IMPROVE UNIVERSITY CAMPUS ROAD SYSTEM WITH COMPLETE STREETS PRINCIPLES: THE CASE OF UNIVERSITY OF MARYLAND

CUI, MINGYU
University of Maryland, PLS 2156, College Park, MD 20742, ozone@umd.edu

KWEON, BYOUNG-SUK
University of Maryland, PLS 2140, College Park, MD 20742, kweonb@umd.edu

MYERS, DAVID N.
University of Maryland, PLS 2146, College Park, MD 20742, dnmyers@umd.edu

1 ABSTRACT

As a reflection of the evolving of the "Complete Streets" principles, the Safe and Complete Streets Act of 2011 (HR. 1780) addresses more on "safety" than its precedents. Based on the legal provisions, also as a response to the Complete Streets movement, this paper will discuss the legislation, safety, public demand, educational functions and sustainability aspects of the need for urban roadway systems to accommodate multimodal traffic on university campuses.

Through the review of the literature, this paper intends to document whether current roadway facilities of the University of Maryland College Park campus is adequate and efficient for daily behaviors of all user groups or whether facilities that ensure the order and safety on our streets are missing. According to a survey done by the Department of Transportation Services, University of Maryland, the important issues at the campus include cut-through traffic on main arterial (Campus Drive), lacking of bicycle facilities, and traffic congestion during rush hours. And further discussions the published results from a pilot trail of temporarily closure of Campus Drive. Therefore this paper will explore the improvement of campus roadways to accommodate some of travel means, especially cycling, currently used by the university community. Furthermore, the paper provides some suggestions on sustainability and education aspects and addresses how our campus roadway system could provide its user groups with more sustainable travel choices.

1.1 Keywords

complete streets principles, traffic conflicts, university campus roadway system

2 ISSUES STATEMENT

Acknowledged as a great industrialist, Henry Ford realized massive productivity in automobile industry by applying constantly-moving assembly lines, subdividing labor, and coordinating operations carefully. The popularization of automobile greatly expanded the range of human activities, in the meantime generated a demand for our urban roadway facility design to be oriented towards automobile travel. As our roads become more and more convenient for vehicles, many potential risks turns into great threaten to public well-being on a daily basis. From a microscopic point of view, traffic collision, right-of-way conflicts, and diseases directly/indirectly caused by automobile-dependency, are threatening individuals' safety and well-being. From a macro perspective, traffic congestion, stormwater drainage from roadway systems, and roadways cutting through habitats, are casting negative impacts on both our social economy and living environment.

2.1 Traffic Collision

Traffic collision (of which types include rear-end, side collisions, head-on, road departure, and rollovers), or "Motor Vehicle Accidents (MVA)" as used by the U.S. Census Bureau (US Census Bureau, 2009), was the sixth leading preventable cause of death in the United States as of 2000 (Mokdad et al., 2004). According to the report, nearly 36 thousand people died and 97 times more were injured in 2009 as results of motor vehicle accidents (National Safety Council, 2011).

There are basically 2 factors facilitating the occurrence of traffic collision: roadway related factors (human factors and road design) and vehicle related factors (vehicle design and maintenance). According to a 1985 study, which used British and American traffic collision reports as data, more than 90% collisions involved roadway related factors. (Lum and Reagan, 1995)

The two components of roadway related factors, roadway design and human factors (or driver factors), are closely related, especially in terms of motor vehicle speed. A 1998 research review on traffic speed done by U.S. Department of Transportation's Federal Highway Administration states that "there is limited evidence that suggests that lower speed limits result in lower speeds on a system wide basis", meanwhile, more research needs to be done on the effectiveness of traffic calming measures (US DOT, 1998). As the 2008 International Transport Forum (ITF) elucidated, "it recognizes that prevention efforts notwithstanding, road users will remain fallible and crashes will occur" (ITF, 2008), inferences can be drawn that road designers have the potential and therefore the responsibility to contribute more to traffic safety by facilitating speed control on road systems other than traffic legislation and law enforcement agencies.

2.2 Right-of-way Conflicts

Right-of-Way conflicts (between automobile and bicyclists, as well as pedestrians, as referred in this article) become one of the obstacles repelling the campaign against urban sprawl as results of lacking adequate supporting facilities (sidewalks, bike lanes / tracks, etc.) for pedestrians and bicyclists' travelling in some roadway segments. Even on roads equipped with these facilities, conflicts still happen at critical segments, especially intersections.

The reasons for ameliorating urban roadway facilities to benefit pedestrians more than automobiles can be perceived from three facets: First, driving is a more advanced skill, which requires meeting minimum standards in several aspects that cannot be legally required of walking. Second, walking is a congenial human right while driving is more of a privilege. It is unreasonable to deprive an individual's right to walk as a punishment in traffic disputes. Third, pedestrian is a group with more complex composition including people with less physical and cognitive skills than drivers, including children, youths, elderly people and people with physical challenges(Houten, 2011). On the basis of above reasons and analysis of traffic statistical data, pedestrians are vulnerable roadway users "much more exposed than others to injury or death in a traffic accident" (Tarko and Tracz, 1995). It should be noticed that the asymmetrical responsibility of pedestrians and drivers in a crash does not simply imply that drivers should take on full responsibilities in all cases. According to the data recording pedestrian crashes during 2000 – 2008 in Santiago, Chile, about 67.2% was caused by pedestrians' irregularities in traffic behavior, while 26.3% was drivers' responsibility, and 6.6% was caused by undetermined factors (Blazquez and Celis, 2012). Avoiding irregular pedestrian behaviors, including imprudence, crossing roads surprisingly or carelessly, violating crosswalks, remaining on the road, disobeying red signal, and other

behaviors, should be taken into consideration in road improvement design as well as pedestrian safety protection measures. In the case of urban low-speed roads, an effective solution to reducing conflicts between pedestrians and automobiles from designing approaches is to apply signs and markings, signals and beacons, and traffic calming measures to roadway segments. Wider pedestrian cross marking, advance stop bars, yield to pedestrians signage, countdown pedestrians signals and various traffic calming techniques including speed humps, speed tables and roundabouts, all have the potential to effectually abate conflicts between pedestrians and automobiles when being applied together with education and enforcement.

Comparing with pedestrian behaviors in the streets, which could simply categorized as travelling "along the road" and "cross the road", the conflict between bicyclists and automobiles is more of a communication problem (Walker, 2011). As pointed out in Chaurand and Delhomme's research, even with a lower absolute number of bike crashes (i.e. NHTSA, 2009; SafetyNet, 2008), "bicyclists have higher exposure rate to injury and fatal crashes than car drivers, be it per time or distance (i.e. Broughton et al., 2010; PROMIZING, 2001)", in addition, bicycle-car collisions are the riskiest situation for bicyclists (Bíl et al., 2010; Kim et al., 2007; Räsänen and Summala, 1998; Summala et al., 1996; Chaurand and Delhomme, 2012). The impairment of agility at start and considerable risk of losing balance in evading actions also contributes to bicyclists' vulnerability. A 1997 study on 188 bicycle-car collisions in four cities reveals some regular pattern of these accidents. First, collisions frequently happen at road intersections, mostly on conflict points of motor vehicles and bicycle travel path. Second, in nearly 40% of collisions in this study, both parties didn't realize the danger nor have time to evade. Third, bicyclists are less noticeable to drivers, and in most cases there's an ambiguity on which party should yield to the other. (RäSäNen and Summala, 1998; also in Kim et al., 2007) This study indicates roadway facility design plays a very important role in travelling bicycle-car interactions besides legislation and education on travelling behavior. Users' right-of-way and yielding hierarchy (especially at intersections) should be clearly defined through signage and markings to reduce the accidents caused by ambiguity in these issues.

2.3 Public Health and Safety

Automobile-dependency threatens public health and safety both directly from traffic accidents and indirectly from impacting on living habits and traffic exhaust emissions. Except traffic collisions mentioned above result in injuries and mortalities, spillover effects, also known as "cut-through running" or "rat running", also distributes vehicular traffic volume into adjacent neighborhoods where streets mainly accommodate communities' daily activities, and therefore threats amenity and safety of local residents especially children.

Different from walking and cycling, driving is more of a highly sedentary activity involves minimum body movements. Perennially lacking of exercises will usually weaken multiple body functions and results in sub-health symptoms and certain diseases. A study of 10,808 households in Atlanta found that every hour spent in the car raises the likelihood of being obese by 6% (ARHF, ARC, 2005). Meanwhile, the gaseous emission from automobile is one of the main causes of Asthma and many other respiratory diseases. A 2003 study by American Surface Transportation Policy Project indicates that the air quality in tens of cities in the U.S. has worsened over the last decade (Surface Transportation Policy Project, 2003), and transportation system is the major contributor to the current air situation (US EPA, 2000). In a 2005 United States Environmental Protection Agency study, except an annual average passenger car emission of 11,450 pounds carbon dioxide, on-road motor vehicles and non-road ancillary equipment (mainly gasoline and diesel stations) also emits mono-nitrogen oxides (NOx), carbon monoxide (CO), hazardous air pollutants (toxics), particulate matter (PM10 and PM2.5), and ground level ozone produced by the reaction of nitrogen oxides and volatile organic compounds (VOCs) (US EPA, 2008).

2.4 Traffic Congestion

Traffic congestion (or "traffic jam") is a contemporarily common phenomenon closely related to urban sprawl and the growth of commuting. As described by Federal Highway Administration, traffic congestion is a condition that occurs as automobiles increasing on a particular section of road network within a certain time period, therefore increase vehicular queuing and decrease travel efficiency (FHA, 2008). The occurrence of traffic congestion is usually accidental. Under current traffic research, it is still hard to forecast which road conditions might lead to a congestion, but what is known is that individual incidents, from abruptly braking of a single car to traffic accidents obstruct a previously smooth flow, may

cause a cascading failure (or “ripple effects”) therefore create a sustained traffic congestion (Science Hobbyist: Traffic Waves, 1998). The negative effects casted by traffic congestion include decreasing in transportation efficiency, consequently impeding regional economic development, and encouraging road rage by stressing and frustrating motorists. In addition, traffic congestion also contributes to spill-over effect and exacerbates exhaust emission mentioned above.

2.5 Other Impacts

Asphalt and conventional concrete is the main pavement material of contemporary urban road infrastructure, and these impervious surfaces generate a large amount of stormwater runoff, which carries oil, brake dust, sediment, lawn chemicals and other toxins as byproducts from travelling of vehicular traffic, and send to nearby watersheds, resulting in degradation of aquatic ecosystem (ARHF, ARC, 2005).

As a conclusion to issues addressed above, which are more or less related to road facility design, there is an imminent call for better practice in road improvements which could benefit all roadway users by providing adequate equipment to maintain traffic order, and encouraging healthier travel modes. Furthermore, it is also expected to contribute in Low Impact Development (LID) by installing green infrastructure to road segments. In order to respond to these immediate challenges in university campus scale, several currently ongoing practices will be studied based on their different emphasis.

3 COMPLETE STREETS CONCEPTS

3.1 Legislation

Complete Streets campaign is more of a top-to-bottom action. In 1971, the State of Oregon passed a "bike bill", which is considered as the first statewide prototypal Complete Streets policy enacted in the United States. The act required that new or rebuilt roads to accommodate pedestrians and bicycles since its effective date, and requested state and local governments to fund pedestrian and bicycle facilities in the public right-of-way (DOT, Oregon, 2011). In 1984, the state of Florida enacted State Statute 335.065, requiring that transportation planning and development give "full consideration" to bicycle and pedestrian facilities (Florida Senate, 2011). It was until the year 2003 when David Goldberg, the communications director for Smart Growth America, first use the term "Complete Streets" as a formal replacement for 'routine accommodation' of walking and biking. Up to that time, the practices were concentrating only on bicyclists’ and pedestrians’ right-of-way from a more technical point of view. In 2005, the National Complete Streets Coalition (NCSC) was founded by a coalition of advocacy and trade groups including the American Society of Landscape Architects (ASLA) to keep developing and promoting the principles of Complete Streets (McCann, 2011).

Different from highways maintained by federal and state government, urban streets where Complete Streets principles targeted are usually maintained by private sectors, and upon which practices require legislation enforcement to benefit more communities. Federal Complete Streets legislation was proposed since 2005, but failed to become federal law (S. 794 IS, 2005, Library of Congress). Though the legalizing process faced repeated setbacks in federal level, major progress was achieved in state and lower-level jurisdictions. As of 2011, Complete Streets policies have been endorsed or adopted by 23 U.S. states and 201 lower-level jurisdictions, from legally effective entries and clauses to non-binding resolutions, executive regulations and transportation plans (NCSC, 2011).

In May, 2011, as a re-introduction of S. 794 (109th): Safe and Complete Streets Act of 2005 and H.R. 5951 (110th): Safe and Complete Streets Act of 2008, the bill H.R. 1780 and S. 1056(112th): “Safe and Complete Streets Act of 2011” was introduced and referred to Committee, which defines a “Complete Street” as “a roadway that safely accommodates all travelers, particularly public transit users, bicyclists, pedestrians (including individuals of all ages and individuals with mobility, sensory, neuro-logical, or hidden disabilities), motorists and freight vehicles, to enable all travelers to use the roadway safely and efficiently” (H.R. 1780, 2011, S. 1056, 2011).

Evolutions and improvements of the principles could be tracked by comparing the dead bill, “Complete Streets Act of 2009”, and its upgraded version, “Safe and Complete Streets Act of 2011”, in which major modifications were made. First, the 2011 bill emphasizes “safe” (“safety”) of all road users as a main goal to achieve, which shows a better comprehension in current urban roadway issues. Second, the later bill refined the category of roadway users. It separates freight vehicles from the category “motorists” into an independent one, to distinguish them from private vehicles and public transit in terms of

their service targets and functions. Generally, the amount of freight vehicles travel on a certain segment of urban roadway is not affected by the factors affecting that of private vehicles. The bill also specifies and clarifies that the term “pedestrians” covers “all ages and abilities”, which implies that ADA accessibility should be considered in roadway design. Third, the 2011 bill was revised to be more of a general guideline, in which many excessively detailed requirements have been trimmed off. It requires that an implementation plan to be created by agency staff under the directions of the Complete Streets policies to make sure the application of Complete Streets policies will be a well-planned and systematic process. Subsection “Promotion” was excluded from “Sec. 3: Complete Streets Policy Requirements”, which requires State DOT and Metropolitan Planning Organization to promote the development of complete streets policies in applicable local jurisdictions (H.R. 1443, 2011, S. 584, 2011), probably because similar requirements has been adopted by the U.S. Department of Transportation in 2010 to support the inclusion of cyclists and pedestrian accommodation in federal-aid projects (USDOT, 2010). The 2011 bill excludes “Sec. 4: User Access & Considerations” as a meticulous design guidance in order to improve adaptability of the bill as a potential act, as well as “Sec. 6: Safety Funding in Noncompliant States” in consideration of improved adaptability of the principles in all states. Last but not the least, some new contents were included in as the principles develops and the coalition grows. The 2011 bill takes “traffic volumes” into considerations in exemption requirements and procedures, and includes two affected communities including the American Society of Landscape Architects in “Research, Technical Guidance, and Implementation Assistance” section, indicating landscape architects’ responsibilities in promoting the Complete Streets principles.

3.2 Performance

The modifications imply that the Complete Streets principles mainly target on roadway users’ safety, and more concerns were put on promotion and broader adaptability of the concepts. Recent years have witnessed practices applying Context-Sensitive (CSS) approaches to follow the gradient of development patterns (i.e. practices in Caltrans, California), which enhanced flexibility and creativity of Complete Streets practices in areas with unconventional conditions. (AASHTO / FHWA, 2007)

Adaptability allows design elements vary to respond to the context changes. Design elements usually include improved pedestrian infrastructure (with ADA accessibilities), bicycle and mass transit accommodations, traffic calming measures and buffers.

Concerning more on safety bring about better performances. A Federal Highway Administration (FHWA) safety review found that properly applying Complete Streets design elements can improve the safety of all roadway users (Campbell et al., 2004). Another study found that installing these elements reduced pedestrian risk by 28% (King et al., 2003). Several other reports and organizations including National Conference of State Legislators also indicated that Complete Streets policies effectively improve public health by encouraging healthier travel means, especially walking and biking (Robbins and Morandi, 2002). A study done by Powell et al. in 2003 found that the percentage of people meet recommended physical activity levels has a positive correlation with whether there are safe places to walk within certain range from their home (Powell et al., 2003). The Institute of Medicine recommendations for fighting childhood obesity revealed a direct link between Complete Street policies and public health (Koplan et al., 2004).

3.3 Practices Variances

The Complete Streets practices in Los Angeles, also known as “Living Streets”, focus more on designing to assert functions of streets as public spaces and their environmental issues. Landscape elements (furniture, swales and rain gardens, etc.) being introduced into streets help accommodating varieties of daily activities, facilitate communications both inside and among communities, and perform on-site stormwater process before discharging to drainage (Bain et al., 2012).

Unlike other forms of Complete Streets practices which articulate that transportation equity must be explicit, “Shared Space” ensures unobstructed traffic flow by integrating different users instead of segregating them. Shared Space practices powerfully reduce the dominance of motor vehicles by eliminating demarcation in different level and exceedingly promote degree of sharing. Substantially introduce more traffic conflicts into streets, these practices inevitably increases potential accidents. But from another perspective, this ambiguity of equity generates more vigilance and dramatically impairs the effect of human factors in provoking conflicts. Meanwhile, the conflicts in a Shared Space are engineered-

in and more predictable to some extent, and thus interact with the definition of “conflict” and boost the development of new Pedestrian-Vehicle Conflicts Analysis (PVCA). (Kaparias et al., 2013)

4 UNIVERSITY CAMPUS ROADWAY SYSTEM

4.1 Introduction

In the past few decades, as transportation-related issues becoming more stringent, with considerable impacts on institutional functions, the importance of transportation planning in university campuses attract increasing attention. Besides benefits of mitigating the negative impacts of heavy vehicular traffic mentioned in the opening paragraph, better transportation facility also contributes to the attractiveness of the university town and push forward research into university town branding, on which few researches have been done (Brandt and Mortanges, 2010).

Transportation planning and facility design is more complicate in university campus context. Though inevitably sharing similar regularities of spatial and temporal traffic patterns with city road network, campus streets have some unique features need to be taken into consideration. Obviously as academic institutions university campus requires stringent safety, legal and environmental restrictions on traffic (especially vehicular traffic) travelling on their inner road networks. As will be revealed in the survey report, in the case of University of Maryland, majority of roadway users adopt non-automobile transportation modes on campus. Transportation problems and institutional problems are closely connected in university campus environment. Kronlid argued that the intimate psychological and physiological relationship between transportation facilities and their users discriminates the preferences (Kronlid, 2008). Later in 2010, Ferreira and Batey’s study quoted this claim and further pointed out that these preferences also influent the development and interaction between facilities and users in return (Ferreira and Batey, 2010), which implies, transportation planning in university campuses is constrained by institutional environment, and vice versa. With this inner connection, the problems cannot be effectively solved unilaterally. Ferreira and Batey’s multi-layer transportation model reveals a connection links transportation back to institutional design through three layers: Supply and demand, time, and perceptions. Within this loop the problems develop and exacerbate themselves. This model was developed upon the study on University of Coimbra (UC) campus in Coimbra, Portugal, which is located in a university town comparable to College Park. These studies also imply that perceiving the problem from appropriate direction is critical to the subsequent performance of improved road segments. (Ferreira and Batey, 2007)

4.2 University of Maryland Campus Traffic Issue

As an urban university, the University of Maryland is embedded in the City of College Park, which located in an increasingly urbanized metropolitan corridor (University of Maryland, 2011). Thus campus streets more or less undertake functions of inner-connection of the city, which brought negative impacts on campus operations. With major issues of traffic congestion and conflicts between vehicles and pedestrians and bicyclists being addressed in campus’ Facilities Master Plan (FMP), detailed practice suggestions will be proposed based upon a 2010 FMP subcommittees survey regarding transportation and aspects of campus environment, to provide guidance for implementation of corresponding contents in the FMP.

With about 40,000 students and 15,000 faculty/staff on campus in 2010, the designed sample capacity was to cover random samples of ¼ the population of both students and faculty/staff. The survey resulted in a responding rate of 14% from students and 29% from faculty/staff, in which students are underrepresented (FMP Subcommittees, 2010).

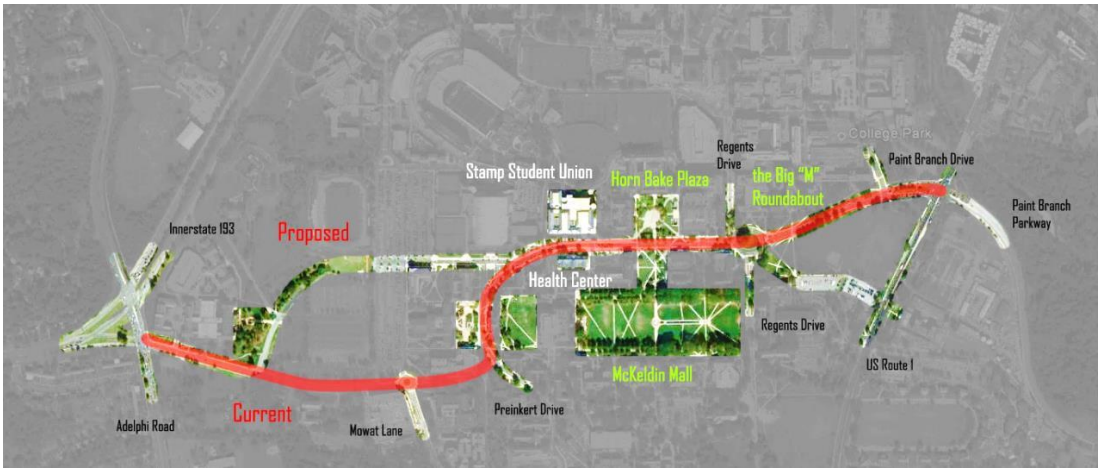

Figure 1. Campus Drive site content and green space connectivity

Through analysis of the survey results, several conditions should be addressed. As living distance to campus increases to about 1 mile, percentage of people choosing driving to campus individually surge up 35%, and 64% of all respondents adopt driving as their most preferred travel mean for commuting to/from campus. Dramatically, 86% choose to travel as pedestrians (walking, skating, skateboarding, etc.) from place to place on campus. Comparing with living distance statistics and Shuttle-UM transit system catchment areas, it indicates that driving will possibly remain as dominant travel mean for commuting within current FMP scope, but could be gradually cut down by constructing ancillary facilities for alternative transportation. Meanwhile, the campus is relatively walkable with a high degree of pedestrian facility coverage. With 62% demands for somewhat to major improvements towards pedestrian-friendly, further questions on travel experiences reveal conflicts between motorists and pedestrians and cyclists: more than 35% considers conflict with vehicles deteriorates pedestrian experience on campus, while about 45% takes reducing conflict with pedestrians as first priority in improving driving experiences on campus. A few pedestrians and drivers also complaint that conflict with cyclists affects their travel experience. These complaints of conflicts reveal ambiguity in travel priority hierarchy of roadway users, which could be better illustrated and clarified by education and roadway facilities such as markings, crosswalk, signage, stop bars, etc. The reason for fewer complaints related to cyclists is due to their small population. Encouraging cycling faces obstruction from multiple aspects. Current requires cyclists to bike on vehicular lanes and follow the same laws and regulations as vehicular traffic. With no markings or signage indicating drivers should share lane with cyclists, and hilly geographic of the campus severely affecting cyclists' travel speed, cyclists and drivers are usually ending up in conflicts of their own right-of-way. Intimidated cyclists usually choose to ride on pedestrian sidewalks and therefore provoke conflicts with pedestrians. There is also a call for ancillary facilities including weather-protected bike parking facilities and showering facilities. All these obstacles contribute to the population of cyclists much less than expected, with 82% of respondents never bicycle on campus.

Figure 2. Traffic congestion on Campus Drive, one of the main arterials of the University of Maryland campus

The survey also implies the demand of improving public transit systems to support on-campus travels, with the huge campus scale and carrying heavy items being revealed as top two factors impelling people from walking under certain conditions.

The existing road facility is one of the constraints for applying Complete Streets policies. With a width of 11 feet on almost all vehicle lanes, it's nearly impossible to squeeze in bike lanes without widening the road or removing one or several vehicle lanes. The suggestion is to apply different principles on different segments of the road network. Bike commute routes info shows there are several routes most frequently used by cyclists on campus (Bike UMD, 2013). These routes are the first priority to equip with bike lanes adapt to their specific conditions. Shared lanes are needed for secondary routes and connectors between routes, but with qualified widths and clear markings and signage to declare equality of cyclists' and drivers' right-of-way. Current Shuttle-UM routes highly overlapped to each other in certain segments inside campus perimeter. The suggestions is to detach inner-campus circulation from commuting transit network to increase coverage, amount of stops and most important of all, frequency of the inner-campus transit network. This will cooperate with strategic planning of pushing major parking lots out to the campus perimeters, and connect them to the core area with inner-campus transit and bike share system to reduce vehicular traffic volume on campus roads. Close campus main streets to outside vehicles might possibly lead to spoil effects affecting other part of the campus. Besides, a phased experiment of closing Campus Drive, one of the main streets on campus, was conducted in 2010, which indicates permanent closer of the road received negative comments from majority of the campus population (Baker, 2011). Shared Space and Living Streets principles are suggested to be applied to main streets of campus (i.e. Campus Drive) to assert pedestrians' dominance and, discourage, but allow cut-through driving before any alternative routes being deployed. The proposed Purple Line light rail and subordinate bike route network is expected to encourage the use of alternative transportation and mitigate the heavy commuting traffic cutting through campus on East-West direction.

Figure 3. Cyclists on campus are encouraged to share the road with vehicles, but frequently they are intimidated and use pedestrian sidewalk, bringing potential collision risks to pedestrians

4.3 Sustainability and institutional functions

Besides targeting on transportation issues, corresponding green infrastructures such as planters, swales and rain gardens should also be configured to install on certain parts of campus roads to reach Best Management Performances (BMPs) on stormwater runoff, in respond to the FMP on designating of the campus as an Arboretum and Botanical Garden, and the prompting in sustainability. The existing campus road facilities cannot meet the needs on sustainability due to the absence of stormwater management facilities. Suggestions include installation of bioswales on main streets, especially Campus Drive, Stadium Drive and Regents Drive, which have significant elevation changes along their reaches. On one hand the topography can contribute to dispersal of processed stormwater, as well as opportunities of designing unique streetscape. On the other hand, these facilities are exposed to road users' daily activity, thus will clearly display how green infrastructures work and efficiently popularize sustainable concepts.

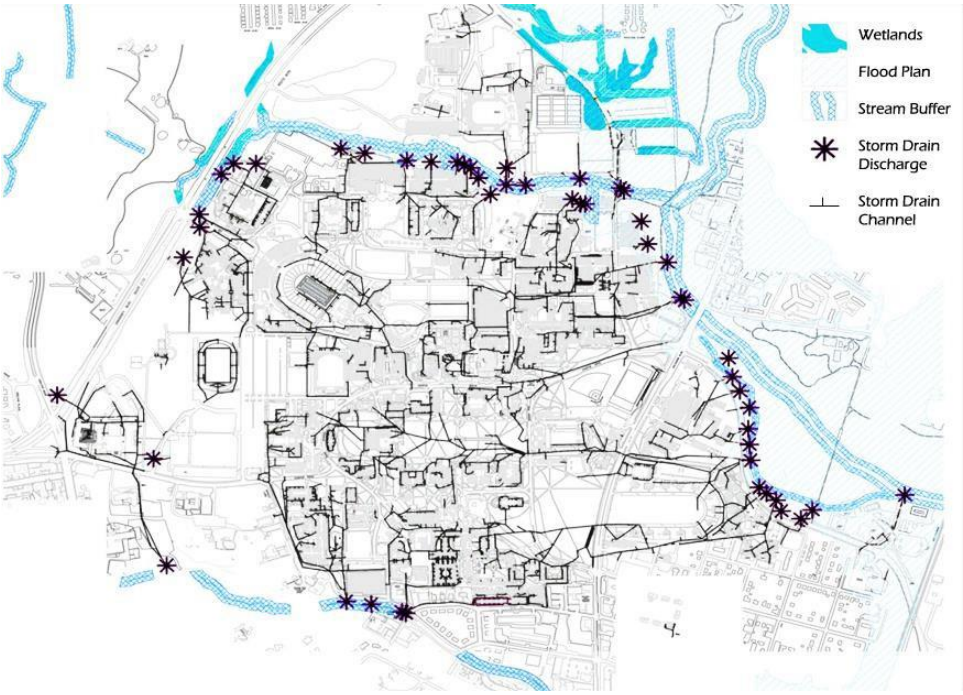

Figure 4. Campus storm drainage network map shows that campus roads are lacking on-site stormwater management facilities (2012) Facilities Management, University of Maryland.

Finally, getting students involved in the detailed design part, such as bus stop shelters and some of the green infrastructures, will also boost the mutual promotion of education and road facility, and form a virtuous circle in Ferreira and Batey's multi-layer transportation model.

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