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Transit System Evaluation Process: From Planning to Realization

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ABSTRACT

Many frameworks exist to help transit agencies plan, operate, and monitor the performance of transit in rural and urban communities. No framework integrates these three critical business practices into one coherent and flexible framework useful to rural and small-sized cities. The primary objective of this research was to integrate planning, operations, and performance measurement activities into a framework designed to evaluate transit in the context of overall mobility. By combining planning, evaluation, and performance monitoring processes, a succinct framework useful to transit agencies and planners was created. In addition to city entities, colleges and universities operating or contracting transit systems also benefit from such a framework by creating a process that can be tailored to their needs as well. The framework outlines the activities necessary to complete a fixed route transit evaluation through an examination of the entire transportation system. Specific methodologies for each activity were not included in the framework because they must be customized to fit the needs and resources available to the evaluating entity but several example methods are presented in a case-study application of the proposed framework itself. The framework was tailored for use by rural and small cities and small- and medium-sized universities; however, it can be customized to meet the needs of any agencies or department regardless of the location. A case study of Clemson University's on-campus transit route, operated by Clemson Area Transit, in Clemson, South Carolina revealed that the proposed framework worked well in bringing stakeholders together and achieving the intended objectives.

INTRODUCTION

Sustainability in all aspects of our daily lives is increasingly important in today's society, especially with respect to transportation. Gas prices, oil spills, congestion, and pollution are constant reminders of the negative effects of our mobile society. One way of moving towards a sustainable transportation system is to incorporate a multi-modal perspective into the planning, operations, and performance measurement of the system. A multi-modal perspective is one that incorporates pedestrian, bicycle, vehicle, and public transportation facilities into the transportation system, encourages transportation demand management techniques such as carpooling, and provides users with the information necessary to make the optimal modal choice. By providing options to users, the dependency on single occupancy vehicles can be reduced and a more sustainable transportation system can be achieved.

This research evolved from a transit evaluation of the Clemson Area Transit's Tiger Route operating on Clemson University's campus in Clemson, South Carolina. A decreasing supply in convenient parking, an increased desire for pedestrian safety, and slimming financial resources moved transit to the forefront of conversation at the university. Academic facility expansions will significantly reduce parking availability and is expected to cause a shift in transit demand; thus, the need to align transportation initiatives and infrastructure was identified. Before the evaluation commenced, a framework to conduct this evaluation from the planning stages to the implementation of any alternatives, and monitoring of the systems performance was required to provide direction. The framework was designed to be customizable to meet the needs of many users, including cities as well as universities or other moderately sized institutions.

A multitude of published frameworks address planning, operations, and performance measurement for public transit and transportation systems separately. When faced with the challenge of zero-base planning of a transit system, researchers at Clemson University noted the usefulness of these three aspects and sought to tie them together into a single coherent and flexible transit planning framework. The resulting framework presented in this paper can guide a transit administration or planning agency through the process of continual improvement of a transit route or transit system. The primary objective of this research was to integrate planning, operations, and performance measurement activities into a comprehensive framework designed to evaluate a transit system in the context of overall mobility for a city with a predominate academic institution or the institution itself. Another objective of the research was to conduct a transit evaluation of Clemson University's on-campus transit route as a case study utilizing the proposed process. The remainder of this paper summarizes the development and explanation of the process created.

LITERATURE REVIEW

Throughout the nation's history many different approaches to transportation planning and evaluation have evolved. From the 1950s to the 1970s, the automobile was considered the primary mode of travel with transit supplementing it during peak hours and servicing the non-driving population (*1*). This limited approach to transportation planning brought "an almost exclusively auto-oriented approach, ineffective solutions to modern transportation problems, 'built-out' urban areas, and severe constraints on financial resources" (*2*). When this approach was evaluated in its time, it was deemed to provide effective solutions. However, this approach led to a limited transit user population often reviewed as captive riders, and the appeal of transit was tarnished by this negative interpretation. Today, transit ridership is increasing because of an integration of transportation modes and technology which is making it easier to use and rising fuel costs.

To attract more choice riders to transit, the system has to perform at a level comparable to driving a personal automobile. Ryus (*3*) identifies four points of view that transit performance should be addressed from:

1) Customer = passenger perceptions and quality of service
2) Community = impact on community and role in meeting broad community objectives
3) Agency = efficiency and effectiveness of the service
4) Driver/Vehicle = performance measures predominately used by traffic engineers such as average travel speed and delay.

One issue that most stakeholders agree on is safety; but even though they agree it is a priority they might have different methods of addressing it (i.e. lighting a bus stops verses transit travel speeds). Transit performances from all of these perspectives need to be evaluated for current and expected future conditions and user demographics. While the growth and demographics of a city are fairly stable over time, universities might change in an unpredictable manner due to the dynamic nature of the student body and research and development directions. That being said, both try to develop plans for growth – just as universities tend to have campus master plans, metropolitan areas also have long range master plans. Due to the strong interdependencies between the various modes of transportation and other activities, transportation planning should be related to city or university planning within an entire transportation
system, regardless of administrative boundaries, and vice versa (*1*).

Published frameworks in planning, operations, and performance monitoring were investigated to determine what activities are crucial in performing these tasks. American and international frameworks in planning, asset management, resource allocation, and performance monitoring were reviewed. The following sections highlight the processes found in each of the three areas of interest – transit planning, transit operations, and transit performance measurement.

Transit Planning

It must be recognized that "a transportation system is usually planned, designed, built, operated, maintained by organizations and individuals with different objectives, mandates, constituencies, and problem definitions" (*4*). In the development of an evaluation process, all stakeholders and constituencies must be considered. To favor one party's objectives over another's objectives lead to a rejection of the results and animosity between the stakeholders. A performance based framework developed for the Federal Highway Administration (FHWA) Highways for LIFE program (HfL), a program that represents longer-lasting highway infrastructure using innovations to accomplish fast construction of efficient and safe highways and bridges, demonstrates the importance of bringing stakeholders together and fostering innovation (*5*). This framework places an important on gathering stakeholders and brainstorming to identify the needs and wants of the users. Brainstorming allows the stakeholders to learn what each group expects from the system and each individual's goals are.

The Transportation Planning Handbook offered a planning framework for large institutions including colleges and universities (*6*). This process highlights the connection between city agencies and the institution both in goals and plans for expansion. It also identifies the three areas in which current conditions should be evaluated – transportation, economic, and environmental conditions. The final planning process investigated was the transit planning process developed by Vuchic (*1*). The transit planning process emphasized the development and revision of goals and objectives and the creation of a performance monitoring plan when initially planning a system or considering a change. Each of these processes identifies key activities to pertinent to beginning of a successful transit evaluation and continual improvement plan.

Transit Operations

Managing transit operations involves the management of not only labor but also the necessary assets. Multiple processes have been developed for transportation asset management all over the world. The Federal Highway Administration (FHWA) described transportation asset management as a "systematic, fact-based, and reproducible decision-making approach to analyzing the tradeoffs between investments and improvement decisions at the system and project level" (*5*). It was that belief that led to the creation of the Transportation Asset Management which emphasizes the use of data gathered from current conditions to bring transparency to the decision making process and minimize the effects of personal beliefs. It also incorporates the short- and long-term plans into the project selection process (*5*). In Victoria, Australia, an integrated approach to asset management and service delivery is utilized across all assets and government departments (*7*). The Australian approach emphasizes the examination of an entire asset base instead of an individual asset during a decision making process. That same approach is essential when evaluating a transit system because it is not the transit system that must be evaluated; rather it is the entire transportation network. A holistic, transparent evaluation process driven by facts is needed to objectively evaluate alternatives and choose the solution that is best for the community or campus.

Transit Performance Measurement

A transportation plan is only effective if performance is measured to determine if the plan worked. A performance measurement system can be structured in a myriad of ways to fit a particular community, agency, or university. In a performance measurement model developed by Nakanishi and List (*8*), some key characteristics such as stakeholder acceptance, linkage to goals, clarity, and flexibility must be present, no matter the form, for a performance measurement system to be effective. The objective of performance monitoring is to identify inefficiencies and budget money for improvements to reach an optimal system status. While the premise behind a performance measurement system has been the same for decades, the value of such systems has been lacking throughout transit agencies across the country. With passing of Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users [SAFETEA-LU (*9)*] making grant money dependent on a performance measurement system, cities and universities must work ever closer with their transit agencies to achieve greater livability and mobility in communities and on campuses. Similar to other processes investigated, performance measurement plays a significant role in an evaluation or decision making framework. In TCRP Report 88, Ryus (*3*) offers eight steps for establishing a performance measurement program:

1) Define goals and objectives.
2) Generate management support.
3) Identify users, stakeholders, and constraints.
4) Select performance measures and develop consensus.
5) Test and implement the program.
6) Monitor and report performance.
7) Integrate results into agency decision making.
8) Review and update the program.

The steps above contain many of the same elements found in the other models such as identifying stakeholders, defining goals and objectives, and monitoring performance. The final step in the process "review and update the program" creates an iterative nature that is necessary for continual improvement. In addition to be continuing process, performance monitoring and transit evaluation must be flexible. Frameworks should be designed to customizable to meet the needs of organizations in "different policy, institutional, organizational, technological, and financial settings" (*10*). Cambridge Systematic created a framework for the American Association of State Highway and Transportation Officials (AASHTO) that can be utilized with a broad view or narrowed down to fit a more manageable scope. This process is focused on allocating resources appropriately which is one of the many reasons to conduct performance monitoring.

Summary

Each area of the evaluation process offers different components that should be incorporated into the proposed transit evaluation process. Existing planning frameworks concentrated on defining stakeholders, defining and revising goals and objectives, and integrating the transportation and development plans of a city and institution to create a unified direction for improvement. Operational frameworks focused on asset management and considering all aspects of the transportation system instead of narrowing down on just one mode or facility. The performance monitoring programs emphasized the important of gathering meaningful and understandable information and using that information to continually improve the system being monitored. It was also evident

from the literature review that broadly defined process steps are a key component in creating a customizable process. Although there is overlap between the various frameworks, each offers a slightly different perspectives and goals that should be incorporated into a transit evaluation process.

PROCESS DEVELOPMENT METHODOLOGY

A review of relevant literature was conducted to identify methodologies for planning, operating, and monitoring the performance of transit systems. The frameworks were chosen for review based on their universality to transportation issues, complexity, and adaptability. The frameworks were then dissected to determine which elements were most common and which elements should be included in the transit evaluation process, based on their efficacy in addressing the planning, operation and monitoring criteria. Table 1 depicts which elements were included in each of the frameworks. Some elements differed merely contextually across the published frameworks. For these similar elements, one broader element is included in the analysis matrix. A bibliometric approach was used to determine which elements should be included in the proposed transit evaluation process based on their presence in a majority of the frameworks reviewed. Elements occurring in fewer than a majority were considered for inclusion based on their relevance to the relationship between a city and an academic institution, the probability that it would overlooked by an evaluator if it was not explicitly included in the process, and its contribution to continual improvement. From these elements, a transit evaluation process for cities containing a predominant academic institution and university campuses emerged.

PROPOSED TRANSIT EVALUATION PROCESS

Figure 1 presents the proposed transit evaluation process developed to help administrators and planners maintain optimal transit systems in a city or university environment by integrating planning, operations, and performance measurement into one framework with an emphasis on continual improvement. By creating a process which encourages feedback, the process and the transit system can continue again and again. It was designed to be adaptable to any settings since no two locations or organizations are exactly alike.

Identify Users & Stakeholders

The first step in the process is to identify the users of the transportation system and all stakeholders that have an interest in the system. The stakeholders of a city's transit system include commuters, the transit users, city administrators, and transit agency administrators as well as any large employers or private enterprises that may help subsidize the transit system. Stakeholders in a university environment include students, faculty, staff, visitors, and vendors as well as city transit stakeholders if the city provides transit services. The stakeholders identified should be specific individuals or from specific community or university groups and agencies with the authority to speak on behalf of the group that they are representing. To ensure acceptance of the alternatives chosen by the coalition formed, it is essential that all major interest groups are identified and engaged before the process proceeds.

Review Planned Expansions and Renovations; Review Transit Agency's Goals and Objectives

Before setting the transportation goals and objectives for the city or university, it is important to know where each is heading the in future, both organizationally and financially. Planned city expansions and expansions of the university can range from a new commercial center to the location of planned resident housing. It might also include plans for the expansion of the transportation system in terms of roadway, bicycle or pedestrian facility improvements. With an understanding of what the city or university has already begun planning for, the stakeholders are able to think critically and creatively to further enhance the transportation system.

Define/Refine Transportation Goals and Objectives

When defining the transportation goals and objectives, it is important to keep a multi-modal perspective. For decades, the only transportation mode that was considered was the automobile, but now cities and universities must plan for pedestrians, bicyclists, motorists, bus riders, rail riders, light rail riders, etc. It is important that the transportation goals and objectives for the city, the university, and transit agency are all consistent with each other so that entities support each other in reaching those goals. Not only should the goals illustrate the level of quality that each agency strives to achieve, but they should also describe where that agency would like to expand in the future. Similar to transportation plans required by the state and federal departments of transportation, creating short term and long term goals helps guide the city's and university's transportation system into the future.

TABLE 1: Elements of Published Frameworks

Method of Evaluation / Evaluation Step	Transportation Planning Handbook	Transit Planning Process	Highways for LIFE Performance Framework	Overview of Asset Management	Australian Asset Management	Resource Allocation and Utilization Process	Performance Measurement Program
Define and Recruit Internal Stakeholders			X				X
Hold initial brainstorming sessions			X				
Review and coordinate with regional and city transportation and development goals	X						
Establish goals and objectives	X	X	X	X		X	X
Evaluate existing transportation conditions	X	X		X		X	
Evaluate existing economic conditions	X			X		X	
Evaluate existing environmental conditions	X						
Develop Alternatives	X	X		X	X		
Analysis, Feasibility, and Testing	X	X	X	X	X	X	
Plan Development	X	X		X		X	
Develop Consensus							X
Implementing Strategies	X			X			X
Establish baseline			X				
Performance monitoring		X		X		X	X
Establish, communicate, and implement requirements for ownership, accountability, and responsibility					X		X
Integrate asset planning and management into plans, and budgetary and evaluation processes					X		X
Review and update the program							X

Evaluate Existing Economic Conditions

Once the goals and objectives of the transportation system are complete, an evaluation of the current system commences. No agency or institution can afford to waste the money of its constituents. In a poor economy, economic sustainability and financial efficiency is even more important. Cities and universities must strive to extend their money through federal grants and/or partnerships with other localities or institutions in the area. Universities have the option to levy a student transit fee while cities have the option to levy taxes to increase available funds for transit although both are generally considered unfavorable options. Funding opportunities are dependent on the rules governing a particular city or university; however, innovation in the transportation area can be encouraged no matter what system is being discussed.

Evaluate Existing Transportation Conditions

The evaluation of the existing transportation system is where most of the numerical data is generated. A ride check survey, which is a form of origin-destination study, can be conducted either manually or through the use of technology such as automatic passenger counters. Ride check surveys reveal where and when a transit line is at capacity and what routes are underutilized. A more detailed origin-destination study that can be conducted is a travel diary study. Other possible studies to evaluate the existing transportation conditions include a parking study, user survey, traffic counts, pedestrian counts, and speed studies. Transportation modeling through simulations can be used to determine the transportation conditions in the future following some change. City and campus administrators must be cautious not to make hasty decisions. If one route receives low ridership, it must not be assumed that route should be immediately cut from service. There might be other extraneous factors such as frequency or alignment that make that route unfavorable. Decisions based on the ridership totals alone can lead to changes which further detract from transit's attractiveness.

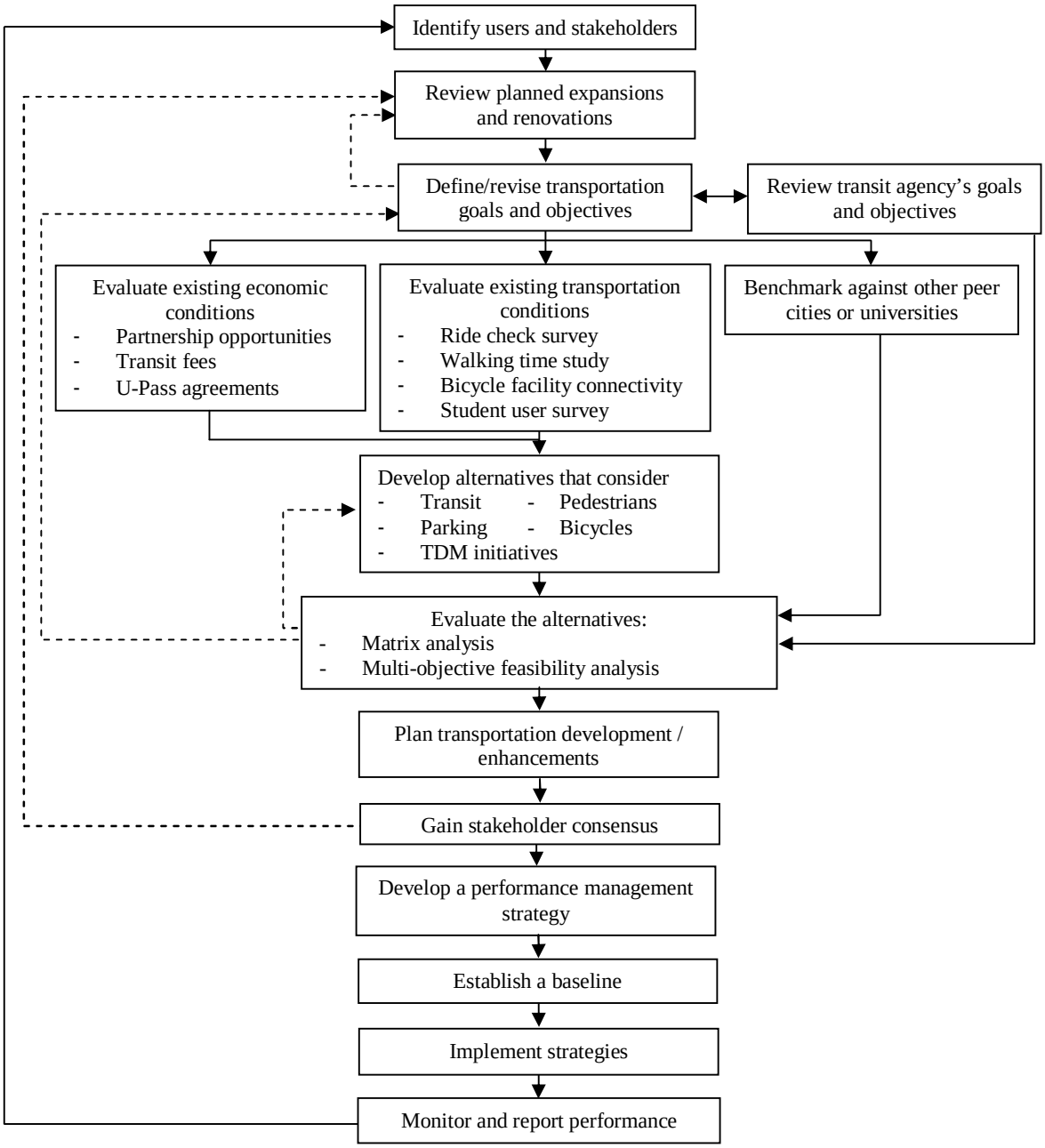

FIGURE 1: Transit Evaluation Process

Benchmark Against Other Peer Cities or Universities

Transportation improvement programs do not have to be like reinventing the wheel. By conducting a benchmark survey of communities or academic institutions with similar transportation systems, administrators can learn from another's mistakes. Similarly, the successes of one city or university might benefit many more if it is known that a particular program works well. Emulating positive practices that work within a community will only strengthen the transportation system.

Develop Alternatives

After gaining a perspective on the financial situation, the existing transportation system, and what similar locations are doing with their transportation systems, it is time for innovation to flourish. Although the process is intended for the evaluation of a transit system, the alternatives generated should not be limited to changes only to the transit system. A transportation system is an interconnected web potentially consisting of a transit system,

roadway network, parking facilities, pedestrian facilities, bicycle facilities, intelligent transportation systems, and demand management techniques. A small change in any one of these areas could prove to have major effects on the transit system. In developing alternatives, it is important to think multi-modally and in terms of the system not the component. Innovation can come from anyone, so this is great opportunity to engage the users and stakeholders of the system.

Evaluate the Alternatives

After developing alternatives, each alternative needs to be evaluated critically and objectively. A matrix analysis, a method commonly used to evaluate roadway projects, is one of the methods for evaluating the transit alternatives. A matrix analysis allows each stakeholder or user to express topics or measures of effectiveness they are most concerned about. A weight is then applied to each of the topics, after a consensus from the stakeholders, by which all the alternatives are measured. Each alternative is then rated on a set scale by topic, weights applied, and a sum taken to arrive at an alternative's total score. The alternative with the highest score represents the "best-compromise solution." It is imperative that all stakeholders are present, else the results will be viewed as biased by the missing group. The number of votes for each constituent group must also be agreed upon early in the process. A multi-objective analysis follows a similar process but allows for a more in depth and mathematical analysis. A utility function is created for each of the measures of effectiveness raised by stakeholders. The functions are solved simultaneously to determine the overall score of a particular alternative. The alternative receiving the highest score is deemed the "best-compromise solution." The method used for alternative analysis should be based on the experience of the analyzer and what level of complexity the stakeholders will be able to easily understand. All alternatives, regardless of the analysis method used, should be in line with the transportation goals and objectives set earlier in the process. If they are not compatible, more alternatives need to be generated or the transportation goals and objectives need to be revisited.

Plan Transportation Development / Enhancement

To fully understand how the best compromise solution will operate, a transportation plan should be developed which outlines basic operating parameters such as hours of operations, headways, and bus stop locations. This plan also describes what transportation improvements are desired for the city or university and a reasonable time frame for the completion of those projects. It is here that the short term and long term goals are addressed again. The proposed transportation plan should give a clear picture of what the alternative will accomplish and how it will likely affect the community and its users. The development of the transportation plan marks the transition from planning into operations.

Gain Stakeholder Consensus

Up to this point in the process, decisions are made using facts and logic to determine the best compromise solution. Before final designs are chosen and detailed plans are developed, a period of consensus building is necessary. This consensus period brings the stakeholders back into the process and ensures that all stakeholder concerns are addressed in the transportation plan. People's opinions change constantly based on the information they receive so it is essential to gain an overall acceptance of the best compromise solution. If the stakeholders identify deficiencies in the alternative chosen, this period allows for revisions to be made before any additional resources are allocated to final design. Bringing the stakeholders back into the process and gaining a consensus creates a knowledgeable group that can help disseminate information to the users of the system throughout the community with a positive attitude.

Develop a Performance Management Strategy

Following the consensus period, a performance management plan needs to be created. The metrics chosen should be dependent on the desired information of the city or university administration, the users, and available technology. In the thousands of possible metrics, it is important to choose a few good measures which are meaningful and easily understandable. Choosing metrics that satisfy the four points of view in the transportation system (customer, community, agency, and driver) ensures that all stakeholders have some data which is useable to them. These metrics should also support the transportation goals and objectives created earlier in the process. However, caution should be used not to pick too many metrics, as measuring and analysis can become too burdensome and the overall system performance is likely to suffer.

Establish Baseline and Implement Strategies

Once the design of the system is complete and the stakeholders are pleased, it is time to implement the resultant transportation plan. Before the system is implemented, a baseline performance should be established based on realistic projections of the systems performance and the performance measurements selected. The baseline should be adjusted periodically (i.e. yearly, quarterly) to reflect the changes in operating conditions. After the baseline has been set, the strategies are ready to be implemented.

Monitor and Report Performance

The final step in the transit evaluation process is critical. Continual monitoring and reporting of the performance of the system is essential in staying ahead of any potential problems. Similar to the construction industry, the sooner a work order change is given, the less it will cost. For the transportation system, the faster a problem is anticipated or identified, the fewer customers will be affected. In the continual monitoring of the system, it is important to periodically review the planned expansions and renovations to ensure that the transportation system is expanding alongside the city or university. It is in this final step that performance monitoring provides information to aid in the planning elements which then affects the operations of the system. With these three disciplines dependent on each other for information, it is essential that an evaluation process incorporate them all.

The proposed transit evaluation process integrates the planning, operations, and performance monitoring of several published frameworks into one complete and coherent framework. The process is designed to be a guide for transit system evaluation in cities with a large university or other academic institution or for an individual university. The methodologies for each component of the evaluation process are dependent on the size of the transit system and the resources available in terms of labor, money, and existing data. If a city or university follows the framework outlined here, it is likely that the existing transportation system will improve.

CLEMSON UNIVERSITY CASE STUDY

To test the applicability o the transit system optimization framework, researchers undertook a test case study involving a medium-sized university. Clemson University, located in Clemson, SC, is situated in a rural area just outside of the Greenville-Spartanburg urban area with an approximate population of 15,000 excluding students. This case study allowed all of the components of the system to be tested in the order specified.

Identify Stakeholders and Define Goals

Clemson University was looking to align its parking and transportation facilities in order to create a more multi-modal transportation system. A primary component of the transportation system was the Tiger Route, a fixed route servicing only campus locations, operated by Clemson Area Transit, an agency within the City of Clemson. The university began the evaluation process in July of 2009. A visioning committee was formed consisting of undergraduate and graduate students, faculty, staff, and members from parking services, campus planning, student housing, facilities, athletics, major events, and university accounting. The Clemson Transportation Continuity Council (CTCC), a student council with two members from each class standing, was also included as a stakeholder in the process. In a university setting, student tenure is short causing a short-term institutional memory. The CTCC encourages the maintenance of the institutional background with respect to transit operations in the university transportation system. These stakeholders were charged with revising the Clemson University Parking Principles to incorporate a multi-modal perspective and develop goals which incorporate pedestrian, bicycle, transit, and transportation demand management considerations. The new principles were adopted in September 2009, however, the coalition continued to serve as the representative stakeholders from the remainder of the evaluation process.

Evaluate Existing Conditions

The evaluation of the existing transportation system was accomplished using several methods. A manual ride check survey was conducted in the summer and fall semesters of 2009 to determine student travel patterns and the demand on the system. Surveyors rode each of the seven buses operating on the Tiger Route for an entire week from 7:30AM to 5:00PM in the summer and from 7:30AM to 3:00AM in the fall. Peak and inactive hours were determined using a peak hour factor (PHF) based on 15 minute intervals with factors greater than 0.6 representing a peak hour and factors less than 0.1 representing an inactive hour. During the summer session, 8:30AM – 10:15AM had the highest PHF ranging from 0.33 to 0.35 but fell short of the 0.6 PHF target. All other

PHF during the summer study period fell below 0.18. The peak hours of service for the fall semester were higher. The peak hours were from 8:15AM to 12:30PM and from 1:15PM to 2:30PM with factors ranging from 0.75 to 0.60, respectively. Inactive hours, hours with PHF less than 0.1, occurred from 5:45 pm to 3:00 am. This decrease in boarding corresponded to the switch to the 30 minute service, conclusion of the main academic day, and the ability of commuter and resident students to park in employee spaces around campus. A summary of the supply and demand on the Tiger route during both ride check surveys can be seen in Table 2.

A walking time study was conducted to determine the average walking speed of Clemson students. The walking speed was necessary to test if the allotted 15 minute class change time was sufficient for students to travel from one building to another across campus. It could also be used to determine what the out of vehicle travel time was, assuming walking was the chosen supplemental mode to transit, for a user traveling from one location to another using campus transit. A cluster sample of 65 students was used in this study which generated 109 samples of walking times. The average walking speeds of the students was found to be 4.43 fps ± 0.14fps with 95% confidence. It was found that the 15 minute class change was sufficient for students to change classes if they walked; however, it was not sufficient if transit was utilized for a cross campus trip.

TABLE 2: Clemson University Ride Check Survey Summary

		Summer Ride Check	Fall Ride Check	
			Day time	Night time
	Dates of Survey	July 27 - July 30	Sept 28 - Oct 4	
Supply	Hours of Operation	7:30 AM - 5:00 PM	7:30 AM - 6:00 PM	6:00 PM - 3:00 AM
	Number of Hours	9.5	10.5	8
	Headway	30 min	8 min	30 min
	Number of Buses Utilized	2	7	2
	Number of Runs Completed	76	385	18
	15 Min Capacity Out of Parking	56	294	56
Demand	Peak Hour	8:45 AM - 9:45 AM	8:30 AM - 9:30 AM	6:00 PM - 7:00 PM
	Highest 15 Min Peak Demand	26	362	27
	Total Ridership	257	18,847	438
	Top Boarding Location	Breezeway [West]	P-3 Parking Lot	Library Circle
	Top Alighting Location	Brackett Hall	Brackett Hall	Hendrix Student Center
	Total Number of People Left	0	457	0

Peer University Benchmark Survey

A benchmark study of peer transportation universities, chosen by members of the visioning committee, was conducted. In comparison to the universities studies, Clemson University ranked near average on all of the financial matters and parking availability. This information was important to the stakeholders when deciding that raising the student transit fee or parking permit fees was not a viable option for raising money. Utilizing this information, the university accounting representative presented the current state of financial affairs for the transportation system. After reviewing the information collected, the stakeholders were convened to develop transportation alternatives for Clemson University.

Generate Alternatives

Throughout Clemson University's spring semester, the students of the visioning committee and the CTCC were convened to develop transit alternatives for the university. In the development of the alternatives, parking lot designations were not held constant, but the number of spaces allocated to each parking permit class was to remain unchanged. Transit alternatives were also solicited from Clemson Area Transit. Seven alternatives were developed and evaluated using a matrix analysis to determine the best compromise solution for Clemson University. Some of the measures included trip directness, route complexity, and driver break locations. A weight of one was applied to each of the measures of effectiveness to show that no group's interests were more important than another's. However, as a group, there may be some factors that can hold heavier weights due to the fact that

they directly support agreed upon objectives and goals. After the analysis, the Clemson Alternative F proved to be the best compromise solution.

To prove the alternative's feasibility, a simulation of the route was conducted to determine the average travel speed of the route and the expected operating headway. The base Vissim model utilized was created in 2007 as part of a larger traffic study conducted on Clemson University's campus (*11*). A worst case scenario was created in the simulation using peak traffic volumes found between 10:00AM and 2:00PM and peak transit ridership volumes found between 8:00AM and 12:00PM. The operating speeds of the transit vehicles were also limited to a maximum of the posted speed limit in conjunction with Clemson Area Transit's operating procedures. The average travel speed on the West side of campus was found to 9.85 mph ± 0.16 mph with 95 % confidence. This is slightly higher than the current operating speed of the Tiger Route on the West side of campus which was found to be 9.4 mph ± 0.45 mph with 95% confidence. It was expected that the operating speeds would be slightly higher than current operating speeds because the simulation is conducted under ideal conditions. Variations in driver behavior and driver aggressiveness could not be modeled in the simulation along with unanticipated random delays due to passenger drop offs and road blockages from larger delivery vehicles. With the operating speeds of the proposed route nearing those of the existing route, it was expected that the headway of the route would be equal to or less than the current operations of the Tiger Route.

Plan Transportation Development / Enhancement

After proving the feasibility of the best compromise solution, a transportation plan was required. Clemson University hired an outside consultant to create the run schedules for the proposed alternative. The schedules were created using only the resources available on the Tiger Route. Clemson Area Transit was consulted prior the creation of the schedules so that operations were in line with their current practices and industry standards. In conjunction with creation of the new transit routes, parking reallocations were considered so that commuter traffic would be dispersed to three primary commuter lots across campus instead of two, which is the existing condition. The creation of the third commuter lot on Clemson University's campus coincides with building programs, parking revisions, and allows for a greater ridership capacity out of the parking lots resulting in a potential for a reduction in travel time, increased ridership, and reduction in the number of users left behind.

Gain Stakeholder Consensus

With all technical aspects complete in the summer of 2010, Clemson University utilized the fall semester to ensure a consensus from the student body, Clemson administration, Clemson Area Transit, the City of Clemson, and members of the community about the proposed transit route alignment changes and the parking allocation changes. With the Visioning Committee and CTCC confident in the proposed transit alignment and parking allocations, public forums open to all members of university, community, and South Carolina Department of Transportation were conducted to allow all stakeholders an opportunity to voice their opinion. In these forums, the proposed changes were discussed and the floor was opened for comments and questions with the objective of refining the changes to ensure maximum consensus. Items such as route naming and alignment display options, included legend information, and locations of bus stops were all considered during this phase. Approximate route headways were also discussed amongst the CAT officials, Clemson University administration, and the CTCC to determine a minimum standard of operation for the new route alignments.

Develop a Performance Management Strategy

In determining what elements were included in the performance management strategy, Clemson University officials looked back to what their goal was in this process which was to improve the transportation system on campus. The objectives of the redesign of the new transit routes and parking designations included:

1. Maximize the use of existing bus capacity
2. Maximize the use of existing parking facilities
3. Increase travel mode options for students to the core of campus

In order to make a useable performance management system, identifiable performance measures which are easily collected must be established for each objective. For objective 1, the performance measure most applicable and easily counted is the ridership demand level. Although true demand cannot be captured, an estimation of the demand can be established with ridership counts and observations of the number of riders left behind at the stops due to a bus being at or over capacity. The success or failure of objective 2 is determined by a comparison of parking utilization and space occupancy percentages captured yearly by the university. This objective can be used

to determine the use of each parking area as well as an indicator for when more parking supply or other demand management techniques must be implemented at the university. The performance measure for the final objective is the mode split amongst students either through survey results or an analysis between pedestrian volumes and ridership volumes on the bus. For each performance measure, an easy and reliable collection method must be used to ensure consistency and comparability amongst the data collected.

Establish Baseline

The establishment of a baseline is to provide a starting point for future trendline analyses. With the "No Change" conditions extensively studied the stakeholders all agreed to use this data as the baseline on which to compare the effects of new transit routes and parking designation changes. If the transportation system proved to have worsened for the users in comparison to this base year, a re-evaluation of the changes would necessary.

Implement Strategies

Beginning, January 10, 2011, the new parking designations and transit route realignments seen in figure 2 went into effect on Clemson's campus. In conjunction with Clemson Area Transit, Clemson University completed an extensive communication plan which included the creation of several YouTube videos discussing the changes, mass email alerts to the university community, newspaper articles and ads in the on-campus newspaper as well as in the local newspapers, and banner sized maps located at major pedestrian and bus stop locations. Trained student ambassadors were also used at a number of the bus stops and on the buses to help answer questions and guide students through the transition process. Through the coordinated, cooperative, and informed efforts of the all the stakeholders, the transition to the new system went very well without many complaints to the on-campus transit hotline or email address.

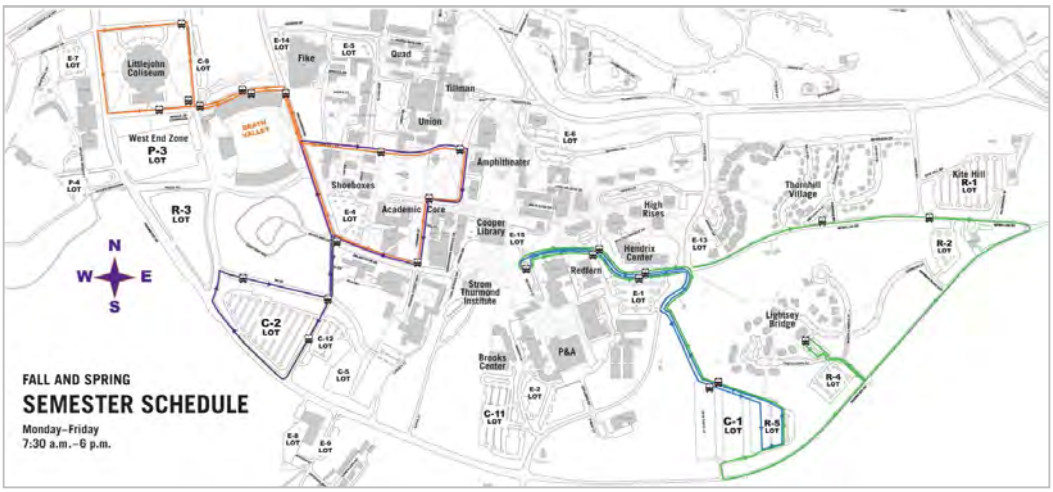

Figure 2: New Parking Lot Designations and Transit Route Alignments

Monitor and Report Performance

With the inception of the new parking and transit changes on campus, Clemson University has been diligently monitoring the performance of the transportation system. Through the use of on-board ambassadors collecting ridership information for the first two weeks of school, a targeted parking utilization study, a pedestrian study, and monthly ridership reports from CAT, all the stakeholders are interested in performance of the new routes. To date, the university has seen a reduction in the number of students being left behind by buses due to buses being over capacity, a more dispersed and increased utilization of existing parking facilities with less cars idling in parking lots waiting for spaces, and an increased number of pedestrians walking from parking lots to the core of campus which satisfies all the objectives initially desired at the onset of this evaluation process. With these positive changes, several consequences have occurred on campus including a reduction in total ridership for CAT which is likely caused by the reduction of captive riders, a great number of vehicles on campus due to the creation of more convenient parking, and the need for more pedestrian facilities and safety measures in the parking lots and along the main routes to the core of campus from the parking areas. All of these issues require more extensive study as the university completes another iteration of this process in the attempts of achieving the goal of improving the transportation system.

Summary

The proposed transit evaluation process proved an effective framework for evaluating Clemson University's transit system. Similar to the objectives of the published frameworks, the proposed process led Clemson University to establish a comprehensive coalition of stakeholders through which it's parking principles, the guiding transportation goals and objectives for the university, were revised to incorporate multi-modal aspects and considerations for reduced parking availability due to planned campus expansions. The evaluation process efficiently guided Clemson evaluators through the examination of current transportation and economic conditions at the university. Although this process proved to be resource intensive, it has led Clemson University to investigate technologies which can be used to continually capture the data collected in this evaluation. This is one important step towards continual improvement. Since the alternatives developed were based on data, the stakeholders were comfortable pledging their support to the best compromise solution and implementing the change. Since the change, Clemson University has solved some of the transportation issues on campus which was causing major grievances with students, yet has caused other issues which now must be address. Although the transportation system is not perfect, the process is still deemed successful because the stakeholders of the system are now versed on the transportation issues at the university, have generated alternatives to solve the current issues now facing the system, are eager to integrate more facilities to expand the mode options of its users, and recognize the importance of continual monitoring and reporting to ensure that the transportation system continues to move forward in a positive and sustainable path.

CONCLUSION

There are many strategies published today that help planners and administrators with planning, operations, or performance monitoring separately. It was necessary to develop a process that incorporates all of these important management pieces based on the requirements identified by Clemson transportation planners because a single published processes could not meet every requirement the of Clemson stakeholders. For other cities or universities to adopt the proposed transit evaluation process customization may be required. The process is designed to guide administrators and planners through evaluation toward an optimized transit solution which takes into account other modal opportunities on campus. The methodologies for the individual pieces of the process must be customized to fit the organizational structure and available resources of the evaluating entity. The system evaluators should investigate what information is currently being collected and aim to supplement that data for a more cost effective evaluation. With a constantly evolving set of needs and wants, cities and universities must plan its transportation system appropriately, know what the current state of the system is, and constantly be looking for ways to improve it based on performance measures. The proposed transit evaluation process helps cities and universities accomplish those tasks through a single framework.

Similar to the iterative nature of the process created, the process itself needs to be continually evaluated. Currently, the proposed evaluation process is more appropriate for rural and small cities and small- and medium-sized colleges and universities outside of urban centers. Further research in the following areas can enhance the usability of the transit evaluation process for a wider range of cities and universities:

- Integration of technology and intelligent transportation systems
- Pedestrian and bicycle facility expansions and integration
- Effect of changes in parking restrictions and reallocations
- Political organizations and agreements between cities and universities in urban areas
- Economic impacts of fare changes – elasticity of demand and
- Economic and political changes that occur if a system is incorporated into a metropolitan planning organization (MPO).

The proposed framework in this paper is unique in that it incorporates planning, operations, and performance measurement tasks into a single framework that can be calibrated to fit individual cities with a large academic institution using their existing technical and non-technical resources. The framework allows for continual feedback to achieve optimal performance of the transit system which satisfies the needs of its stakeholders. No matter what city or university wishes to utilize the proposed transit evaluation process, it must be customized to the political, organizational, and economic atmospheres and be supported by the belief that positive change is possible.

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