to the KYTC modeling team for a final evaluation. At that point, the travel time savings results will be corrected for any coding errors found. If no errors are found, the travel time will be assigned a zero value.

Economic Competitiveness Formula (Statewide Level Analysis only)

Economic Competitiveness quantifies the economic benefit a project is anticipated to provide over a span of 10 years, estimating the number of long-term jobs created and the percent change in value added by a project. Economic Competitiveness uses an economic model, TREDIS, to quantify the economic benefits a project is anticipated to provide over a set period of time, in this case a 10 year period.

Statewide Economic Competitiveness Score = [(Scaled version of "Cumulative # of job-years of employment created over a 10 year period" from TREDIS) * (50%)] + [(Scaled version of "% Change in Value Added to the County Economy over a 10 year period" from TREDIS)* (50%)].

Cumulative # of job-years of employment created over a 10 year period from TREDIS = [(Scaled version of "Number of Long-Term Jobs Created for the County over a 10 year period" from TREDIS)*(50%)*(10 years)].
Once all projects obtain this "raw" number, then this number is scaled from 0 to 100 to two decimal places for each project before running the Statewide Economic Competitiveness Score calculation.

% Change in Value Added to the County Economy per 10 year period is also scaled from 0 to 100 to two decimal places for each project before running the economic score calculation noted above for each project.
% Change in Value Added to the County Economy per 10 year period = [Long-Term Total Value Added for the County per 10 year period from TREDIS] / [Baseline (Existing) Economic Condition for the County from TREDIS.]

The following defines the origin of the data behind this equation per NCDOT as follows:

- Long-Term Total Value Added for the County per 10 year period (millions in 2017 dollars). (This data is located in the TREDIS Bulk Export Spreadsheet under column "W".)

- Baseline (Existing) Economic Condition for the County per 10 year period (millions in 2017 dollars). (This data is located in the TREDIS Baseline Economic Patterns Data of the Bulk Export Spreadsheet under column "O".)

It should be noted where the project crosses county lines, Travel Time Savings (TTS) is calculated for the entire project across the multiple counties and used in the single county TREDIS analysis for the county containing the majority of the project. This is done as a practical solution to avoid over or under valuing the project impact over the larger economic area of multiple counties.

Accessibility / Connectivity:

Economic Growth Score Part 1 Regional 2020

Accessibility / Connectivity Formula

Regional: 10%

Regional Score = 10% * Accessibility/Connectivity Measure (ACM):

$ACM = f(P_{TYP}, TIER_{NEED}, AADT_{CAPPED})$

(Scaled)

Measure	Description	Summary Method	Source
P_{IT}	Project Improvement Type	Eligible Project Improvement Type†	SYP, CHAF
$TIER_{NEED}$	Tiers based on County Economic Indicators	County Tiers based on Negative and Positive Economic Indices†	CED,KSDC and BSSC
$AADT_{CAPPED}$	Annualized Average Daily Traffic	Length Weighted Avg, Max 20,000 (cap higher values)	Jackalope

Need Indices

Positive Indices:
- High School Education+ Index (2012-2016)
- Population Change Index (2000-2010)
- Median Household Income Index (2012-2016)
- Annual Wage and Salary Per Worker (2016)
- Per Capita Gross Domestic Product by County (2016)
- Labor Force Participation Rate (2012 - 2016)

Negative Indices:
- Annual Average Poverty Rate Index (2016)
- Unemployment Rate Index (2014-2016)

Pts by Project AADT & County Tier

Tiers	Points (Max 100)
Tier 1	AADT capped/200
Tier 2	AADT capped/200
Tier 3	AADT capped/300
Tier 4	AADT capped/300
Tier 5	AADT capped/600
Tier 6	AADT capped/600

Ineligible Project Improvement Types:
- Transportation studies
- Other improvement types

As previously noted, Accessibility/Connectivity quantifies the importance of improving access to rural and less-affluent areas while improving interconnectivity of the network to help improve economic conditions. Accessibility/Connectivity is measured using the travel time savings of facility type upgrades, and county tier designations indicating levels of distress, and a facility's average daily traffic.
Through collaboration with CED and KSDC, the County Economic Index was identified as a baseline with a few modifications (Table 1). KSDC recommends Median Household Income (MHI) as it excludes income derived through government assistance, and therefore, better reflects the quality of life within a county compared to Per Capita Personal Income. Adjusted Property Tax Base per Capita as used by North Carolina is not readily available in Kentucky; therefore KYTC proposes to use the same measures as the County Economic Index with one addition: Population Change. The indices are calculated as the ratio of the county value to the statewide average. For the unemployment rate and poverty rate, the inverse ratio is applied with statewide average to county value. Labor Force Participation Rate (LFPR) was also added at the recommendation of the CED to show the population of a county from the working ages of 18 years of age and older who are actively employed or seeking work. KYTC, CED and KSDC worked together to develop this additional parameter used to help define the profile of a county in need.

*Kentucky CED Data Sources: U.S. Census Bureau, U.S. Census Bureau- American Community Survey

Table 1. Economic Index Comparisons*

KY County Economic Index (*Sources)	Accessibility/ Connectivity	NC Dept of Commerce (**Sources)
High School Education Attainment (2012-2016)	Same	
Average Annual Unemployment Rate (2014, 2015, 2016)	Same	Average Unemployment Rate
Per Capita Personal Income (2016)	Median Household Income (2012-2016)	Median Household Income
Average Annual Wages Per Worker (2016)	Same	Adjusted Property Tax Base per Capita
Estimated Gross Domestic Product Per Capita (2016)	Same	
Annual Average Poverty Rates (2012-2016)	Same	Poverty Rate (5-year)
	Population Change (2000 – 2010)	Population Growth
Labor Force Participation Rate (2012-2016)	Same	

(ACS), U.S. Bureau of Labor and Statistics (BLS), U.S. BLS – Local Area Unemployment Statistics (LAUS), U.S. Bureau of Economic Analysis (BEA), U.S. Department of Commerce, U.S. Bureau of County Business Partners, U.S. Department of Agriculture, U.S. Geological Survey, IMPLAN Model.

**North Carolina Department of Commerce Data Sources: U.S. Census Bureau, U.S. Census Bureau-American Community Survey (ACS), U.S. Bureau of Labor and Statistics (BLS), U.S. BLS – Local Area Unemployment Statistics (LAUS), U.S. Bureau of Economic Analysis (BEA), U.S. Department of Commerce, U.S. Department of Agriculture, N.C. Office of State Budgets and Management (OSBM), N.C. Department of Public Instruction (DPI), U.S. Geological Survey, TREDIS Model.

With the revised index, tiering was established (Table 2) to be proportional to the distribution of counties among the County Economic Index and similar to their index group range. The tiering from Table 2 provides a tier for a project by county association. The project is then compared against the Project Improvement Type List (Table 3) to determine if the project would improve accessibility and connectivity within the county and/or region. If the project is identified to be one of those listed in Table 3, the project moves to the next stage. Otherwise, the project is not considered further to enhance accessibility/connectivity. From that point, the roadway volume (Average Daily Traffic (ADT)) of the project determines the ultimate score per the matrix in (Table 4.) It is in Table 4 that the distribution of counties by equation is also provided.

Table 2. County Tier Distribution (Counties per Tier)

County Tier	County Economic Index (by CED) (2016 to 2018)	Accessibility/ Connectivity (2016 to 2018)	NCDOT
1	21 to 25	22 to 22	40
2	22 to 24	18 to 18	40
3	28 to 24	23 to 26	20
4	20 to 23	28 to 26	
5	19 to 11	13 to 12	
6	10 to 13	16 to 16	

Table 3. Project Improvement Types (Enhance Accessibility/Connectivity)

1.	Arterial to Full Control	7.	Add Lane to Full Control Facility
2.	Arterial to Partial	8.	2 to 4 Lane Divided Rural
3.	Full Control to Interstate	9.	2 to 4 Lane Divided Urban
4.	Construct Road in New Location	10.	Install 2-Way Left Turn Lane
5.	Upgrade to Grade Separation	11.	Modernize Roadway: Major Widening or Reconstruction
6.	Grade Separated to Interchange	12.	Recommended Addition: New Routes

Table 4. Economic Competitiveness Scoring Elements			County Distribution by Equation	
County Tier	NCDOT (50%)*	Accessibility/ Connectivity	Number of Counties 2016	Number of Counties 2018
1	Volume/200	Volume/200		
2	Volume/300	Volume/200	40	40
3	Volume/600	Volume/300		
4		Volume/300	51	52
5		Volume/600		
6		Volume/600	29	28
Total			120	120

* - Remaining 50% derived through improvement type and travel time savings for the Accessibility/Connectivity Criteria only.

(Optional to include)

The following Table 5 shows the counties with tier changes and those counties that change equations from 2016 to 2018 given Table 1 Economic Indices.

Table 5. Counties Changing Tiers and Equations from 2016 to 2018

Location	Overall Index 2016	Overall Index 2018	County Tier 2016	County Tier 2018	Change In Tier?	Change in Equation 2018	Change Eqn-More Distressed 2018	Change Eqn -Less Distressed 2018
Kentucky	100.000	100.000						
Ballard	88.599	79.663	Tier 4	Tier 3	Yes			
Bath	72.425	71.229	Tier 3	Tier 2	Yes	Yes	Yes	
Carlisle	71.825	74.916	Tier 2	Tier 3	Yes	Yes		Yes
Casey	69.676	72.568	Tier 2	Tier 3	Yes	Yes		Yes
Garrard	98.965	99.742	Tier 4	Tier 5	Yes	Yes		Yes
Hickman	66.253	56.431	Tier 2	Tier 1	Yes			

Kenton	108.650	113.955	Tier 5	Tier 6	Yes			
Madison	121.947	109.926	Tier 6	Tier 5	Yes			
Magoffin	63.144	49.457	Tier 2	Tier 1	Yes			
Martin	57.952	63.174	Tier 1	Tier 2	Yes			
McLean	73.551	71.821	Tier 3	Tier 2	Yes	Yes	Yes	
Meade	99.884	97.330	Tier 5	Tier 4	Yes	Yes	Yes	
Monroe	57.848	60.297	Tier 1	Tier 2	Yes			
Owen	87.703	82.381	Tier 4	Tier 3	Yes			
Simpson	99.754	98.267	Tier 5	Tier 4	Yes	Yes	Yes	
Webster	84.730	74.903	Tier 4	Tier 3	Yes			

Freight:

Freight Formulas

Statewide: 10% **Regional: 5%***

Statewide Score = 10% X Freight Economic Growth Measure (FEGM) :

FEGM =RRatio X ((Freight X AADT)/KHFN_Factor) †Scaled

Regional Score = 5%* X Freight Economic Growth Measure (FEGM) :

FEGM =((Freight X AADT)/KHFN_Factor) †Scaled

Measure	Description	Summary Method	Source
RRatio	Truck Reliability Ratio	Length Weighted Average	HERE Data
Freight: Statewide: (0.20 X SU + 0.80 X CO) Regional : (0.60 X SU + 0.40 X CO)	Freight Statewide and Regional Factors SU: % Single Unit Trucks; Vehicle Class 4-7 CO: % Combo Unit Trucks; Vehicle Class 8-13	 Length Weighted Average Length Weighted Average	 HIS HIS
AADT	Annualized Average Daily Traffic	Length Weighted Average	Jackelope
KHFN_Factor: KHFN/$V_{TR,KHFN-MAX}$	KHFN: Kentucky Highway Freight Network Tier $V_{TR,KHFN-MAX}$: Max Truck Vol in each KHFN Tier††	Dominant Max	HIS HIS

* Standard Regional % listing, Regions may adjust priorities by up or down by 5% with a minimum of 5% in any individual criteria.
†Scaled - The percentile rank of the value. Converts value to score of 0 to 100.
†† Coal Haul included as a tier 5 in KHFN for scoring purposes

The Freight portion of the SHIFT formula is calculated for the statewide and regional scoring criteria. The freight section makes up 10 percent of the SHIFT Score. The 2018 SHIFT freight formula works as follows:

- (Percent Freight traffic * AADT) / (KY Freight network Tier / Maximum Truck Volume in each Truck Tier)

The Freight Committee met several times and considered possible improvements and sources of new data that could be used for the Freight formula. Among those considered were:

- Incorporation of Coal Haul information
- Use of Bridge Weight Restrictions
- Using Single and Combo Unit Trucks separately
- Use of Truck Crash information
- Use of Truck speed reliability information
- Incorporation of bridge clearance data
- Use of turning radii information
- Use of Oversize / Overweight truck information

Upon reviewing all possible data sources for modifications, the freight committee decided that all but three changes were not possible to implement at this time. The reasons range from lack of data to inability to apply any new measure fairly to all possible freight projects. The three changes to the freight formula that were recommended and approved are:

- Separation of Single and Combo Unit trucks and different weights at the statewide and regional levels
- Incorporation of truck reliability ratio into the formula
- Addition of Coal Haul routes as a fifth tier, whereas previously there were only four.

Each change was recommended due to the ability to apply new information fairly and universally to all freight projects. Coal routes and single/combo truck splits utilize data that KYTC has been collecting for years across all state-maintained roads. KYTC has purchased a new data set of speed data from HERE that covers nearly all state maintained roads and also has access to a separate set of speed data from INRIX through the NPMRDS. As a part of the performance measures reporting, truck reliability is already calculated for NHS routes and as a result, a significant amount of effort has already been expended to create a process to calculate truck reliability. The new formulas are:

- Statewide = Truck Reliability Ratio * ((0.20 * Single-Unit Truck volume + 0.80 * Combo Unit Truck Volume) * AADT) / (KY Highway Freight network tier / Max Volume in respective Tier)
- Regional = ((0.60 * Single-Unit Truck volume + 0.40 * Combo Unit Truck Volume) * AADT) / (KY Highway Freight network tier / Max Volume in respective Tier)

Benefit / Cost:

Benefit / Cost Score 2020

Formulas

Statewide: 20% **Regional: 15%**

Statewide Score = 20% * (Benefit / Cost) Measure (BCM) :

Regional Score = 15% * (Benefit / Cost) Measure (BCM) :

$$0.5 * \left(\frac{BTTS}{C_{PROJ}}\right)_{\text{Scaled}} + 0.5 * \left(\frac{BSAF}{C_{PROJ}}\right)$$

Measure	Summary Method	Source
BTTS: Travel Time Savings Benefit $	†Travel Time Savings * sum of delay costs by vehicle type	KY Statewide Model HCM Method Jackelope HIS
BSAF: Safety Benefit $	Safety Benefit Factor of specific improvement type * crash costs over last 5 yrs, 2013-2017	Crash Database CHAF
CPROJ: Family Project Cost Phases R,U & C	Summary	SYP CHAF

Safety Benefit Calculations

The Safety Benefit (B_{SAF}) is the first component in the calculation of the Benefit-Cost Measure. For SHIFT 2020 it recommended to keep the 2018 B_{SAF} formula and methodology.

$$B_{SAF} = SBF(N_{KAB} * C_{KAB} + N_{CO} * C_{CO})$$

In reviewing the 2018 Safety Benefit Factors (SBF) scores and their associated improvement types, it was determined that Kentucky specific planning level Crash Modification Factors (CMF) list could be used to improved estimate SBF values. The objective was to directly relate the Kentucky CMF values to the 2018 SHIFT improvement types. Upon further review, it was noticed that 2018 SHIFT SBF values were either over or under estimating safety benefit (some were about the same) compared to the planning level CMFs. This finding ultimately led to creating additional improvement types.

Figure 1 shows the 2018 improvement type Highway and/or Railroad Crossing with a SBF of 90. This score mainly reflected a grade separation of the highway and railroad crossing. Other railroad projects were receiving an overestimated safety benefit. Figure 2 shows the two new improvement types for Highway/Railroad Crossing Projects. Projects other than grade separation received a reduce SBF score reflective of the planning level CMFS.

Figure 1. 2018 Highway/Railroad Crossing Improvement Type

Improvement Type	SBF	Definition
Highway/Railroad Crossing	90	Improving existing highway and railroad crossing intersections primarily by constructing grade separations separating the two modes.

Figure 2. 2020 Improvement Types for Highway/Railroad Crossing Projects

Current New Improvement Type Recommendations	SBF	Definition
Improve Railroad Crossing	55	Install flashing lights and sound signals and/or automatic gates
Grade Separation of Highway/Railroad Crossing	90	Construct Grade Separation to Separate two Modes

The same reasoning was applied to other improvement types. Innovative Intersections such as restricted crossing U-turns (RCUT) and roundabouts were separated from the 2018 Improve Intersection improvement type as shown in Figure 3.

Figure 3. Intersection Improvement types separated into two.

Current New Improvement Type Recommendations	SBF	Definition
Improve Intersection	26	Install left turn lane, Install right turn lane, offset Left turns, new signal, etc.
Innovative Intersection	51	Improve an intersection by employing an innovative intersection design such as a roundabout, J turn, restricted crossing U-turn, median U-turn, etc..

Other improvement types were created to better define varied travel time savings projects. For instance the Modernize Roadway benefit type was divided into three improvement types based on differing travel time savings scenarios (Figure 4).

Figure 4. 2020 Modernize Roadway Improvement Types

Current New Improvement Type Recommendations	SBF	Definition
Modernize Roadway-Rural	26	Realignment or reconstruction to bring geometric (Vertical, horizontal) deficiencies up to modern standards, etc. To include minor Widening of lanes and shoulders, Reconstruction, Safety Hazard eliminations, Spot Improvements, Turn Lanes
Modernize & Widen Roadway - Rural	26	Realignment or reconstruction to bring geometric (Vertical, horizontal) deficiencies up to modern standards and to provide additional through capacity, including passing lanes or 2+1 configuration.
Modernize Roadway-Urban	16	Reconstruction of urban roadway without additional through lanes; may include curb and gutter, bike lanes, sidewalks, etc.

This same rationale was applied to two way left turn improvement types and interchange improvement types (Figure 5).

Figure 5. 2020 Two Way Left Turn and Interchange Improvement Types

Current New Improvement Type Recommendations	SBF	Definition
Install Two-way Left Turn lane	28	Widening existing pavement through addition of Two Left Turn Lane. Typically used in areas where there appears to an issue with turning related crashes such as rear-end and head-on on two lane roads. **NOTE:** Does not include Road Diets where number of through lanes will be reduced.
Road Diet	37	Reconfigure roadway to convert through lanes to a two-way left turn lane. May include bike lanes. Typically is when a 4 lane undivided urban road is coverted to a 3 lane section with bike lanes
Interchange Safety Improvements	35	Improve the safety of an interchange by extending acceleration/deceleration ramps, converting a cloverleaf interchange to a stop controlled interchange, etc.
Innovative Interchange	40	Improve an interchange by converting the existing interchange to an innovative interchange such as diverging diamond or SPUI (single point urban interchange)

Major Interchange Reconstruction	32	Reconstruct interchange to reduce conflict points or improve ramp geometry by adding loops or flyovers or replacing loops with directional ramps.

Through the SHIFT 2020 Workgroup discussions, the lack of consideration for bike and pedestrian related projects was brought up. The Bike and Pedestrian (Bike / Ped) improvement type with an SBF estimation of 13 was created. Through further discussions, the idea of using this benefit as a secondary option was debated. However, a defensible way to apply the secondary SBF could not be determined. After much discussion, the decision was made to instead offset the cost of Bike / Ped in the cost portion of the project. The extra cost associated with Bike / Ped improvements penalizes projects in the Benefit / Cost analysis. The group felt that the better method to address Bike / Ped needs was to remove the extra cost associated with it rather than try to look at a secondary safety benefit.

Considerations for the next SHIFT workgroup should be to re-evaluate SBF scores with applicable updated planning level CMFs. The next SHIFT workgroup should also consider secondary improvement types for projects, specifically what improvement types can be used as secondary improvement types. If a logic check on improvement type entries could be developed that will be beneficial as well.

The method for adding the secondary improvement of Bike/Ped is described below:

Adding Secondary SBF to Primary SBF:

1. Convert Primary (1) and Secondary (2) SBFs to CMFs

$$CMF_1 = 1 - (SBF_1/100)$$

$$CMF_2 = 1 – (SBF_2/100)$$

2. Multiply CMFs to get new project level CMF

$$CMF_{proj} = CMF_1 \text{ X } CMF_2$$

3. Convert Project level CMF back to SBF

$$SBF_{proj} = (1-CMF_{proj})*100$$

See Appendix B – Improvement Types for details on the research behind the Kentucky specific planning level Crash Modification Factors and a complete listing of the 2020 Improvement Types.

Travel Time Savings Calculations

Travel time savings (TTS) are estimated using one of two different methods, depending on the project type and scope. Projects that would be expected to significantly alter travel patterns, including new routes, new interchanges, and significant improvements to major routes in congested urban areas, are normally analyzed using the Kentucky Statewide Travel Demand Model (KYSTDM) , these projects are referred to as modeled projects. The other projects, which are referred to as non-modeled projects, are analyzed using spreadsheet-based methods. For more information on the analysis of negative TTS, see the discusson of Absolute Value of TTS vs. Zero value of TTS in the Economic Competitiveness section.

The Kentucky Transportation Cabinet (KYTC) asked Stantec to review the methods it has employed to measure TTS for both modeled and non-modeled projects. KYTC asked Stantec to consider and provide comments on the two approaches, as well as on the overall measurement of TTS in general. Stantec provided analysis in a memorandum addressing the following four questions related to improving upon the current methods:

1. When is it appropriate to use the KYSTM to analyze travel time?
2. What are the best options to account for TTS for smaller projects and projects associated with intersections?
3. How to best convert daily travel time estimates and the associated benefits to a 10-year period?
4. Should the value of time differ within regions of Kentucky?

This memorandum, "Modeled vs Non Modeled TTS Analysis", is in Appendix C – Travel Time Savings.

Modeled vs Non-Modeled TTS Results

Independent criteria is applied to determine eligibility for KYSTM modeling and for non-modeling methods. It is possible to have projects quality for both KYSTM modeling and for non-modeling methods. These projects will have TTS estimates from both methods. If a project has both modeled and non-modeled TTS estimates, the greater savings is assigned to the subject project. So where (TTS_M)= Total Modeled savings and (TTS_{NM})= Total Non-model savings

$$\text{IF } (TTS_M)>(TTS_{NM}) \text{ THEN } (TTS_M) \text{ ELSE } (TTS_{NM})$$

The result of this statement will be assigned as the travel time savings for the subject project.

Summary of Benefit Cost Equations

Benefit / Cost Measure	**$.5 * (B_{TTS} / C_{Proj}) + .5 * (B_{SAF} / C_{Proj})$**
B_{TTS}	Travel Time Benefit $
B_{SAF}	Safety Benefit $
C_{Proj}	Project Cost $
Safety Benefit	$B_{SAF} = SBF_{Proj}(N_{KAB} * C_{KAB} + N_{CO} * C_{CO})$
N_X	Number of Accidents by Severity X
SBF_{Proj}	Safety Benefit Factor by Project Type
C_X	Cost By Severity
Proj	Project Type
KAB	Number Killed, Incapacitated or Bloody
CO	Number Injured or Property Damage Only
Project Cost	$C_{Proj} = C_R + C_U + C_C$
CX	Cost by Phase
D, R, U, C	Project Phases (R= ROW, U=Utilities, C=Construction)
Travel Time Benefit	$BTTS = (CPC*PPC)TTS_c + (CTr*PTr)*TTS_T$
C_X	Delay Cost by Vehicle Type
P_X	Percent of Volume by Vehicle Type
TTS	Travel Time Savings (Modeled or Calculated)
PC	Passenger Car
Tr	Trucks (Single Unit and Combination combined)

Travel Time Savings Modeled Vs Non- Modeled		See Appendix C for more detailed Travel Time Savings explanations
TTS	= IF (TTS_M)<(TTS_{NM}) THEN (TTS_M) ELSE (TTS_{NM})	
TTS_M	Total Modeled savings	
TTS_{NM}	Total Non-model savings	
Modeled Travel Time Savings (TTS_M)		
TTS_C	({2017 NoBuild TTS_C - 2017 Build TTS_c} + {2026 NoBuildTTS_c - 2026 Build TTS_c}) *.5 *260*10	Travel Time Savings Private Vehicles
TTS_T	({2017 NoBuild TTS_T - 2017 Build TTS_T} + {2026 NoBuildTTS_T - 2026 Build TTS_T}) *.5 *300*10	Travel Time Savings Private Vehicles
TTS_M	=TTS_{T+} TTS_C	Modeled Travel Time Savings
Estimating Total Non-Modeled Travel Time Savings (TTS_{NM})		
TTS_{NM}	= max(ITTS,SWTTS) + RTTS	
TTS Segments (SWTTS)		
TTI	TTI = 2*VSF^2 – 1.1*VSF + 1; minimum TTI = 1.0	Travel Time Index to VSF relationship
	If TTI >1, VSF = 0.68*ln(TTI)+0.55	
DTTI	DTTI = 0.7*exp(0.61*VSF); minimum DTTI = 1.0	Daily Travel Time Index
ADT_{10}	=ADT_0*(1+g)^10	Future ADT
	If TTI_{KTC}>1.0, $VSF_{0,No-Build}$ = 0.68*ln(TTI_{KTC}) + 0.55; Otherwise, $VSF_{0,No-Build}$ = VSF_{HIS}	Estimate VSF
$SF_{No-Build}$	= k * ADT_0 / $VSF_{0,No-Build}$	Service Flow under no-build scenario
$VSF_{0,Build}$	=$VSF_{0,No-Build}$*$N_{No-Build}$/N_{Build}	VSF ratio for the current build scenario
$VSF_{10,No-Build}$	=$VSF_{0,No-Build}$*ADT_{10}/ADT_0	VSF ratio for the future no build scenario
$VSF_{10,Build}$=	=$VSF_{10,No-Build}$*$N_{No-Build}$/N_{Build}	VSF ratio for the future build scenario
$TT_{0,No-Build}$	= (L/S)*$DTTI_{0,No-Build}$*ADT_0*260	annual weekday total travel time for the current no-build scenario
$TT_{0,Build}$	= (L/S)*$DTTI_{0,Build}$*ADT_0*260	annual weekday total travel time for the current build scenario
$TT_{10,No-Build}$	= (L/S)*$DTTI_{10,No-Build}$*ADT_{10}*260	annual weekday total travel time for the future no-build scenario
$TT_{10,Build}$	= (L/S)*$DTTI_{10,Build}$*ADT_{10}*260	annual weekday total travel time for the future build scenario
SWTTS	=5 * ($TT_{0,No-Build}$ - $TT_{0,Build}$ + $TT_{10,No-Build}$ – $TT_{10,Build}$)	10-year segment widening travel time savings
ADT_0:	Current ADT reported in HIS; length-weighted average	
g:	Traffic growth rate reported as a decimal; assume g=0.0125	
TTI_{KTC}:	Travel Time Index calculated using KTC methodology,	
VSF_{HIS}:	Current VSF ratio reported in HIS; length-weighted average	
k:	The k factor reported in HIS; if unavailable, assume k=0.10; length-weighted average	
L:	Project length in miles; from CHAF	
S:	Reference speed from KTC methodology, in miles per hour;	
D:	Directional factor indicating type of operation; D=1 for one-way, 2 for two-way	
$N_{No-Build}$:	Number of existing through lanes	
N_{Build}:	Number of through lanes upon completion of the proposed project	
TTS Intersections (ITTS)		
$IVSF_0$	= ∑(0.1*ADT_i)/(900*N_i)	Exisitng Intersection Volume to Service Ratio
$IVSF_{10}$	= ∑(0.1*$ADT_{10,i}$)/(900*N_i)	Future Intersection Volume to Service Ratio
$DHDR_0$	if $IVSF_0$ < 0.7: $DHDR_0$ = 66.1*$IVSF_0$^3.4 ; Otherwise $IVSF_0$ >= 0.7: $DHDR_0$ = 100*$IVSF_0$ - 50.41	Existing Design-hour delay reduction (DHDR)
$DHDR_{10}$	if $IVSF_{10}$ < 0.7: $DHDR_{10}$ = 66.1*$IVSF_{10}$^3.4 ; Otherwise $IVSF_{10}$ >= 0.7: $DHDR_{10}$ = 100*$IVSF_{10}$ - 50.42	Future Design-hour delay reduction (DHDR)
$ADT_{i,10,ann}$	= $ADT_{i,0,ann}$*(1 + g_i)^10	Future ADT
$ITTS_0$	= 0.013 * $DHDR_0$ * Σ($ADT_{i,0,ann}$/D_i)	Annual weekday intersection travel time savings in the current year
$ITTS_{10}$	= 0.013 * $DHDR_{10}$ * Σ($ADT_{i,10,ann}$/D_i)	Annual weekday intersection travel time savings in the future years
ITTS	= 5 * (TTS_0 + TTS_{10})	10-year weekday intersection travel time savings
N_i:	Number of through lanes on approach i	
$ADT_{i,0}$:	$ADT_{i,0}$: Current ADT reported in HIS for approach i (in both directions for two-way approaches);	
$ADT_{i,0,ann}$:	$ADT_{i,0,ann}$: Current ADT for approach i to use for converting DHDR to annual TTS;	
g_i:	g Traffic growth rate for approach i reported as a decimal; assume g_i=0.0125	
Di:	1 for Couplet or one way; 2 for two-way	
TTS Railroad Grade Separation (RTTS)		Railroad Grade Separation 10 yr Travel Time Savings
RTTS	= 0.06 * N_T * (ADT_0 + ADT_{10})	
N_T	Number of trains per day using the crossing, which can be obtained as follows:	
	ATD_0 and ADT_{10} are the same as above for SWTTS	

Asset Management:

Asset Management Formulas

Statewide: 15% Regional: 10%*

Statewide Score = 15% X Asset Management Measure (AMM) :

Regional Score = 10%* X Asset Management Measure (AMM) :

AMM = Max(Pavement, Bridge)

Pavement = (PDIvalue + YEARvalue)† **(Scaled)**

Measure	Description	Summary Method	Source
PDIvalue	Pavement Distress Index weighting value Max 10	Dominant	PMS
YEARvalue	Year of treatment index value	Dominant	PMS

Improvement Types Included - Grade Separation of highway/Railroad Crossing, 2 lane to 4 lane divided-Rural, Arterial to Full Control, Upgrade to Grade Separation, Arterial to Partial Control, Access Consolidation, Modernize Roadway-Rural, Modernize & Widen Roadway-Rural, Modernize Roadway-Urban, Full Control to Interstate, 2 lane to 4 lane divided-Urban, Major Widening-Urban Streets and Major Widening-Rural Multilane.

Bridge = f(BC, LR, VC, Ratings)

Measure	Description	Summary Method	Source
BC	Bridge Closed	If more than one bridge within project limits the maximum bridge score is used.	BRM
LR	Load Rating-Bridge Posted or TR4WT	If more than one bridge within project limits the maximum bridge score is used.	BRM
VC	Vertical Clearance	If more than one bridge within project limits the maximum bridge score is used.	BRM
Ratings	Deck Rating (RD), Substructure Rating (RSB), Superstructure Rating (RSP)	If more than one bridge within project limits the maximum bridge score is used.	BRM

Bridge Measure:

The current SHIFT asset management formula for the bridge measure (Bbm) was analyzed extensively with SHIFT project information and found to work overwhelmingly well in assigning the asset management score. The bridge measure calculation utilizes a sequential multistep test with a yes/no algorithm to allocate bridge asset management boost points. This algorithm looks at specific National Bridge Inventory (NBI) Items that are key to a bridge's condition and capacity. As noted in **FIGURE 1**, points vary depending on which item is true in the argument.

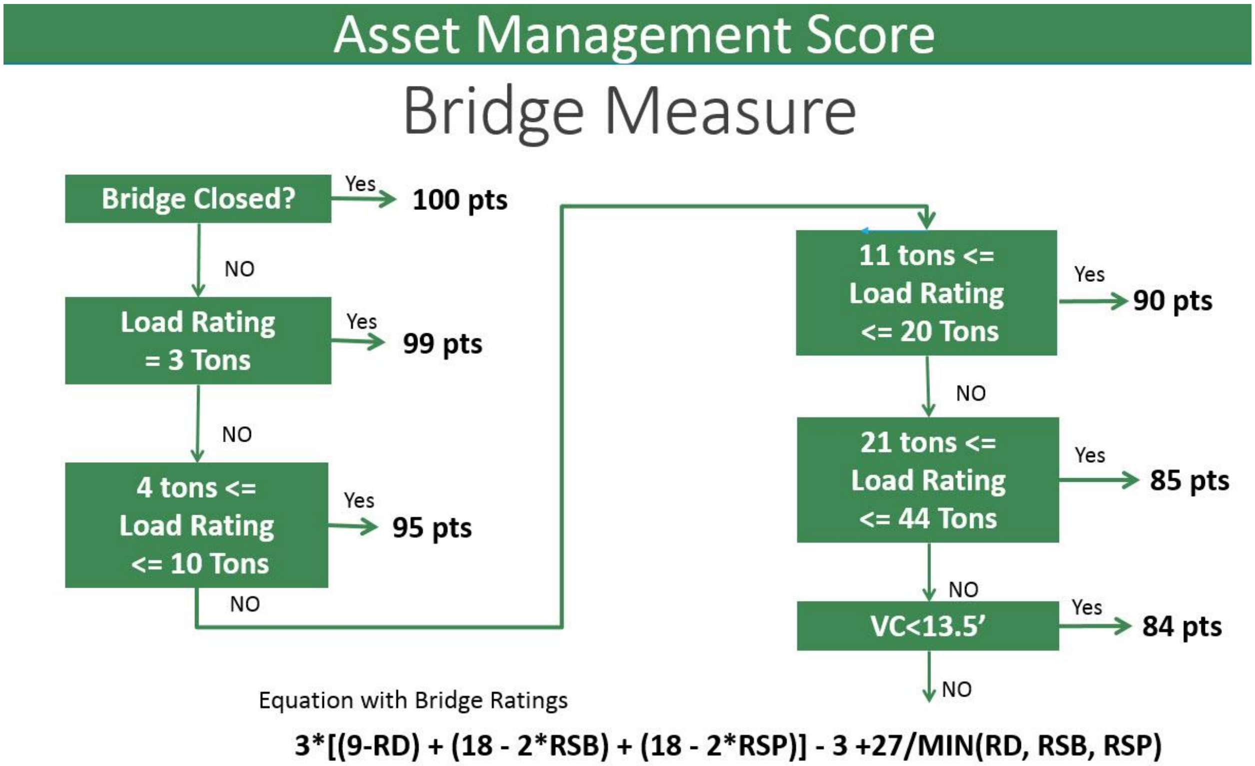


FIGURE 1

The first step in the bridge measure is whether or not a bridge is closed (NBI Item 41) to the travelling public. If so, 100 points are given. If not, the formula starts to look at the bridge's capacity from the bridge inventory load rating (NBI Item 66). Depending on which threshold the capacity falls under, a score of 99, 95, 90 or 85 points can be assigned. If the bridge load rating is greater than 44 tons (all of the previous arguments are no) then the bridge vertical underclearance (NBI Item 54b) is examined and if less than 13.5 feet, 84 points are assigned for the bridge measure.

If all of the above agreements are no, the score for the bridge measure is assigned based on the bridge rating equation in step 2. This encompasses the rating for the deck RD (NBI Item 58), the superstructure RSP (NBI Item 59) and the substructure RSB (NBI Item 60). These three NBI Items have a numerical condition rating from 0 to 9 with 9 being in excellent condition and 0 being a failed condition per the National Bridge Inspection Standards (NBIS). Although the derivation of step 2 could not be determined, the analysis concluded that it is a weighted formula based on the three bridge conditions and if all three are in excellent condition (all 9's), then zero points are assigned.

From the team's analysis, it was determined that the multistep process works very well to assign the bridge measure points and does not need to be modified because what is not captured in step 1 ends up being captured in step 2. The team did try to incorporate several other factors such as the health index, the bridge condition (good, fair or poor), and the scour rating but those conditions are already captured indirectly in either step 1 or step 2 based on current bridge inspection procedures and policies. For instance, a poor bridge is classified as having a condition rating of less than or equal to 4 and would be captured in step 1 if that was due to a load rating issue or it would be picked up in step 2 in the bridge rating equation. Likewise, if a bridge was scour critical (NBI Item 113 ≤ 3), it would already be posted or per policy have a low rating for Item 60; therefore, being capture in step 1 or 2 as well.

Point values were also reviewed to see if they needed to be modified but considering a closed bridge should be given the maximum amount of boost points, the other point values were adequately proportioned in step 1.

Pavement Measure:

The idea behind a Shift score for existing assets is to capture the value added for projects that address pavement sections in poor condition. Funding Shift projects where Good conditions exist is not fiscally responsible. To measure this value a function of remaining pavement life, pavement condition index, and project cost was developed.

A focus group consisting of pavement, bridge, and planning individuals analyzed available data to determine the best possible criteria to evaluate asset value for Shift projects. The previous formula was given as: 10/(Year of next treatment – 2016 +1) * Cost per mile * Length

This previous formula used 10 years as the base life of a pavement treatment, then divided that base life by how much remains. This creates a pavement life ratio factor that is multiplied with the Shift project cost. The Year of next treatment is a recommendation from engineer evaluation of the pavement. If a pavement section is in need of treatment now, it is considered to be in Poor condition. Poor sections receive the maximum of a 10 pavement life ratio. A new pavement section, one that might not need another treatment until 2027, would then receive a pavement life ratio score of 0.83. These factors are then multiplied by the project cost, and then scaled, to get the final pavement asset score.

On review, there were limitations found with this original formula. Mainly, though recommended treatment year is a valid indicator of pavement condition, it is only a single piece of the data collected on pavement sections by Pavement Management. Pavement Management collects cracking, rutting, and smoothness data for all State Primary, State Secondary, and Supplemental routes in the state. This pavement data, along with traffic volume, is then used to create an index value, Pavement Distress Index, which indicates the overall condition of the pavement section. This index, in conjunction with Recommended Treatment Year, is a very good indicator of pavement asset condition.

Other factors were reviewed for inclusion as well, namely truck traffic and remaining asset value. After analysis, these factors did not affect the asset score greatly, and the committee felt these factors were addressed through other Shift committees.

The final recommended pavement formula is:

Scaled [(Least((0.688-Least(Pavement Distress Index,0.687))/0.688,10) + (10/Year Next Treatment – Year Shift Plan +1)) * Length]

This formula equally weights the Pavement Distress Index with the Recommended Treatment Year.

Future refinement might change the 50/50 split between recommended year and PDI in the formula. This split follows the general practice currently in Pavement Management, but future data collection practices, so as advances in automated pavement distress collection, might require a move more fully to PDI.

Pavement Measure

(PDIvalue + YEARvalue) $_{scaled}$

PDIvalue: Pavement Distress Index Value
YEARvalue: Year of treatment Index Value

Sub Formulas

PDIvalue = 1 / PDIweight (Capped at 10)
PDIweight = PDI (Capped at .687)
YEARvalue = 10/($Year_{NT}$ – $Year_{SYP}$)+1) (if $Year_{NT}$ – $Year_{SYP}$ <1 the use 1)
$Year_{NT}$: Year of next Treatment
$Year_{SYP}$: Year of Six Year Plan

SHIFT Flags (Missing Criteria)

The Missing Criteria team was tasked with exploring ideas and concepts for implementation in SHIFT 2020 that were not previously accounted for in the 2018 SHIFT process.

Research

The current SHIFT program is heavily based on a prioritization scheme developed by North Carolina. The Missing Criteria team examined other states' prioritization plans, including Alaska, California, Missouri, Texas, Washington, Wisconsin, and Vermont. Washington, Wisconsin, and Vermont are the most similar to Kentucky in that the legislature has a substantial role in final project selection. However, according to direct conversation with Vermont DOT, the legislature actually shows marked deference to the DOT's recommend highway plan due to the perceived robustness of their prioritization process.

States which have access to a statewide data source generally utilize that data in project prioritization and identification. However, states differ wildly on the actual process used. California distills project information into twelve different “benefits” which is then compared to the project cost and sorted by this ratio. On the other hand, Alaska utilizes a more subjective rubric style of grading projects with more arbitrary scoring cutoffs.

Every state examined has some form of subjective measure within their formulas or rubric. Usually it appears underneath a specific category with points given for “other issues” or something similar. None of these states had a process where a blanket boost analogous to regional SHIFT boosting was applied without very specific guidelines. However, it does not appear that other states have a level of local involvement which compares to SHIFT.

Regional Prioritization

Rationale for inclusion of lower scoring projects	Draft Definition
Strategic Budget Priority	Project has a lower cost than higher-ranked projects and, therefore, more likely to be completed due to budget limitations.
Efficiency Bundling	Including project along with adjacent projects will save money and/or improve efficiency.
Continuation of Existing Project	Project is a component of an existing project already underway, funded and/or ready for letting.
Continuity with Existing Project(s)	Project is related to other project(s) underway that will improve the overall corridor.
Investment Impacts	Anticipated investments or changes may impact need or timing of project. (Examples may include new or expanded industry, or development, construction of a new school, renovation or expansion of utilities.)
Official Plan	Included in Local, Regional or Statewide Plan including TIP/STIP and Comprehensive Plans.
Program Balance	A successful infrastructure program needs a balance of projects in various stages to ensure timely delivery of projects. Project improves pacing of local projects.
Project Adjustment	Further review of project resulted in needed adjustments and improvements before submitting for SHIFT analysis in future cycle.
Rail Crossing Remediation	Project includes railroad crossings, which can be more hazardous and disruptive to traffic flow than traditional intersections. Remediation will improve safety and/or connectivity on the overall system.
Regional Collaboration	Other projects have greater regional value and support among local agencies (Highway District, Area Development District and Metropolitan Planning Organization).
Statewide Balance	Project elevated to ensure geographic balance across the state and better utilize available system resources (e.g. project manager, contractors, etc.)

Rationale for not selecting higher scoring projects	Draft Definition
Complementary Project	An adjacent project (underway or in development) will likely improve the overall corridor and impact the project’s need.
Anticipated Letting/Funding	Project already has letting date scheduled or anticipated funding.
Illogical Termini	(For corridors with multiple projects) Project is not the most logical starting point for the overall corridor improvements.
Investment Impacts	Anticipated investments or changes may impact need or timing of project. (Examples may include new or expanded industry or development, construction of a new school, renovation or expansion of utilities.)
Lower Support	Other projects have greater local support given budgetary constraints.
Lower Cost Alternative	A lower-cost alternative is being considered to address one or more of the components (e.g. safety, connectivity, etc.)
Regional Collaboration	Other projects have greater regional value and support among local agencies (Highway District, Area Development District and Metropolitan Planning Organization).

In the SHIFT 2018 process, Regional Summits were held where the Districts established projects of critical need and projects that the Districts could address in 6-10 years under a variety of funding scenarios. Select projects were considered critical needs due to factors not accounted for in the SHIFT score. These factors are shown above and were used as a starting point for developing other measures to use when data alone does not tell the full story.

Flags

The SHIFT process does not yet account for substantive project issues which do not have hard data to account for them. The missing criteria team endeavored to find a way to account for these issues while keeping CHAF simple, avoiding diluting the other quantitative measures, and incorporating bike/ped improvements into the process.

The missing criteria team recommends that "flags" be incorporated into the SHIFT process. These flags are qualitative indicators which can be readily incorporated into CHAF and can inform decision makers as the recommended highway plan is developed. Of the following seven flags, a maximum of two should be selected along with a comment field for context. Every project may not have even one or two flags which would apply.

Once implemented, the flags should be viewable until the recommended highway plan is complete. A comment field should also be provided to allow for additional context, or to provide hyperlinks to relevant documents.

Flag #1 – Comp Plan/MTP

This project is included in a local comprehensive plan or metropolitan transportation plan. Inclusion in other planning documents, such as the TIP or STIP, is not sufficient. A link to the relevant plan and a reference to the page or section should be provided in the comment field.

Flag #2 – Corridor Completion

This project is the final improvement or segment needed to complete a homogeneous corridor.

Flag #3 – Imminent Economic Growth

This project will directly serve needs generated by publicly announced economic development. This includes manufacturing, healthcare, education, and any other large employment generator. A link to the public announcement should be provided in the comment field.

Flag #4 – System Resiliency

This project will address recurring problems caused by flooding, slope failures, maintenance issues, and other extreme events which decrease the resiliency of the highway network.

Flag #5 – PBFS

The project was re-scoped and scaled back using KYTC's Performance Based Flexible Solutions guidelines. The original scope and cost should be provided in the comment field.

Flag #6 – Railroad Crossing Improvement

Railroad crossings can be more hazardous than traditional intersections. Remediation or removal of these crossings may result in significant improvements in safety and connectivity on the overall system.

Flag #7 – Bike/Ped

This project includes dedicated bicycle and/or pedestrian accommodations consistent with a documented, published bicycle and/or pedestrian plan. A link to the relevant plan and a reference to the relevant page or section should be provided in the comment field.

Members of the Missing Criteria team are available to assist the SHIFT team in reviewing and applying flags within the CHAF system so a timely recommended highway plan can be assembled.

Conclusion

The purpose of the flags is to aid decision makers who assemble the Recommended Highway Plan by providing context for a project which addresses issues not fully distilled by a SHIFT score.

The Missing Criteria team recommends the following items be implemented into the SHIFT process:

- Flags 1-7 be incorporated into CHAF, with a maximum of two being able to be selected for each project.
- A comment field should also be incorporated to provide additional context or hyperlinks to relevant documentation.
- Flags should accompany the project on all documentation leading up to the assembly of the recommended highway plan. After this point, flags should fall away.
- More flags can be considered; however, the number should be kept small so as to not overwhelm CHAF.