City of Columbia, Missouri
Request to Experiment:
Use of Colored Pavement Markings on On-Street Bikeways
February 25, 2009 Rev. 3

Prepared by: **City of Columbia, Missouri Non-Motorized Transportation Pilot Program (NMTPP)**

Approved: _____

John Glascock, PE
City of Columbia, Missouri Public Works Director

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ELEMENT	**PAGE**

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BACKGROUND

The City of Columbia, Missouri has a growing network of on-street bikeways including bike lanes and shared roadways. These facilities serve a wide geographic area within the city and are intended to both encourage bicycling and increase motorist awareness of the presence of bicyclists. The City of Columbia addresses requirements for new bicycle and pedestrian facilities in a 2006 update to the City Street Standards[1].

Columbia was recently designated as one of four Federal Non-Motorized Transportation Pilot Project (NMTPP) communities. These funds are being used to plan, design and construct additional bicycle and pedestrian facilities to encourage a modal shift to non-motorized transportation modes. With Columbia's population growth and a planned modal shift, the potential exists to incorporate additional experimental facilities as part of the Federal NMTPP. This document is a request to the Federal Highway Administration to experiment with the use of colored pavement treatments on existing and planned on-street bikeways.

NATURE OF THE PROBLEM

Bike lanes in Columbia are striped on the right edge of the outside travel lane, immediately adjacent to on-street parking. There are no local standards for how bike lanes approach and continue through intersections along the bicyclist's route, although a typical practice in Columbia is to drop the bike lane upstream from intersections. In some cases the bike lane is dropped completely while in others the lane is only dropped in the area where motorists maneuver into a dedicated right turn lane. These conditions often force cyclists to cross paths with motorists, while creating ambiguity for bicyclists and motorists at these locations. The following sections describe four typical problems created when bike lanes drop at intersection areas.

Problem 1: Bike Lane Crossing a Dedicated Right Turn Lane

At intersections where the roadway widens to provide a dedicated right turn lane, motorists must maneuver across the bike lane to access the turn lane (see Figure 1). This movement forces right-turning motorists to cross paths with thru-moving bicyclists. Preparing to turn right, motorists must either maneuver in front of or behind forward-moving bicyclists. It is often unclear to both motorists and cyclists as to where automobiles should maneuver into the turn lane, with added confusion as to who must yield the right-of-way. This situation can create safety and comfort issues for bicyclists continuing straight through the intersection, who may not be watching for automobiles moving into or through their lane of travel.

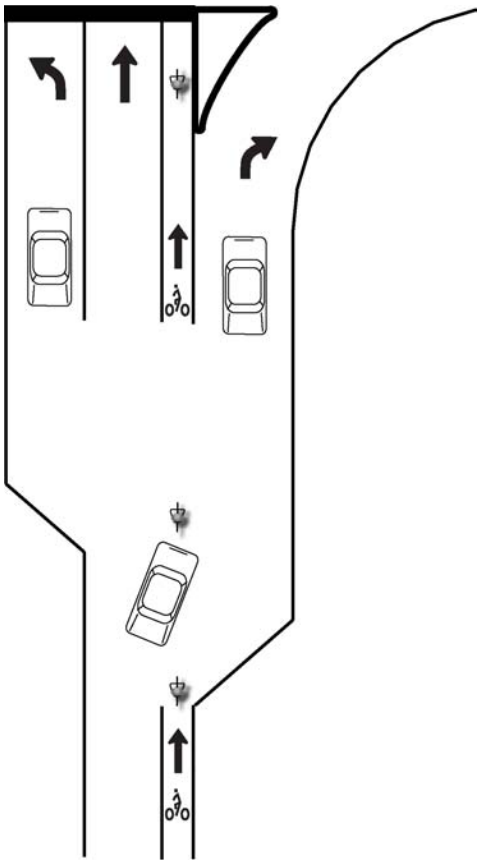

Figure 1 – Motorists must cross the bike lane while maneuvering into a dedicated right turn lane

Problem 2: Lack of Accommodations for Bicyclist Turning Movements

Columbia's on-street bikeway network includes several routes following multiple roadways,

occasionally requiring bicyclists to make left- and right-hand turns onto and from major streets in order to remain on a designated bike route. As most dedicated bike lanes drop on intersection approaches, cyclists currently lack accommodations to safely and comfortably position themselves in the desired lane (e.g., left turn lane, thru lane, or right turn lane, depending on the direction of travel, see Figure 2). These conditions can create a challenging riding environment, with bicyclists and motorists crossing paths while approaching the intersection. Additionally, motorists approaching an intersection may not expect bicyclists to maneuver into or across the vehicle travel lane. An effective treatment would encourage bicyclists to maneuver predictably (and motorists to expect this movement).

Problem 3: Bike Lane Crossing a Channelized Turn Area

The broad turning radii of channelized turn lanes typically induces higher vehicle turning speeds, especially when motorists do not encounter STOP or YIELD signs. Motorists passing through channelized right turn areas may briefly look left for oncoming vehicle traffic but may fail to notice bicyclists approaching in the adjacent bike lane (see Figure 3). The wide turning radius at channelized turn areas also lengthens the area where bicyclists may be vulnerable to vehicles entering the roadway. These conditions could be addressed by alerting motorists in the channelized turn area to expect bicyclists approaching from the left.

Problem 4: Bike Lane Drops to Create Room for a Dedicated Right Turn Lane

Similar to Problem 2 described earlier, bike lanes approaching intersections commonly drop to provide space for a dedicated right turn lane. The absence of a dedicated bike lane in this area

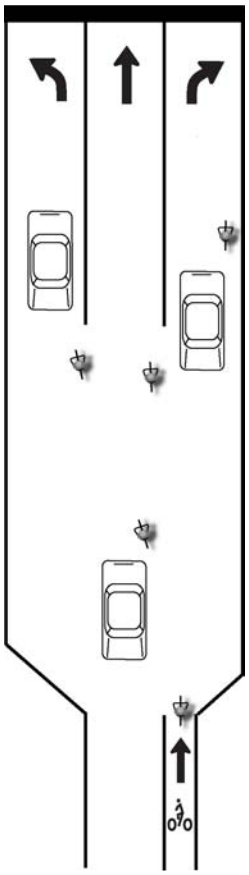

Figure 2 – Bicyclists must often cross vehicle travel lanes to make thru movements or left turns, often without formalized accommodations

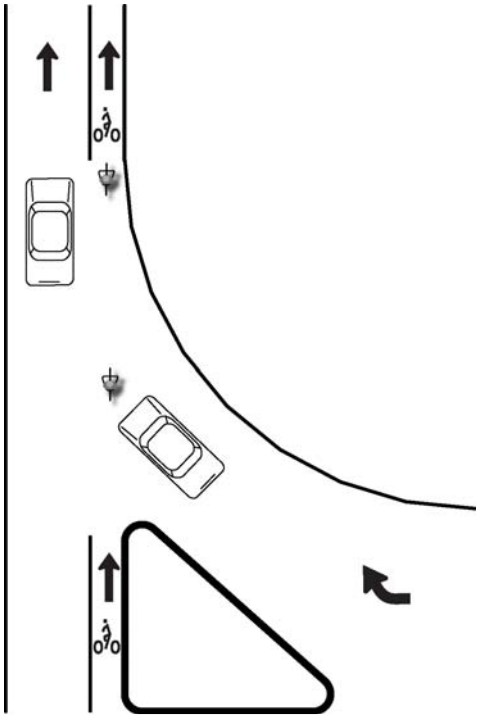

Figure 3 – Channelized right turns can create challenging riding conditions by lengthening the zone where bicyclists and motorists interact

can create safety and comfort issues for all transportation users, and the lack of guidance regarding proper bicycle positioning in this area can create confusion. The most common challenge in this area occurs as thru bicyclists must share the same space, and cross paths with, right-turning motorists (see Figure 4). The speed differentials between bicyclists and motorists in this shared space can also potentially impact safety and comfort.

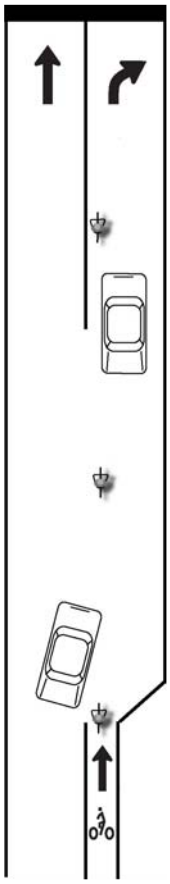

Figure 4 – Where bike lanes drop to provide space for a dedicated right turn lane, thru cyclists may experience confusion regarding proper lane positioning

DESCRIPTION OF PROPOSED EXPERIMENT

While the Manual on Uniform Traffic Control Devices (MUTCD) permits bike lanes marked with white striping, limited guidance exists on the use of colored pavement markings. The MUTCD specifies intended uses of various signage and pavement marking colors. Applicable to signage only, the color green specifies permitted traffic movements while providing directional guidance. The MUTCD currently specifies only white and yellow pavement markings for bicycle facilities. The City of Columbia proposes to use high-visibility green pavement markings to enhance visibility and clarify expected bicyclist and motorist behaviors in the typical areas described above.

The City of Columbia proposes to apply a combination of solid and dashed green pavement markings, consisting of a slip-resistant retro-reflective material, at 12 locations where these problem areas exist. Bike lanes would continue to be marked with standard white striping and pavement stencils, per the MUTCD and AASHTO's *Guide for the Development of Bicycle Facilities*. Generally speaking, the target user group is different for solid versus dashed pavement markings. Solid markings are intended to alert motorists to yield to bicyclists before crossing a dedicated bike lane. Dashed markings are intended to indicate a shared vehicle/bicycle space, with each user yielding the right-of-way according to the Vehicle Code.

Treatment 1

To address Problem 1 (described earlier), the City proposes to fill an existing or proposed bike lane with solid green marking where motorists would cross the bike lane while maneuvering into a dedicated right turn lane (see Figure 5, next page). The solid green marking would begin approximately ten feet upstream from the right turn lane taper, and end where the bike lane meets the channelized island (or at the intersection stop bar where a channelized island does not exist). The green marking would provide clear indication to motorists that they must yield to bicyclists before crossing the bike lane. A bike lane stencil would also be installed adjacent to lane markings separating the right turn lane from the bike lane to indicate the preferred bicyclist position and to increase driver awareness of bicyclists in this area. Treatment 1 would also include a post-mounted sign and placard located immediately upstream from the right turn lane taper (see Figures 5 and 6, next page).

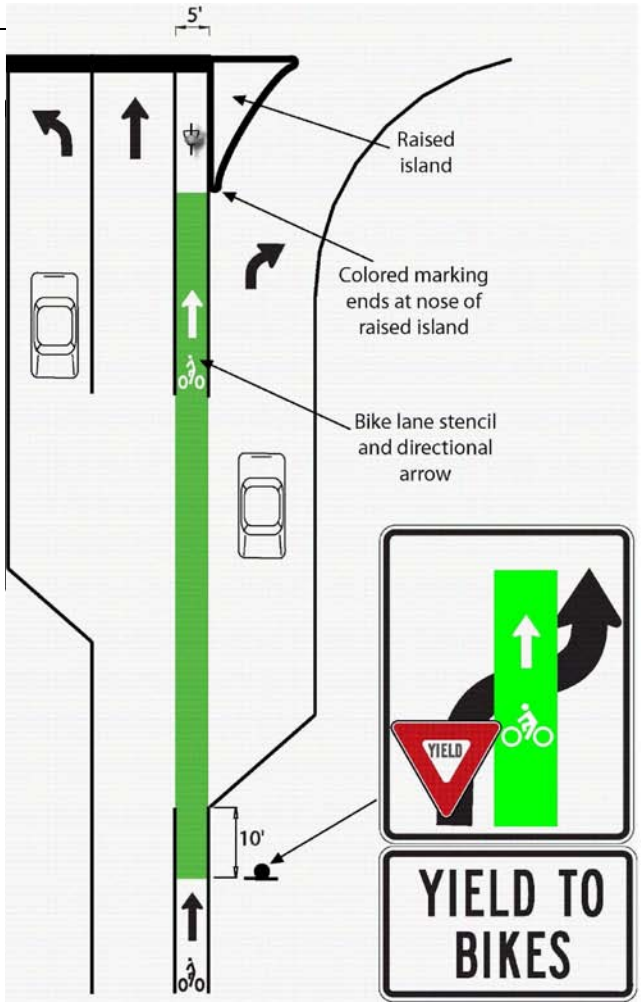

Figure 5 – Proposed Treatment 1 markings and signage

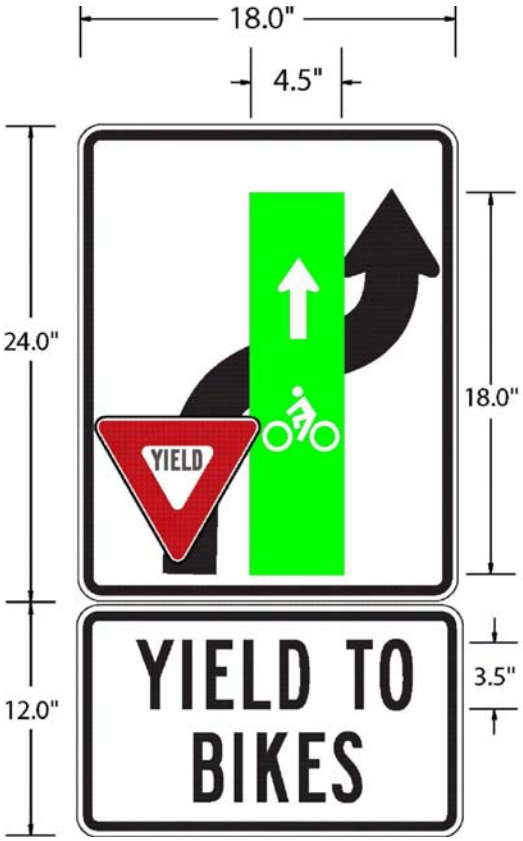

Figure 6 – Proposed Treatment 1 sign specifications

Treatment 2

Treatment 2 addresses bicyclist issues when a bike lane drops approaching an intersection and where demand exists to better accommodate left, thru, and right turn movements for bicyclists. To address this problem, the City proposes to apply dashed green pavement markings where motorists and bicyclists cross paths while approaching an intersection (see Figure 7, next page). The dashed markings would begin immediately downstream from the bike lane "drop point," and end immediately upstream from the lane markings delineating thru and turn lanes (a distance of approximately 60 feet as shown in Figure 8, next page). Within this area, the dashed marking widths would gradually increase with a ratio as per lane width, and include a supplemental white "MERGE AREA" text marking. A post-mounted sign, located at the bike lane drop point, would supplement the pavement markings (see Figures 7 and 9, next page). Although not shown in Figures 7 and 9, the sign's supplemental placard would utilize standard MUTCD lettering.

The markings and signage are intended to convey to both bicyclists and motorists that they have entered a shared space. Left-turning bicyclists are encouraged to maneuver across the adjacent travel lane to reach the left turn lane.

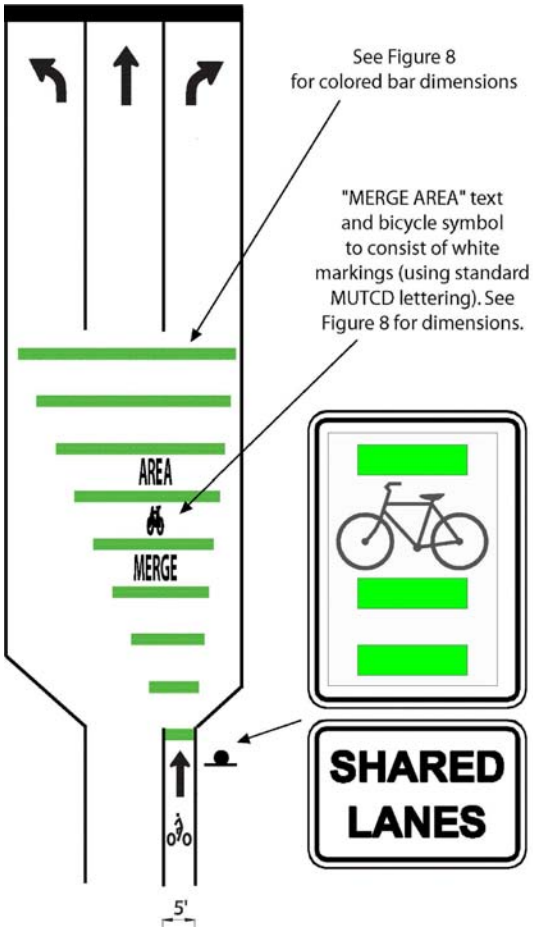

Figure 7 – Proposed Treatment 2 markings and signage

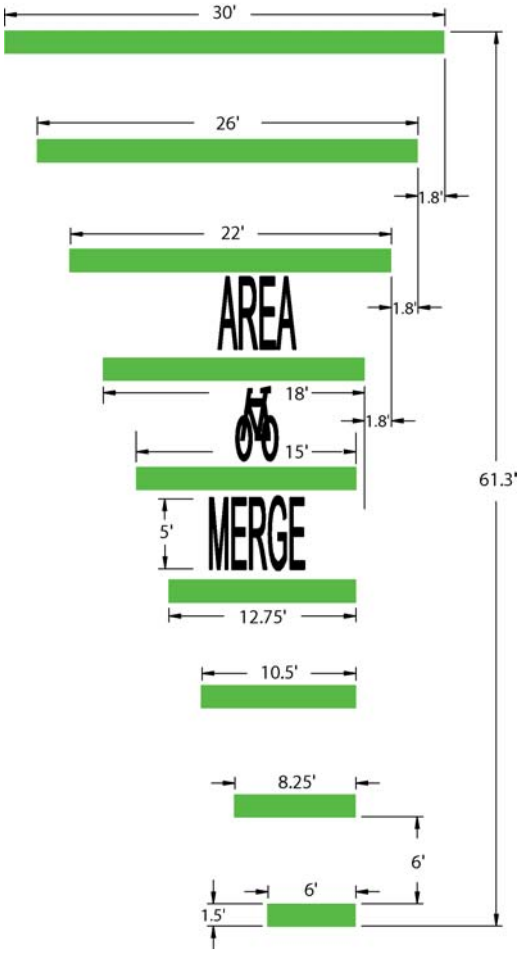

Figure 8 – Proposed Treatment 2 markings specifications

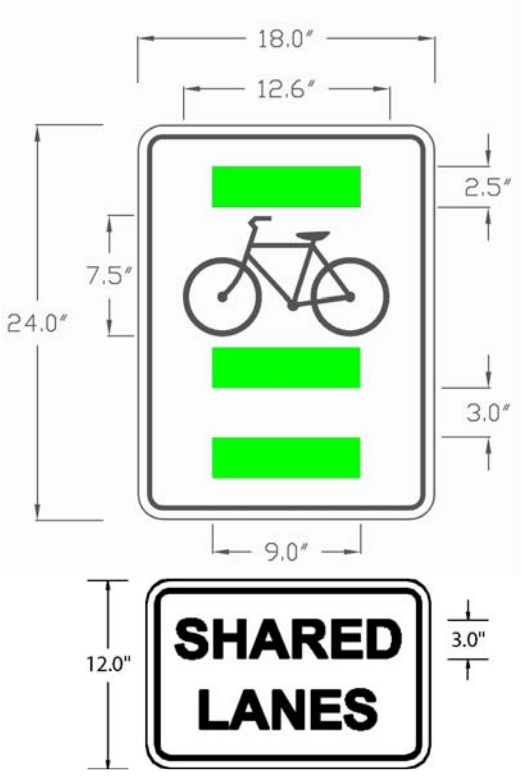

Figure 9 – Proposed Treatment 2 sign specifications

Treatment 3

To address Problem 3 (described earlier), the City proposes to fill an existing or proposed bike lane with a solid green marking where motorists enter the roadway on the right side from a channelized turn area (see Figure 10). The coloration would demarcate the intended thru bicycle movement at this location. The green marking would begin approximately ten feet upstream from the beginning from the channelized island, and end approximately ten feet downstream from the turn channel area's endpoint. In addition to bike lane stencils immediately upstream and downstream from the colored pavement, a bike lane stencil would be installed approximately ten feet into the merge area to increase driver awareness of bicyclists' presence. Treatment 3 would also include two post-mounted signs oriented toward motorists entering the right turn channel area (see Figures 10 and 11). The signs would supplement traditional "Yield" signs instructing motorists to yield to vehicle traffic on the approaching street.

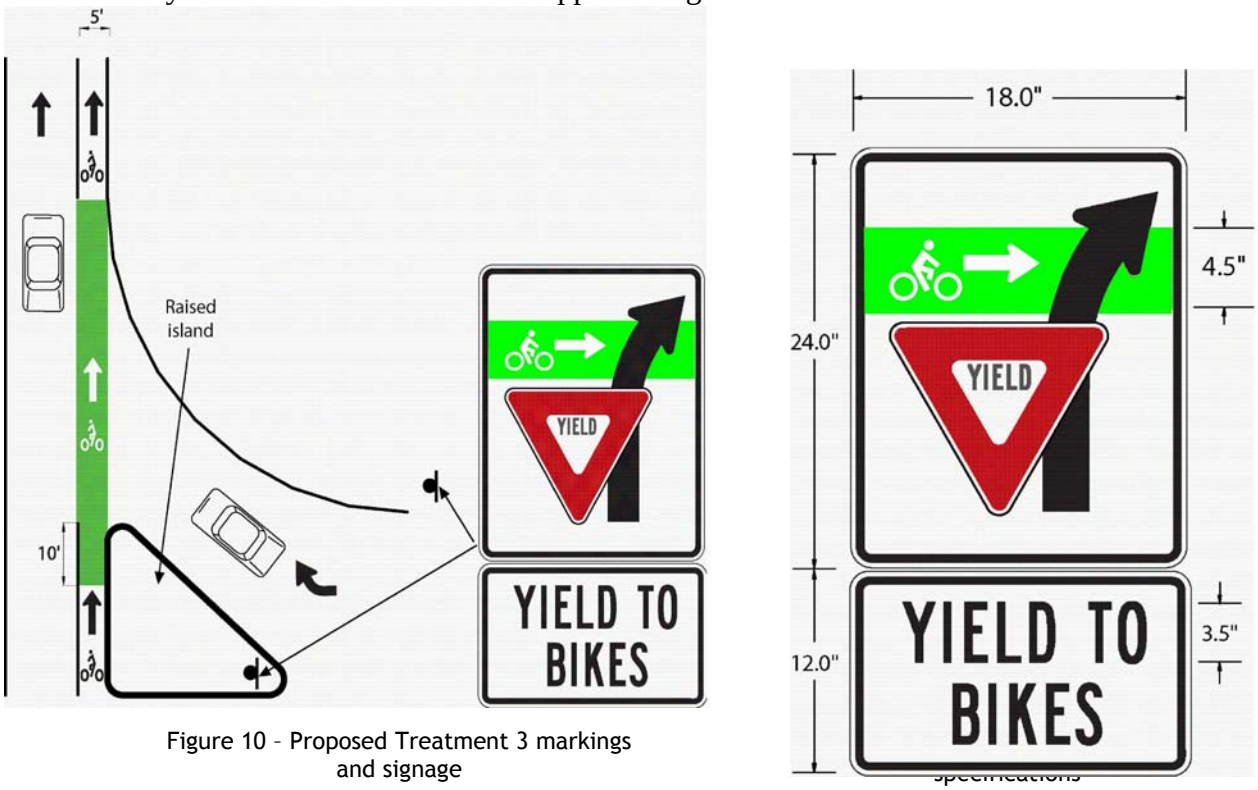

Figure 10 – Proposed Treatment 3 markings and signage

Treatment 4

Treatment 4 addresses bicyclist issues when a bike lane drops approaching an intersection to provide space for a dedicated right turn lane (described earlier as Problem 4). To improve riding conditions in this shared space, the City proposes to apply dashed green pavement markings within the right turn lane (see Figure 12, next page). The markings would begin immediately downstream from the bike lane "drop point" and end at the intersection stop bar. The markings would span roughly as wide as the upstream bike lane (approximately five feet), and be spaced roughly five feet apart (see Figure 13, next page). A post-mounted sign, located at the bike lane drop point, would supplement the pavement markings (see Figures 12 and 14, next page). Although not shown in Figures 12 and 14, the sign's supplemental placard would utilize standard MUTCD lettering. The markings and signage are intended to convey to both bicyclists and motorists that they have entered a shared space.

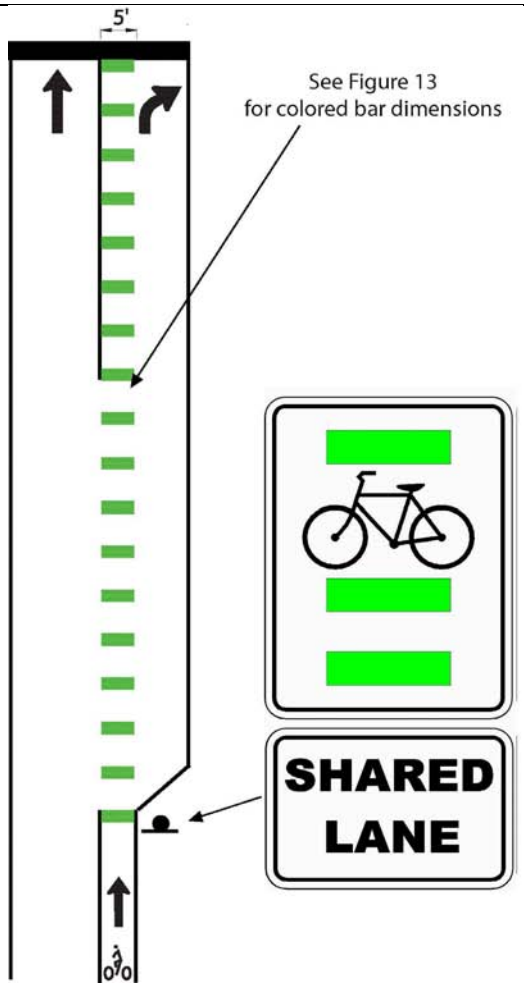

Figure 12 – Proposed Treatment 4 markings and signage

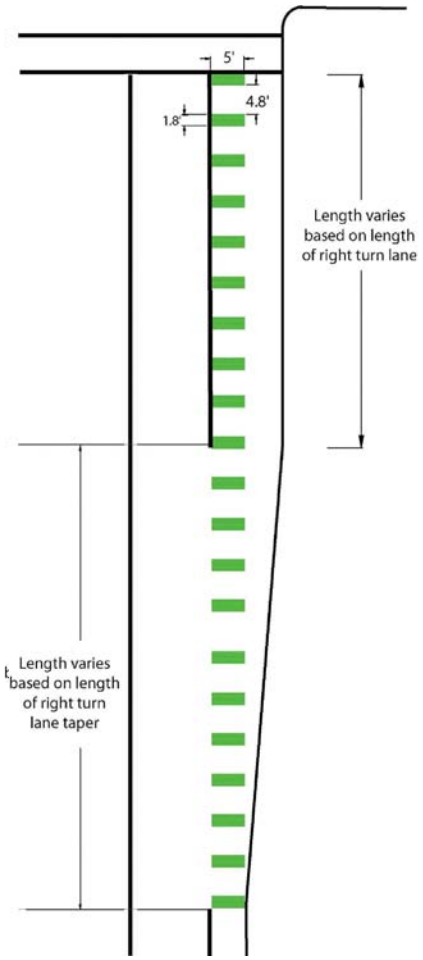

Figure 13 – Proposed Treatment 4 markings specifications

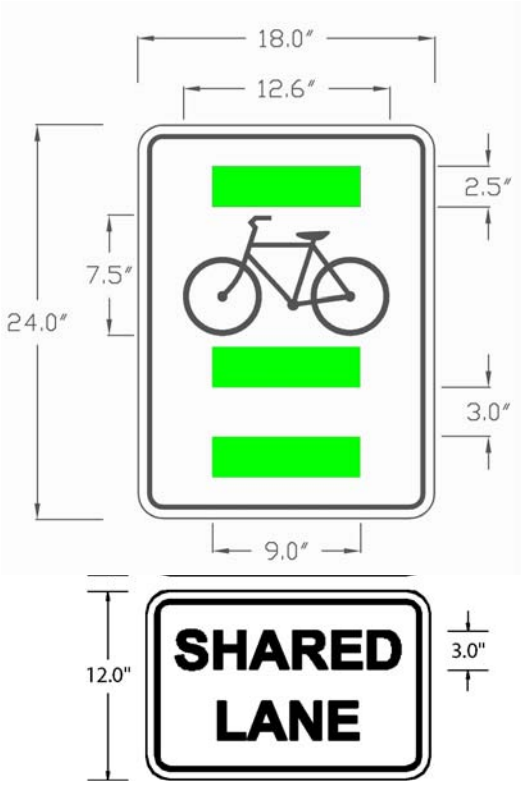

Figure 14 – Proposed Treatment 4 sign specifications

SCOPE AND WORK PLAN

Summarized in Table 1, the City of Columbia proposes to apply green pavement markings to City-maintained on-street bikeways at 12 locations. The table specifies the proposed treatment type for each intersection approach (some intersection approaches will not include green pavement marking treatments).

Table 1 – Proposed Experiment Locations

Intersection	Treatment Type*			
	North Leg	South Leg	West Leg	East Leg
Fairview Road at Broadway	Treatment 1	--	--	--
Forum Boulevard at Nifong Boulevard	--	Treatment 2	--	Treatment 1
Nifong Boulevard at Bethel Street	Treatment 2	Treatment 1	--	--
Maryland Avenue at Hospital Drive	Treatment 2	--	--	--
Stadium Boulevard at Old Highway 63	Treatment 3	--	--	--
Providence Road at Vandiver Drive	--	--	--	Treatment 2
Stadium Boulevard at West Boulevard	--	--	Treatment 3	--
Forum Boulevard at Chapel Hill Road	--	--	Treatment 2	--
Range Line Street at Vandiver Drive	Treatment 4	--	--	--
Grindstone Parkway at Buttonwood Drive	--	--	--	Treatment 4

* Treatments 1, 2, and 4 would be applied immediately upstream from the intersection, while Treatment 3 would be applied immediately downstream from the intersection.

Proposed Data Collection Methodology

As part of the NMTPP, the City of Columbia has contracted with Alta Planning + Design (Alta) to coordinate data collection activities. If this request to experiment is approved, Alta's data collection methodology will seek to identify various aspects of the experiment including:

- Impact on bicyclist and motorist behavior
- Developing appropriate designs for proposed sites

Prior to and after placement of the experimental green pavement markings, Alta will focus on observed measurable behavior through field data collection using several or all of the following techniques:

- Before and after videos at specific periods
- On-going video recording through mounted cameras
- Field observations at specific times and dates
- Tube/hose/signal data collection

Using these data collection techniques, the following observations will be recorded:

- Motor vehicle and bicycle volumes
- Bicyclists' behavior, including signaling, sidewalk riding, shoulder checks, path of travel through the colored pavement treatment area
- Motorists' behavior, including signaling, yielding right-of-way, any changes in turning movement behavior (e.g., crossing the bike lane immediately before a right turn versus maneuvering into the bike lane farther upstream from the intersection)
- Relative distance between motorists and cyclists while crossing each other's paths
- Frequency of bicycle/motor vehicle crashes (particularly "right hook" crashes)
- Durability of the colored pavement markings

These observed measurable data will be collected in the field over the course of the study period. Alta will be responsible for collecting data via their own professionals, trained volunteers, or outside resources such as contractors for videotaping. Variations may include weekday and

weekend periods, during various seasons and weather conditions, and during peak and non-peak periods.

Phasing

Implementing the treatments in phases could provide a better understanding of motorist and bicyclist responses to individual and combined elements of the experimental treatments. Table 2 summarizes proposed phasing for each treatment. Phasing under Treatments 1, 3 and 4 would include colored pavement markings installation followed by supplemental signage. Due to its unique characteristics, the Treatment 2 signage and pavement markings would be concurrently installed. Phasing for this treatment would first consist of signage/markings application at one location, followed by application at the remaining locations listed in Table 1. This phasing approach is intended to address concerns regarding motorists' and bicyclists' understanding of this unique treatment.

Table 2 – Proposed Experimental Treatments Phasing

Phase	Treatment 1	Treatment 2	Treatment 3	Treatment 4
1	Install colored pavement markings	Install colored pavement markings and supplemental signage at one location	Install colored pavement markings	Install colored pavement markings
2	Install supplemental sign and placard	Install colored pavement markings and supplemental signage at remaining locations listed in Table 1	Install supplemental signs and placards	Install supplemental sign and placard

Education and outreach represent a potential additional implementation phase. Supplementing the infrastructure improvements described above, these efforts would aim to inform transportation users of the treatments' purpose as well as proper behaviors in these areas. Potential strategies include radio and television public service announcements, billboard advertising, and distribution of flyers with utility bills or at major destinations. Although not included as an element in this Request to Experiment, education and outreach could serve as a follow-up experiment if these treatments are allowed to remain in place at the conclusion of this study.

SCHEDULE

Table 3 presents the proposed colored pavement markings experiment schedule. The schedule assumes FHWA approval by Winter 2009. The project will conclude with removal of the colored pavement markings in the event that the MUTCD is not updated to include such surface treatments before December 2010.

Table 3 – Proposed Colored Pavement Markings Experiment Schedule

Task	Winter 2009	Spring 2009	Summer 2009	Fall 2009	Winter 2010	Spring 2010
Submit RTE to FHWA						
Finalize Specific Data Collection Point Locations						
Collect "Pre-Application" Data						
Install Colored Pavement Markings (Treatments 1, 3, and 4); Install Colored Pavement Markings and Signs at One Location (Treatment 2)						
Collect "Post-Application" Data (Round 1)						
Install Signage (Treatments 1, 3, and 4); Install Colored Pavement Markings and Signs at Remaining Locations (Treatment 2)						
Collect "Post-Application" Data (Round 2)						
Synthesize and Analyze Data						
Prepare Report Summarizing Data Analysis Results and Conclusions						

EVALUATION PROCEDURES/MEASURES OF EFFECTIVENESS

After data collection is complete, City of Columbia staff will work with Alta to determine if there were measurably significant changes in the following behavioral areas listed below. If positive changes are noted, the City of Columbia will suggest that the treatments be considered as standard and included in a future MUTCD revision. These behavioral changes include:

- Improved bicyclist behavior, including reduction in sidewalk riding, signaling and shoulder checks
- Improved motorist behavior, including signaling, yielding right-of-way
- Awareness of proper lane placement for bicyclists and motorists
- Perception of motorists and cyclists of the colored pavement treatments

REPORTING

Reporting will be submitted as specified by FHWA and submitted to the Columbia City Council, Missouri Department of Transportation, FHWA Missouri Division Office and FHWA National Headquarters Office.

ADMINISTRATION

The City of Columbia will be the sponsoring agency with support as needed from consultants including Alta. The proposed colored pavement markings are not protected by patent or copyright.

REMOVAL OF EXPERIMENT

The City of Columbia will remove the experiment within three months of completion of the study in the event FHWA reaches a decision that changes to the MUTCD are not warranted to include colored pavement markings. In the event the experiment creates substantial safety hazards that warrant removal prior to the planned end of the experiment, the City of Columbia will discontinue the experiment.

REFERENCES

1. City of Columbia, *Street Standards*, Accessed http://gocolumbiamo.com/PublicWorks/Engineering/street_storm_toc.php on November 14, 2007.
2. City of Chicago, Illinois. *Green Pavement Markings for Bike Lanes*, FHWA Experiment No. 9-77(E), Cited in http://www.sfmta.com/cms/bproj/documents/SF_Colored_Pavement_Experiment_Request_May_2007.pdf. Accessed on November 14, 2007.
3. City of New York, NY, *Evaluation of Solid Green Bike lanes to Increase Compliance and Bicycle Safety*, Cited in http://www.sfmta.com/cms/bproj/documents/SF_Colored_Pavement_Experiment_Request_May_2007.pdf. Accessed on November 14, 2007.
4. City of Portland, OR, *Evaluation of the Blue Bike Lane Treatment used in Bicycle-Motor Vehicle Conflicts in Portland, Oregon*, Accessed *http://www.bicyclinginfo.org/rd/operations.cfm#cros1* on November 14, 2007.
5. State of Vermont, *Solid Green Bike Lane in a Potential Conflict Area*, FHWA Experiment no. IX-67(E), Cited in http://www.sfmta.com/cms/bproj/documents/SF_Colored_Pavement_Experiment_Request_May_2007.pdf. Accessed on November 14, 2007.
6. City of Columbia *PedNet Infrastructure Working Plan*, Accessed November 14, 2007.