Sustainability Systems Semester Projects Report

CSUMB | ENSTU 375 | Fall 2015

Prepared by Michelle dela Cruz

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Sustainability Systems Report

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I. Introduction

Sustainability Systems

In the fall semester of the 2015 school year, Dan Fernandez's Sustainability Systems class had the opportunity to apply systems thinking to two real-world transportation projects. For the first project, the class examined campus transportation patterns as part of a California State University (CSU)-wide sustainability initiative called Campus as a Living Lab (CALL). For the second project, the class helped initiate CSUMB's first Sustainable City Year Program (SCYP) by working with the City of Salinas to model the effects of a proposed "road diet" within the city. The class divided into seven groups and picked a specific aspect to study for both projects, but they were allowed to focus more deeply on one project for their final reports. Students also used the Monterey-Salinas Transit (MST) bus system and submitted a weekly survey about their public transportation experience throughout the semester. By the end of the course, the students collected an extensive amount of data that could be applied to both projects for analysis.[1]

Systems Modeling

Examining transportation projects using systems thinking requires understanding what systems are and describing how systems function using causal loop diagrams, stock and flow diagrams, and computer modeling software. In short, a system is an organized set of elements or factors that interact to achieve a purpose.[2] Causal diagrams illustrate an interaction in the system with a link that shows a positive or negative correlation between two elements. Links can form feedback loops between elements that are either *reinforcing*, which has an even number of negative links and amplifies an effect in the system; or *balancing*, which has an odd number of negative links and keeps the system in a steady state of equilibrium. **Figure 1** is an example of a causal loop diagram that includes positive and negative correlations, as well as reinforcing and balancing loops.

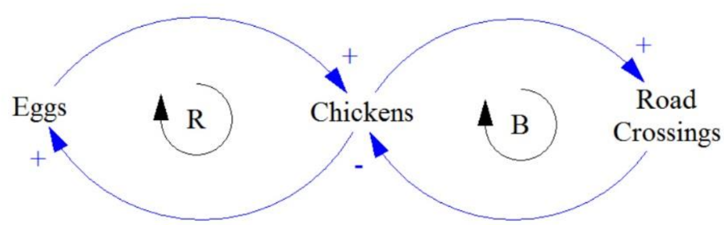

Fig. 1. An increase in eggs causes an increase in chickens, which causes an increase in road crossings. But more road crossings leads to less chickens (due to roadkill), which leads to less eggs.

[1] Fernandez, D, "Sustainability Systems Syllabus Fall 2015."
[2] Meadows, D. H., *Thinking in Systems: A Primer*. (White River Junction, VT: Chelsea Green Publishing, 2008), 11.

Stock and flow diagrams describe systems in greater detail by quantifying elements and describing interactions in terms of mathematical functions. The Sustainability Systems class used a computer modeling program called STELLA to create stock and flow diagrams that simulate interactions in transportation systems. Students learned how to construct stock and flow models using four components in STELLA: stocks, flows, action connectors, and converters. Stocks represent the quantity of an element that fluctuates over time. Flows change the quantity of a stock by allowing material to flow into or out of the stock; the "cloud" that is attached to a flow represents a source that stock material flows in from or flows out to.[3] Action connectors form a relationship between components in the model so that their values are linked mathematically in a function. Finally, converters represent a static value or quantity of interest (e.g., a constant rate) that can influence flows or other converters, but not stocks. **Figure 2** is an example of a simple stock and flow diagram, which also illustrates the level of experience the Sustainability Systems class had with STELLA at the beginning of the semester. By the end of the course, students were able to construct basic stock and flow models of transportation systems.

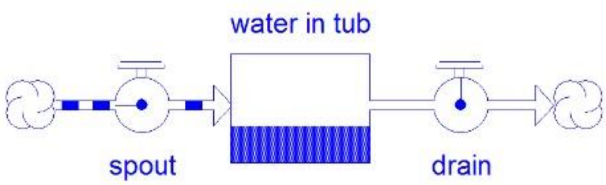

Fig. 2. The spout flow adds a given quantity of water to the tub per time step, which increases the stock of water in the tub. In this model, water does not flow out of the tub because the drain rate is set at zero.

[3] Meadows, D. H., *Thinking in Systems: A Primer*. (White River Junction, VT: Chelsea Green Publishing, 2008), 18.

II. CSUMB Transportation Project

History and Background

California State University, Monterey Bay (CSUMB) was established in 1994 between Marina and Seaside, California after the U.S. Army closed its base at Fort Ord. The U.S. Army occupied Fort Ord from 1917 to 1994 and provided unique basic training opportunities—troops could practice military maneuvers at a landscape level which was not available at the Monterey Presidio Grounds.[4] After the base was decommissioned in 1994, the local community suggested repurposing the land for a new state university, and CSUMB commenced its first classes in 1995 with 654 students.[5] CSUMB's Campus Master Plan, which included an expected enrollment cap of 25,000 students by 2030, was approved in 1997.[6] However, in 2015 the enrollment cap was revised to 12,500 students by 2020 due to water allocation issues in the area.[7] CSUMB has steadily grown to accommodate over 7,000 students (shown in **Figure 3**) by renovating its campus with new facilities such as the Chapman Science Academic Center and Tanimura & Antle Family Memorial Library; the newest additions are the Business Information Technology building and Promontory student housing which opened in 2015.

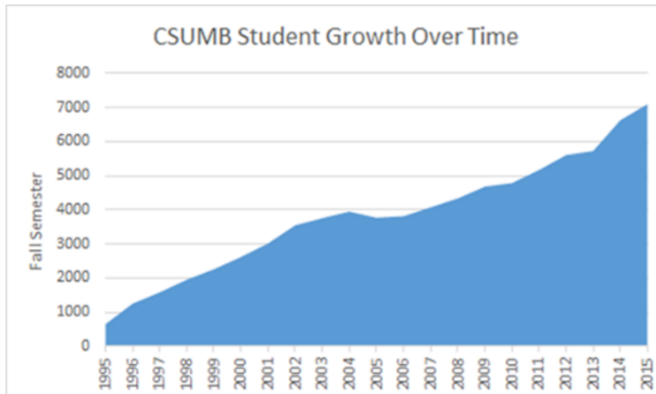

Fig. 3. CSUMB's student enrollment for fall semesters between 1995 and 2015.

Current Situation

CSUMB will continue to expand with environmental sustainability in mind, but its location on a former military base presents challenges in establishing a sustainable campus transportation system. The military development on Fort Ord required extensive roadwork for efficient vehicle mobility; however, this infrastructure is no longer appropriate for a university that aims to promote other modes of transportation and reduce its greenhouse gas emissions. For example, Inter-Garrison Rd. is a long, straight road that was designed to facilitate transportation between the Main Garrison at the northwest corner of Fort Ord and the East Garrison at the

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[4] Bureau of Land Management. "*Fort Ord History*." Accessed January 23, 2016. http://www.blm.gov/ca/st/en/fo/hollister/cultural/lightfighters.htm
[5] CSUMB. "*About CSUMB - History*." Accessed January 23, 2016. https://csumb.edu/about/history
[6] Pitnick, R. A critical look at Cal State University Monterey Bay--is CSUMB meeting its own goals? *Monterey County Weekly*, September 24, 1998. Accessed January 23, 2016. http://www.montereycountyweekly.com/news/local_news/a-critical-look-at-cal-state-university-monterey-bay-/
[7] Salinas, C. M. CSU Monterey Bay master plan to accommodate 12,500 students. *Monterey Herald*, August 28, 2015. Accessed January 23, 2016. http://www.montereyherald.com/article/NF/20150828/NEWS/150829773

southeast corner.[8] Today, Inter-Garrison Rd. is used by many single-passenger vehicles because it connects Salinas, Marina, and Seaside; and it is the main entrance to CSUMB for students who live in East Campus housing. As a result, single-passenger vehicles commute from multiple locations and create heavy traffic at peak hours near CSUMB.

The Systems class considered the stakeholders involved and how they might be affected by proposed traffic solutions. Students and faculty who drive to school may need to commute from out of town. Students and faculty that live nearby or on campus could make the greatest impact by choosing to use the bus or ride a bicycle; however, they may need to bring their cars to campus because of regularly scheduled activities outside of class, such as a part-time job or family responsibilities. City people who regularly commute through campus are not the focus group for encouraging other modes of transportation, but they would likely support reduced traffic on campus. If a bicycle incentive program is implemented on campus, participants could promote the program to other students and offer insight about bike paths that could be further developed for comfort and safety. However, implementing an incentive program would require bringing in a new stakeholder to provide the awards and prizes to be used as incentives.

Research Interests

About half of the groups studied parking while the other half focused on bicycle use on campus. Parking was considered with varying detail: Group 2 took a general approach to see how commuters used campus parking lots; Group 4 narrowed their focus to impacted central lots; and Group 5 looked specifically at whether or not Promontory students were choosing to drive on campus instead of walking. Groups interested in bicycle use thought about how funding for CALL could be used to encourage bicycling and reduce driving on campus. Group 7 actually sent out a survey to students to determine their current perceptions about sustainable transportation and a possible bike incentive program. Group 1 researched the features and affordability of different bike counters that could be used to incentivize bicycling on campus, while Group 3 examined policies and regulations that could discourage driving instead. Assuming the purchase of bike counters, Group 6 considered where the most effective location might be for a bicycle counter on campus. Each group collected data, drew causal loop diagrams, and created STELLA models based on the focus of their research.

Graphs and Data Collection

Most groups collected data by counting cars, bicyclists, pedestrians, and parking permits at different times and locations around campus. However, one group obtained data from CSUMB's Office of Institutional Assessment and Research (IAR), and another group engaged students with a transportation survey. Most groups collected data over a short time period and noted that the scope of their data collection was a limiting factor in the results of their projects.

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[8] Military Museum. "*Fort Ord*." Accessed February 08, 2016. http://www.militarymuseum.org/FtOrd.html

- Group 2 used IAR data to compare transportation costs between off-campus and on-campus students. On average, commuting students spend $600 more on transportation than on-campus students (**Figure 4**).
- Group 4 counted cars that entered, parked, and exited the Chapman parking lot on 6th Avenue. An average of 15 cars per half-hour drove through the lot even when it was full (**Figure 5**).
- Group 5 visited multiple parking lots and counted Promontory parking passes. Data for the Student Center parking lot are shown in **Figure 6**. In general, they found 3 to 5 Promontory permits in lots with an estimated 100-car capacity.
- Group 1 and Group 3 counted a combination of cars, bikes, pedestrians, busses and police vehicles on Inter-Garrison Road. Group 3 counted from the 7th Avenue intersection, while Group 1 used a cellphone app to take counts near 8th Avenue. They observed a high amount of traffic on Inter-Garrison Road just before 8am (**Figure 7**).
- Group 6 counted bicyclists in the afternoon at three locations on campus. The west side of campus had the most traffic with 14 bicyclists on Divarty Street (**Figure 8**).
- Group 7 sent an online campus transportation survey to a sample of CSUMB students. Of the 99 students who responded, roughly 70% drive to campus alone; 46% would not use a bicycle for incentives, but about 40% would switch to public transportation if there were incentives (**Figure 9**).

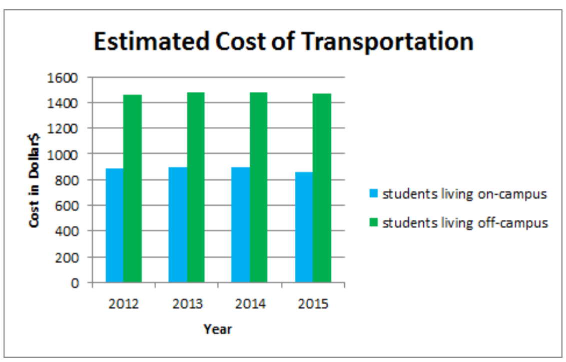

Fig. 4. Group 2 data: Transportation costs between on-campus and off-campus students.

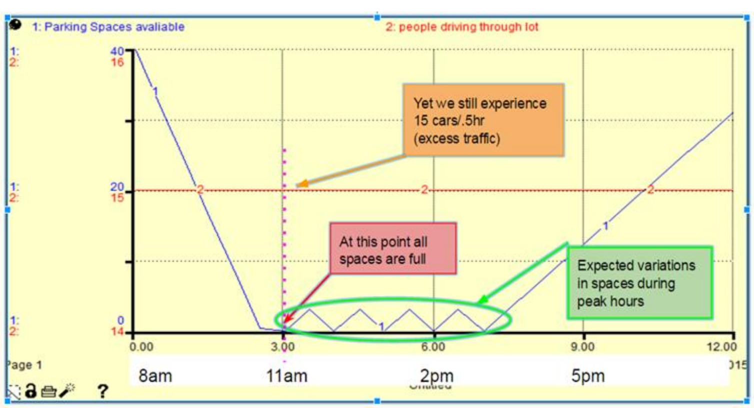

Fig. 5. Group 4 data: Parking availability in the Chapman lot throughout the day.

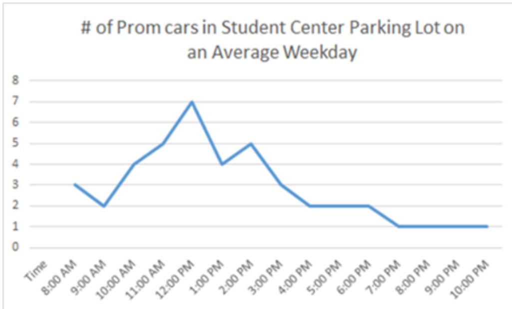

Fig. 6. Group 5 data: Promontory permits in the Student Center parking lot throughout the day.

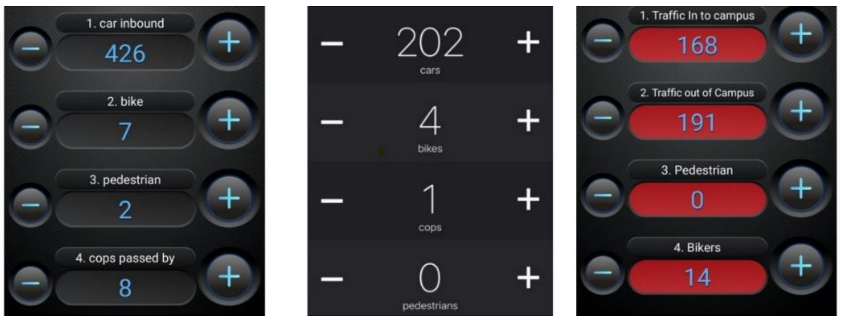

Fig. 7. Group 1 data: Counts of cars, bikes, pedestrians, and cops on Inter-Garrison Road.

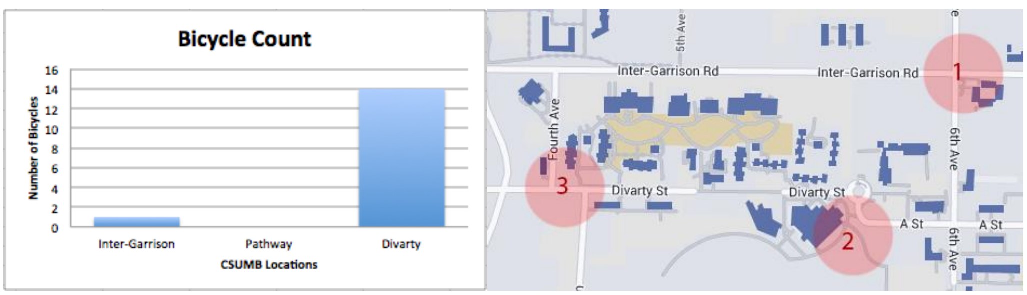

Fig. 8. Group 6 data: Bicycle counts at three bicycle count locations.

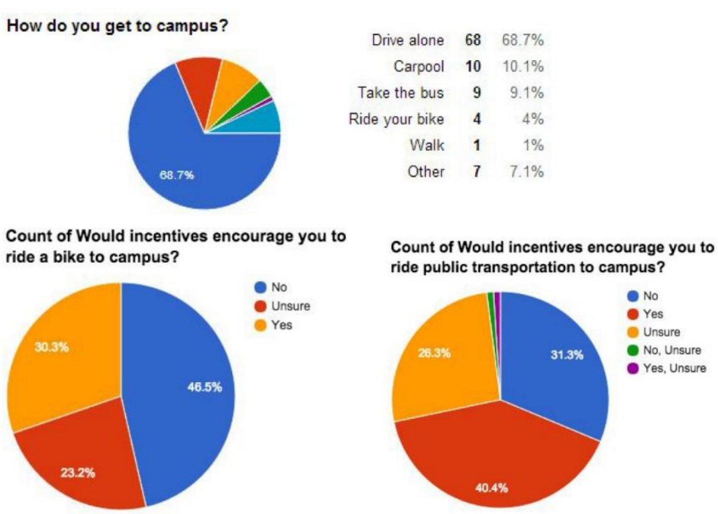

Fig. 9. Group 7 data: CSUMB transportation survey results.

Causal Loop Diagrams

Similarities. Even though each group focused on specific aspects of CSUMB's transportation system, there were many common elements in their causal loop diagrams. All the diagrams included a traffic element; some groups called it "congestion" or "number of cars," and sometimes it referred to traffic among pedestrians or bicyclists.

- Groups 2, 4, 5, and 7 included a *distance-from-destination* or *commute time* element, which some groups linked to quality of life—they made the general assumption that people feel less satisfied with life as their commute times increase.
- Groups interested in the parking aspect included a *parking-availability* element that was positively correlated to traffic or *attractiveness-of-driving*. Available parking attracts people to driving because it makes the experience more convenient, and traffic would increase as more people choose to drive.
- Groups that focused on the biking aspect included a *biking-incentive* element which would increase bike ridership; bicycling becomes more attractive as the quality or convenience of incentives increase.
- Some groups included a link or loop where *an increase in bicyclists causes a decrease in traffic* (or number of cars) and vice versa. The assumption is that students who start biking instead driving would take their cars off the road and out of traffic; or if traffic is bad enough, they might switch to bicycling because it becomes faster or more convenient. Neither assumption is necessarily true, but it's a possible approach for reducing traffic and its inherent carbon emissions on campus.

Differences. Groups expressed critical thinking by adding unique and conceptual elements that can influence a person's choice of transportation. These elements can be intangible and difficult to quantify. Some groups added *hash marks* on links to indicate a delay in the cause-and-effect relationship between elements.

- Group 2 included a *feeling-of-community* element that is postively linked to a person's quality of life, in that people tend to feel better when they experience a sense of safety and belonging in their community. This element recognizes a pscyhosocial benefit of walking, biking, or busing that people may not be aware of.
- Group 2 also included the *costs of transportation* in their diagram. Some people may prioritize economic or environmental factors when choosing their mode of transportation, depending their culture or values.
- Some groups mentioned *perceived safety* (of pedestrians or bicyclists) in their diagrams. Students may be choosing to drive because they think it's safer than walking or biking.
- Group 5 linked *weather* to perceived safety because students may not feel safe biking or walking with strong winds, rain, or other unfavorable conditions.

- Group 1 linked favorable environmental conditions to perceived safety, such as *lighting* and *protected bike lanes*, which would help bicyclists feel safer about traveling with traffic.
- Group 6 considered how the frequency or number of bus stops might influence the *convenience of public transportation*. People are more likely to use public transportation if it is convenient.

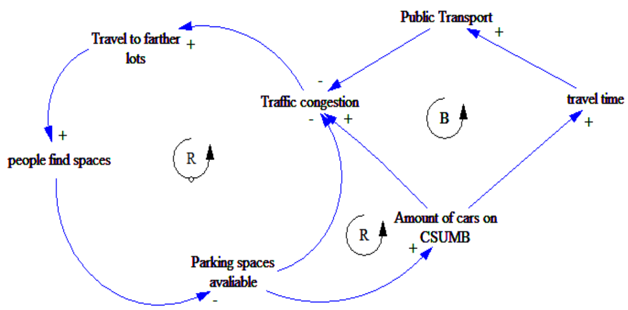

Fig. 10. Group 4's causal loop diagram.

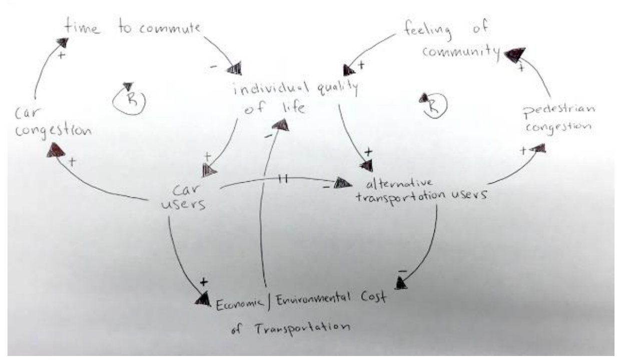

Fig. 11. Group 2's causal loop diagram.

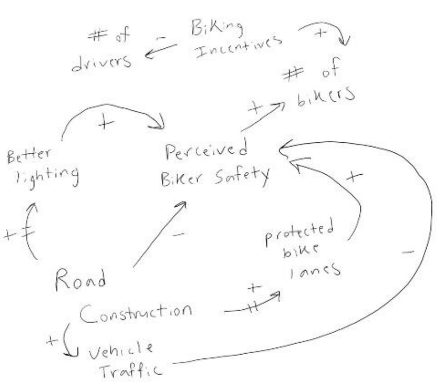

Fig. 12. Group 1's causal loop diagram.

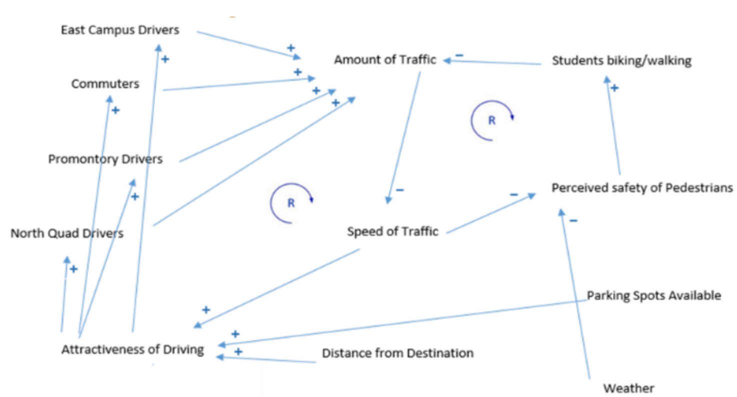

Fig. 13. Group 5's causal loop diagram.

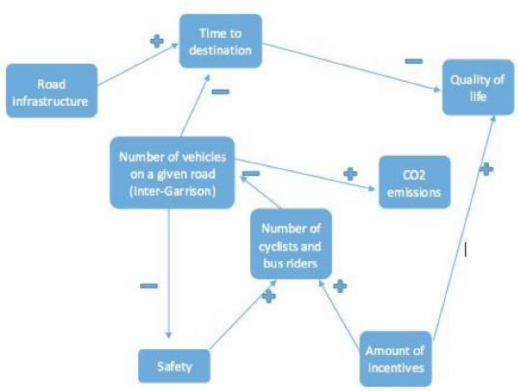

Fig. 14. Group 7's causal loop diagram.

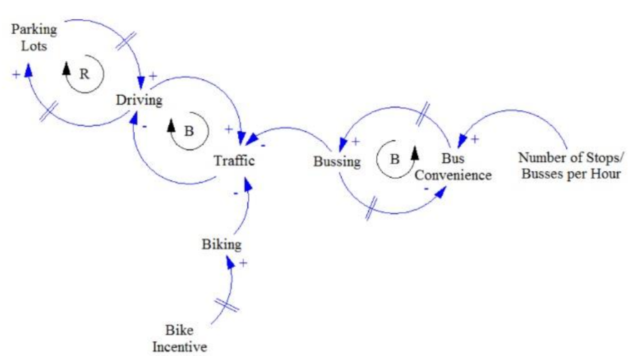

Fig. 15. Group 6's causal loop diagram.

Stock and Flow Models

Throughout the course, students learned how to translate causal loop diagrams into stock and flow models in STELLA. In general, groups looked at the elements of their causal loop diagrams, decided if they were stocks or converters, and used action connectors to represent the links in their diagram. The correlations of a link could be represented by having an action connector tied to an inflow or outflow of a stock. The following models illustrate how students thought critically about representing elements with numerical values and quantifying relationships with equations, graphs, and basic computer programming.

Seaside Commuter Parking Model. Group 2's stock and flow model was not based on their causal loop diagram, but their model simulated how Seaside commuters might park in Lot 508 and Lot 12 on campus during the day (**Figure 16**). They used a graphical input to represent the influx of commuters over the course of a day (**Figure 17**) and IF THEN statements to determine the flow of commuters between lots. Their model and simulation results are shown in **Figure 18** and **Figure 19**.

- *inflow for lot 508* is determined by capacity 508 and cars commuting from seaside (converters), and lot 508 (stock). If there are enough spots to accommodate all seaside drivers, then all the seaside drivers will flow into the lot. If there are less spots available than the amount of seaside drivers, then the amount of cars equal to the amount of available parking spots will flow in. If there are no spots available, seaside drivers will flow into lot 12, which has available parking.
- *outflows*: If the time is before 7am, then no cars leave the lots. If the time is past 5pm, then 75% of the cars in the lot will leave per time step. If the time is between 8am and 4pm, then 10% of the cars in the lot will leave per hour.

Fig. 16. Map showing the locations of Lot 508 and Lot 12.

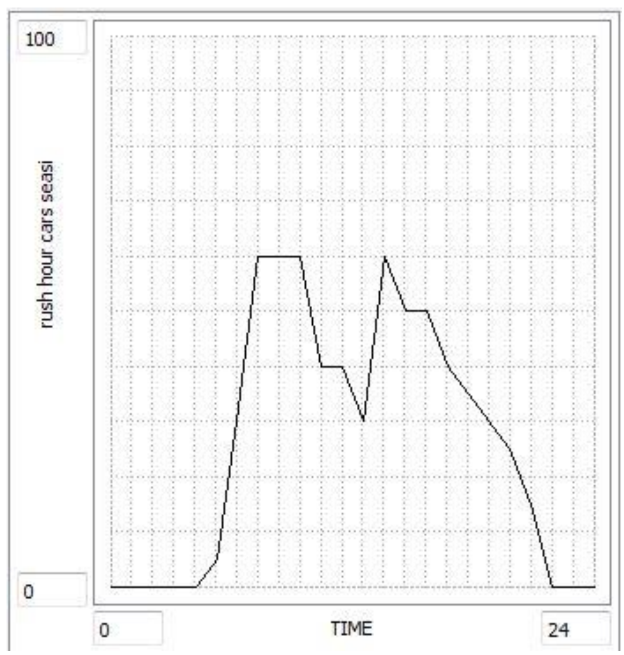

Fig. 17. Graphical input showing peak times when commuters enter and leave campus.

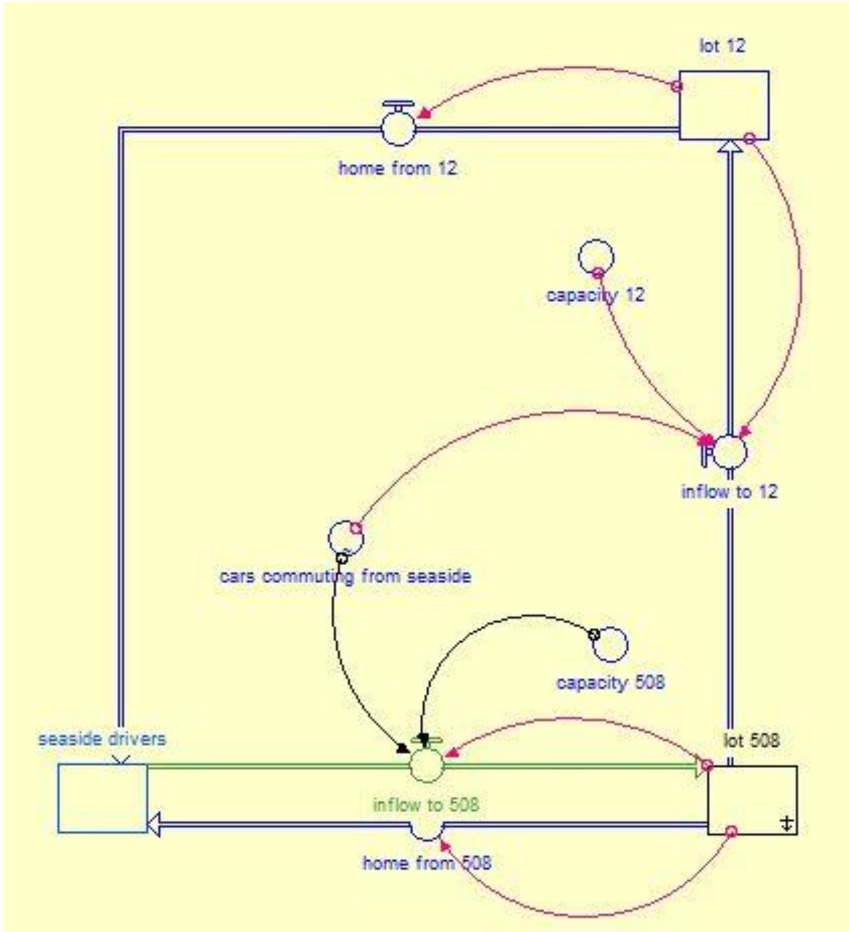

Fig. 18. Group 2's model of Seaside commuters parking in Lot 508 and Lot 12 at CSUMB.

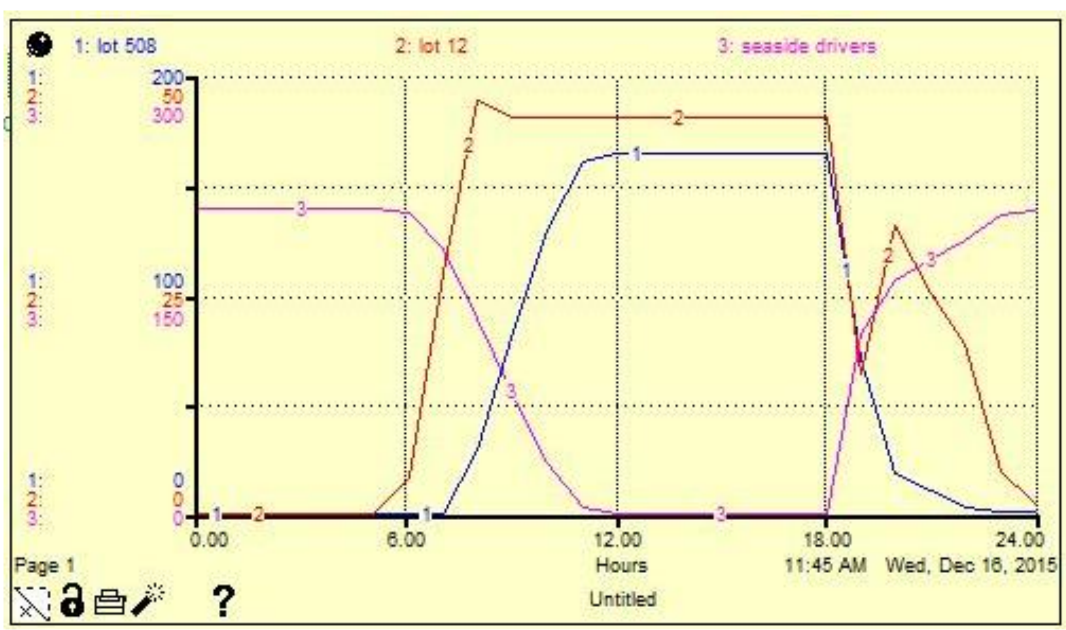

Fig. 19. Simulation results from Group 2's STELLA model.

Group 2 simulated a 24-hour period with their model. There are 210 Seaside drivers until 6am when students wake up and go to class. Lot 12 and Lot 508 fill to capacity between 6am and 12pm. Students begin leaving campus around 6pm (18.00 hours); the amount of cars in the parking lot stocks decreases; and the number of seaside drivers increases. Lot 508 shows a steady decline after 6pm, while Lot 12 experiences a spike sometime before 9pm. Group 2 was able to model the parking behavior of CSUMB commuters from Seaside, but did not reach a conclusion on how commuters affected campus traffic.

Chapman Science Academic Center Parking Model. Group 4 based their stock and flow model (**Figure 20**) on the general framework of their causal loop diagram and used their data to specifically model the parking system they observed in Lot 13. They provided numerical values and equations for some components of their model.

- *Spaces available* refers to the parking spaces available on campus and had an initial value of 40 based on Lot 13 observation data.
- *Cars enter campus* refers to the average number of cars that enter campus every half hour based on the Lot 13 data.
- *Cars leave campus* represents the cars that leave campus and reduce congestion based on the average number of cars that exited Lot 13.
- *traffic congestion* was determined by *cars on campus* divided by *Spaces available*. This value may have been multiplied by an assigned "congestion" factor.
- *travel time* was determined by *desired travel time* minus a ratio between *travel time* and *traffic congestion*.

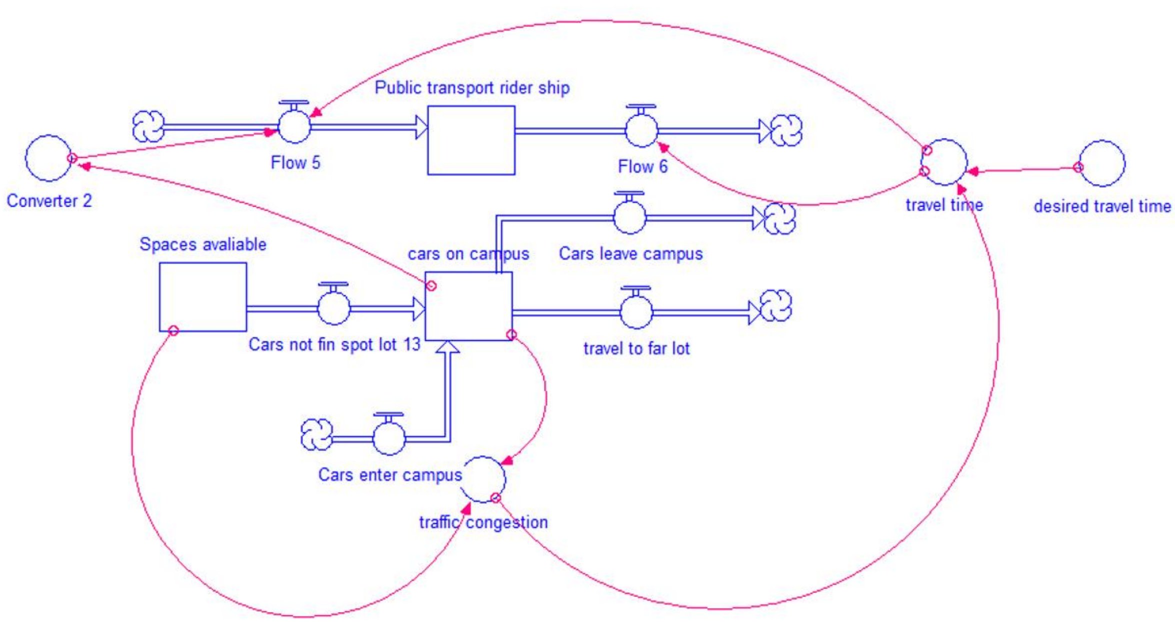

Fig. 20. Group 4's model of the parking and traffic situation on 6th Avenue next to Lot 13.

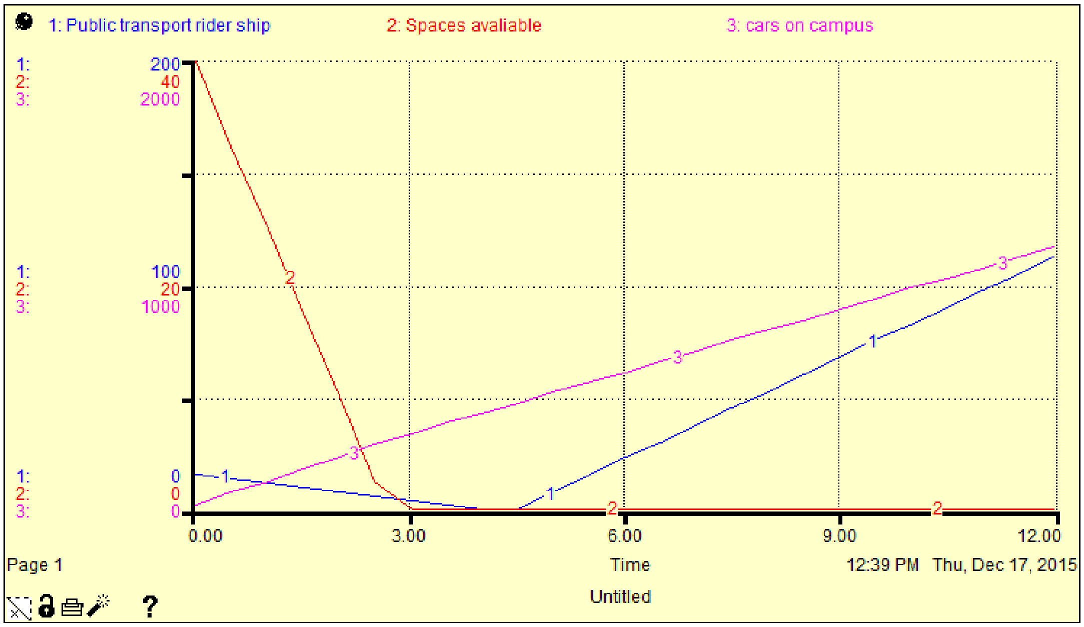

Fig. 21. Simulation results from Group 4's STELLA model.

Group 4's results in **Figure 21** show the number of available parking spaces decreasing throughout the day while the amount of cars on campus and the amount of public transportation ridership increases. They assumed public transportation ridership would increase as finding parking becomes more difficult.

Conclusions

Most groups felt their models and results were highly limited by the small sample sizes of collected data. However, many groups concluded their CSUMB transportation study with insightful recommendations. Group 1 did thorough research on incentivized bike counters and recommended the Dero ZAP system for counting bicyclists on Inter-Garrison near East Campus Housing. Dero ZAP requires participants to install a radio tag on their bicycles and it records a variety of data that can be accessed online by participants and administrators. Group 4 analyzed the benefits of a road diet that was implemented on 5th Avenue and recommended a similar road diet for 6th Ave. to reduce traffic near Lot 13. The area could be more pedestrian friendly with additional crosswalks, a median, and a roundabout at the 6th Avenue and A Street intersection. Group 5 concluded that the small number Promontory students who use parking lots close to campus have no significant impact on traffic. Group 7's transportation survey revealed the need for developing a bike and bus culture among students; they recommended gearing sustainable transportation incentives towards freshman and transfer students and implementing a no-car policy for freshman. The work completed by this class may be a good starting point for Sustainability Systems or Infrastructure students that address campus transportation in the future.

III. West Alisal Road Diet Project

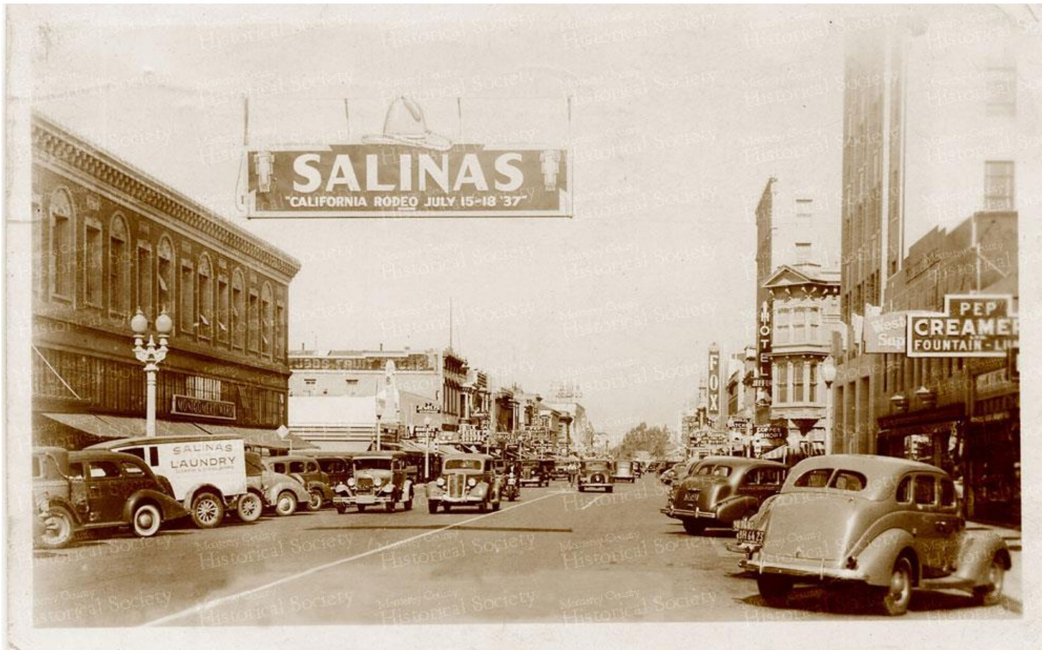

Fig. 22. *Downtown Salinas*. 1937. Monterey County Historical Society, Salinas, California, accessed April 24, 2016. http://mchsmuseum.com/salinas/

History and Background

West Alisal Street is located in the south side of Salinas, California—a Central Coast city known as the "Salad Bowl of the World." The Salinas Valley was originally a wetland habitat occupied by Ohlone Native Americans until Spanish settlers appeared in the late 1700s.[9] Within a century of their arrival, over 90 percent of the wetlands were drained, fertile soils were exposed, and the agriculture industry took root by the late 1860s.[10] James Bryant Hill and Jacob Leese quickly seized the opportunity for agricultural development and purchased over 16,000 acres of rancho land combined.[11] Hill attempted a farming project at Rancho Nacional near the foothills of Mount Toro, but it failed financially.[12] Further out in the valley, Leese's Rancho Sausal thrived and eventually developed into the City of Salinas.[13] After the Southern Pacific Railroad connected to Salinas in 1872, the city was incorporated into Monterey County two

[9] US Fish & Wildlife. "Salinas River: National Wildlife Refuge," Brochure, May 2008, accessed April 17, 2016. https://www.fws.gov/uploadedFiles/generalbrochure.pdf
[10] Ibid.
[11] Seavey, K. "A Short History of Salinas, California." Monterey County Historical Society, accessed April 17, 2016. http://www.mchsmuseum.com/salinasbrief.html
[12] Ibid.
[13] Ibid.

years later.[14] The city and its surrounding farms have expanded rapidly into the 20th and 21st centuries—as a result, the valley now produces 80% of lettuce and artichoke supply in the nation.[15] Although the population of Salinas has grown from 4,700 to over 155,000 since the 1860s[16], the city's dated infrastructure still reflects industry needs, making it unsuitable for community enjoyment and sustainable living. Extensive roadwork and wide lanes were once appropriate for transporting bulk produce through the city. However, these roads are now surrounded by housing developments. Public transportation inefficiently accommodates the urban sprawl, and residents have grown accustomed to traveling primarily by car. In March 2015, the City of Salinas planned to address these issues by adopting a Downtown Vibrancy Plan that prioritizes pedestrian, bicycle, and public transportation. The plan includes sustainable parking and infrastructure upgrades and aims to create an engaging cultural environment for the community.[17]

Current Situation

The Downtown Vibrancy Plan recommended a road diet which would reduce the number of road lanes on sections of Alisal Street closest to downtown.[18] On a broader scale, the Transportation Agency for Monterey County (TAMC) worked on a separate plan called the Marina-Salinas Multimodal Corridor Project to promote public transportation and bicycle use between Salinas and Marina; and they recommended extending the road diet to include part of West Alisal Street (**Figure 23**).[19] The surrounding neighborhood is primarily suburban, but Hartnell Community College sits along a significant portion of the road. West Alisal street is currently a four-lane undivided road with street parking on each side and no bike lanes. In this case, the road diet would convert the four lanes into a three-

Fig. 23. W. Alisal corridor section. *Final Report: Marina-Salinas Multimodal Corridor Conceptual Plan.* TAMC, June 2015, accessed April 22, 2016. http://www.tamcmonterey.org/wp-content/uploads/2015/09/TAMC_MMC-Final-Report.pdf

14 "History of Salinas," City of Salinas. Accessed April 22, 2016. http://www.ci.salinas.ca.us/visitors/history.cfm
15 Ibid.
16 Seavey, "A Short History of Salinas, California."
17 "Salinas Downtown Vibrancy Plan" City of Salinas, CA. Accessed April 22, 2016. http://www.ci.salinas.ca.us/services/downtownvibrancy.cfm
18 Ibid.
19 Mitchell, J. Multimodal project to put Salinas on 'road diet.' *The Californian*, May 30, 2015. Accessed April 08, 2016. http://www.thecalifornian.com/story/news/local/2015/05/29/multimodal-project-put-salinas-road-diet/28180361/

lane road with a center turn lane, as shown in **Figure 24**. The proposed road diet could significantly impact commuters that use West Alisal to get to Marina and other cities on the Monterey Coast. For the Sustainable City Year Program, the Systems class aimed to model the West Alisal traffic system in STELLA and run simulations to assess the potential impacts of the road diet.

Students considered how the road diet could affect stakeholders. Each group focused on different sets of stakeholders depending on their topic of interest. Overall, the class discussed implications for local residents, commuters, students, bicyclists, Monterey-Salinas Transit (MST) personnel, and MST passengers. Local residents might worry about traffic getting worse with fewer lanes, having to adjust to the changes, and roadwork disturbances. On the other hand, residents might welcome the safety features: the speed limit may decrease on their street, and they could get to their driveways from a center turn lane instead of waiting to cross oncoming traffic from a travel lane. Most groups figured commuters would be upset if less lanes meant more traffic and longer travel times. Many groups noted the benefits for bicyclists because slower traffic and room for bike lanes would increase biking safety. Group 6 thought some Hartnell students would favor slower traffic from the road diet if they have to cross the street to get to campus. Having one travel lane could be stressful for students who parallel park, but through traffic could use the center turn lane to drive around the person parking. Groups 2, 5, and 7 noted that the road diet could complicate bus routes and scheduling for MST—bus drivers might not mind because it's their job, but it could disrupt travel routines for some passengers.

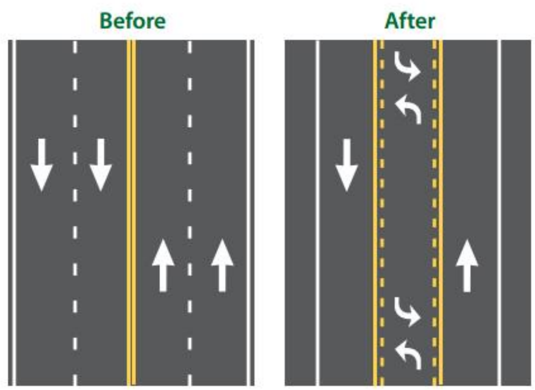

Fig. 24. Basic road diet design. *Road Diet Informational Guide*. FHWA Safety Program, November 2014, accessed April 22, 2016.

Research Interests

Groups were generally interested in modeling how the road diet would affect bike ridership, pedestrian safety, and the MST bus system. Group 4 wondered whether there were enough bicyclists in the area to make a strong argument for implementing the road diet. Group 1 was interested in how the road diet could improve environmental conditions and increase pedestrian safety. They observed damaged sidewalks along West Alisal which could be hazardous—bicyclists might use the sidewalk since there are no bike lanes which then puts pedestrians at risk of colliding with bicyclists. Groups 5 and 7 considered how the road diet could impact bus systems. Group 5 focused on changes in travel times for bus routes, while Group 7 focused on having a designated bus lane during peak traffic hours. Groups 2, 3, and 6 were interested in modeling a wider range of impacts, and how the reduction of car lanes and addition of bike lanes and bulb-outs might affect the efficiency of all modes of transportation.

Graphs and Data Collection

While most groups focused more on the CSUMB transportation project, some groups collected car, bike, and bus data for the road diet project. Several groups took bike, bus passenger, pedestrian, and car counts along W. Alisal Street. These groups collected data over a short period of time which was a limiting factor in their project results. One group analyzed data from the MST bus surveys that systems students completed each week during the semester.

- Group 4 counted bicycles that passed by or were on bus racks in half-hour increments from the southeast corner of Hartnell College near Homestead Avenue. They counted an average of 1.8 bicyclists per half hour (**Table 1**).
- Group 6 counted the number cars backed up on the W. Alisal stoplight at the Homestead intersection for one hour between 10am and 11am. They observed 1 car waiting at the stoplight most frequently, and there was an average of 3 cars backed up at the stoplight for that hour (**Figure 25**).
- Group 6 also recorded the amount of time it took for pedestrians to cross W. Alisal Street at the Homestead Avenue intersection. They found that people took an average of 13.8 seconds to cross W. Alisal Street (**Figure 26**).
- Group 5 compared the average number of minutes Bus 20 (Salinas-Monterey) and Bus 25 (CSUMB-Salinas) were early and late based on the weekly bus surveys from the class. They found that Bus 20 consistently late by 1 to 2 minutes, and that buses were more often late than early (**Figure 27**).
- Group 7 counted buses, pedestrians, bicyclists, and cars during peak hours at the W. Alisal and Homestead intersection. They observed twice as many cars on W. Alisal during a weekday compared to a weekend at peak hours (**Table 2**).

Date	**Time**	**Person**	**Bicyclist Riding Through**	**Bicyclist Entering Hartnell**	**Bikes on Rack**	**Bikes on Rack upon Leaving**
11/30	2:00 PM	Emma	0	0	0	0
12/01	10:00 AM	Kyle	3	0	1	0
	4:00 PM	Jesse	3	0	2	2
12/02	10:00 AM	Jesse	2	0	1	1
	4:00 PM	Jesse	1	1	0	0
12/03	8:00 AM	Kyle	4	1	1	1
	10:00 AM	Kyle	2	0	1	1
	12:00 PM	Jenny	2	1	1	1
	4:00 PM	Jesse	1	0	3	1
avg			**1.8**	**0.3**	**1.11**	**0.78**

Table 1. Group 4 data: Bike observations on West Alisal Street.

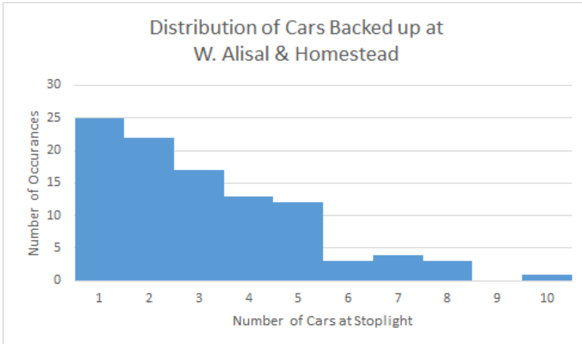

Fig. 25. Group 6 data: Observation of cars backed up on W. Alisal at the Alisal and Homestead stoplight.

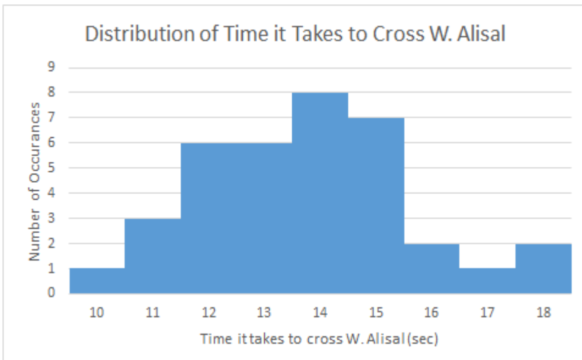

Fig. 26. Group 6 data: Amount of time it takes for pedestrians to cross W. Alisal Street.

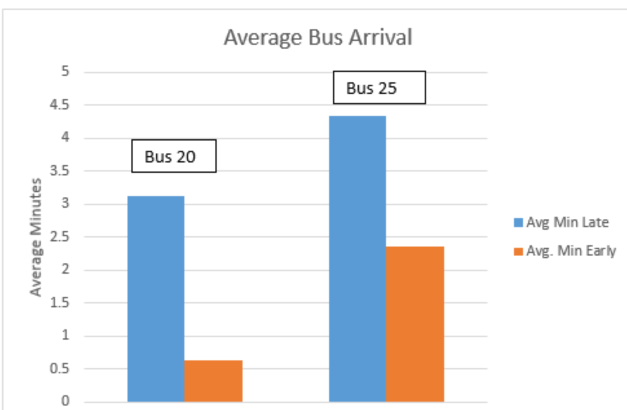

Fig. 27. Group 5 data: Average number of minutes late and early for buses 20 and 25.

date	bus towards downtown salinas	bus towards blanco rd.	# of pedestrians	# of bikers	# cars	traffic light efficiency
11/20	MST rides 5:17 line 25 at 5:21pm line 20 at 5:24pm	line 20 at 5:00pm line 23 at 5:13 pm line 25 at 5:32pm	4 pedestrians between 5:25-5:30pm	1 biker 5:22pm	200 cars b/t 5:20-5:30pm	every 30 secs
11/21	MST rides 4:58pm line 20 5:09pm	line 20 at 4:43 pm	7 pedestrians b/t 4:50-5:10	1 biker at 5:22pm	93 cars b/t 4:45-4:55pm	every 30 secs

Table 2. Group 7 data: Bus occurrences; and pedestrian, bicyclist, and car counts on W. Alisal Street.

Causal Loop Diagrams

Similarities. There were many common elements among the causal loop diagrams between groups that focused on a certain aspect of the road diet project. All groups included a car traffic element, which was sometimes written as the number of drivers, the number of cars, or the traffic during peak hours.

- Groups 4 and 5 included an *appeal* or *attractiveness of driving* element that was positively correlated to the amount of traffic in the system, so that traffic increases as driving becomes more attractive.
- Groups 1, 5 and 6 included a *speed of traffic* element. As traffic moves more slowly, pedestrian safety would increase because drivers would have more time to react to danger, but riding the bus would be less attractive because travel would take longer.
- Groups 3, 4, 6 and 7 included a *bike lanes* element. If bike lanes were added to W. Alisal Street, it could make the environment safer for bicyclists, which would help make bicycling a more attractive mode of transportation and increase bike ridership in the area.
- Groups 1, 4, 6 and 7 included a *safety* element that related to bicyclists and/or pedestrians. These groups assumed that as bicyclists and pedestrians feel safer while traveling, biking and walking would be more attractive as a mode of transportation, so more people would start biking or walking.

Differences. Groups focused on different aspects of the road diet and included particular elements that related to cars, bikes, pedestrians, and buses in their causal loop diagrams.

- Group 4 included an *appeal to bike riding* element which influenced bike ridership. They assumed bicycling would be more appealing with additional bike lanes and safety features, and less appealing with more cars on the road.
- Group 6 included the *amount of time to cross the street* and *bulb outs* as elements of pedestrian safety. They assumed safety would decrease as pedestrians take more time to cross the street. Bulb outs would make the street safer by extending the corner of the sidewalk and shortening the crosswalk (**Figure 28**).
- Group 1 mentioned other factors of pedestrian safety in their diagram, such as *better lighting*, *crosswalk conditions*, and *sidewalk conditions*.
- Group 7 included a *bus only lane* element in their road diet system that would increase bus ridership, but negatively impact car traffic.

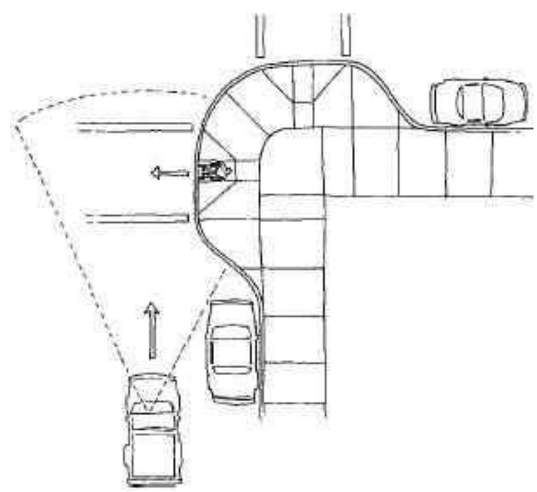

Fig. 28. Full curb extension bulb out. *Designing Sidewalks and Trails for Access.* FHWA Bicycle and Pedestrian Program, February 2014, accessed May 28, 2016. http://www.fhwa.dot.gov/environment/bicycle_pedestrian/

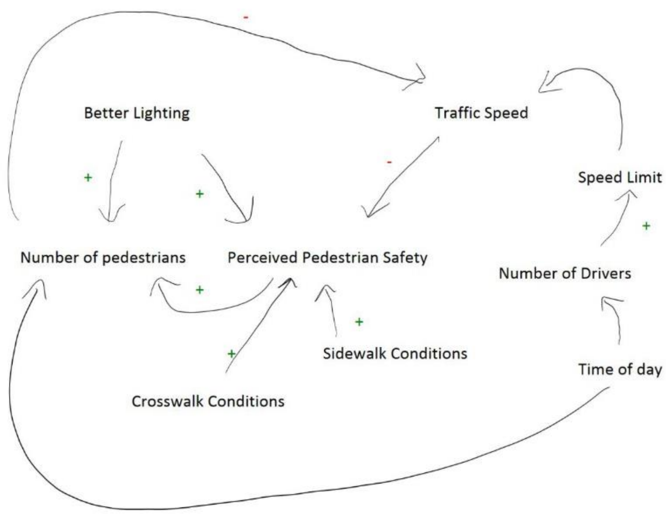

Fig. 29. Group 1's diagram on pedestrian safety.

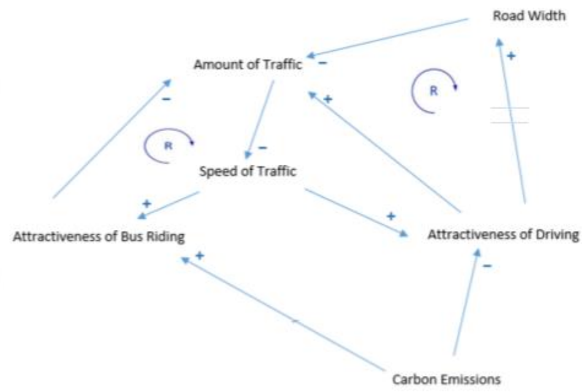

Fig. 30. Group 5's diagram on bus ridership.

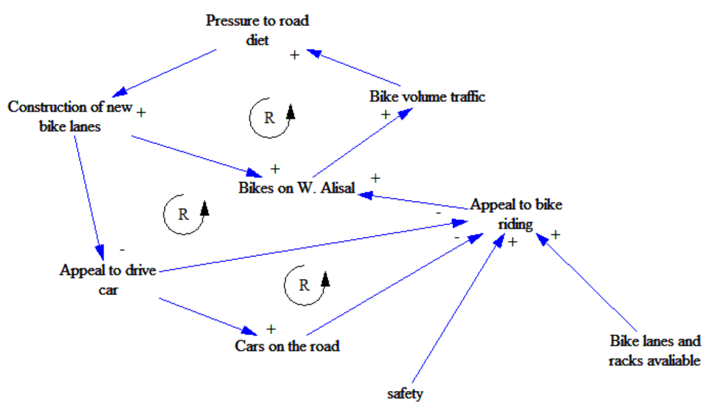

Fig. 31. Group 4's diagram on bicycle ridership.

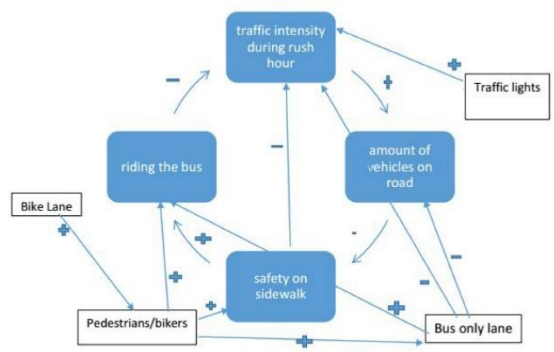

Fig. 32. Group 7's diagram with a designated bus only lane.

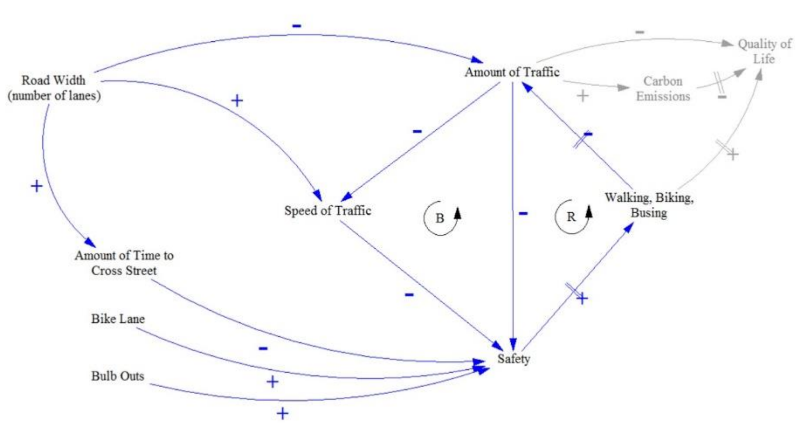

Fig. 33. Group 6's diagram on pedestrian safety.

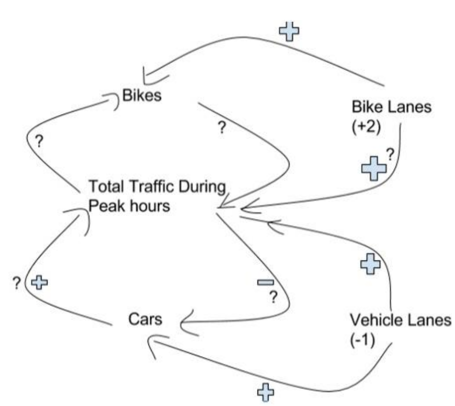

Fig. 34. Group 3's diagram on peak traffic

Stock and Flow Models

Some groups created stock and flow models of an aspect of the road diet based on their causal loop diagrams and collected data. Groups 5 and 7 modeled systems relating to public transportation. Group 5 focused on the attractiveness of riding the bus, while Group 7 simulated a temporary bus lane scenario. Groups 3 and 7 had models that focused on vehicle traffic during peak hours. Group 4 modeled the road diet's effect on bike ridership, and Groups 1 and 6 modeled its effect on pedestrian safety.

West Alisal Bike Ridership Model. Group 4 created a simple model (**Figure 35**) that described how the amount of bike ridership and bike safety changes in relation to the road diet, the number of cars on the road, and the desire to travel by car.

- *Bike safety* was inversely related to the number of cars on the road, so bicyclists were safer as the amount of cars on the road decreased. It was quantified on a scale from 1 to 10, with 1 being the least safe and 10 being the safest.
- *Bike Ridership* had an initial value of 5 bicyclists based on the data that Group 4 collected. They assumed bike ridership would increase as bike safety increased.
- *Desire to drive* influenced the number of cars on the road depending on the amount of bike safety. Group 4 assumed more people would drive instead of riding a bicycle if bike safety fell below a certain point, and less people would drive if bike safety was above that point.
- *Road Diet* also influenced the number of cars on the road depending on the amount of bike safety. If bike safety fell below a certain point, the road diet would occur and decrease the amount of cars on the road.

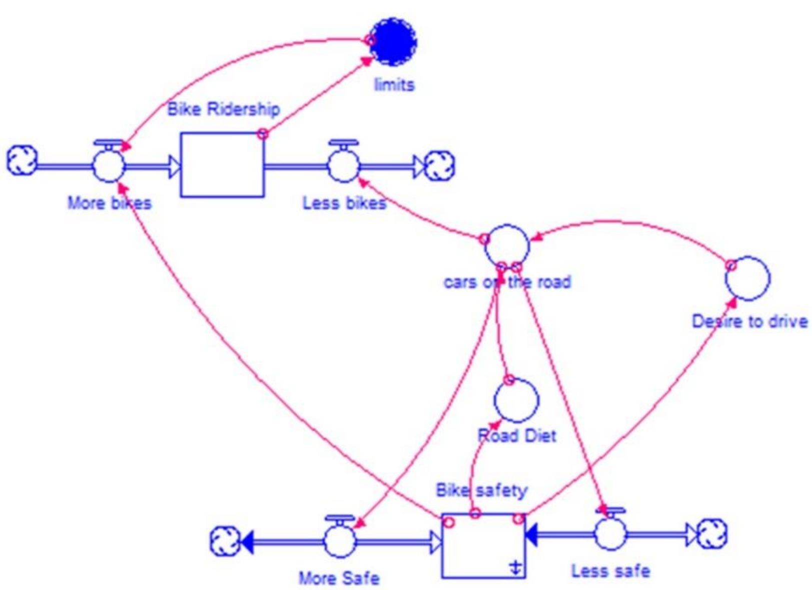

Fig. 35. Group 4's model of bike ridership on W. Alisal with a road diet.

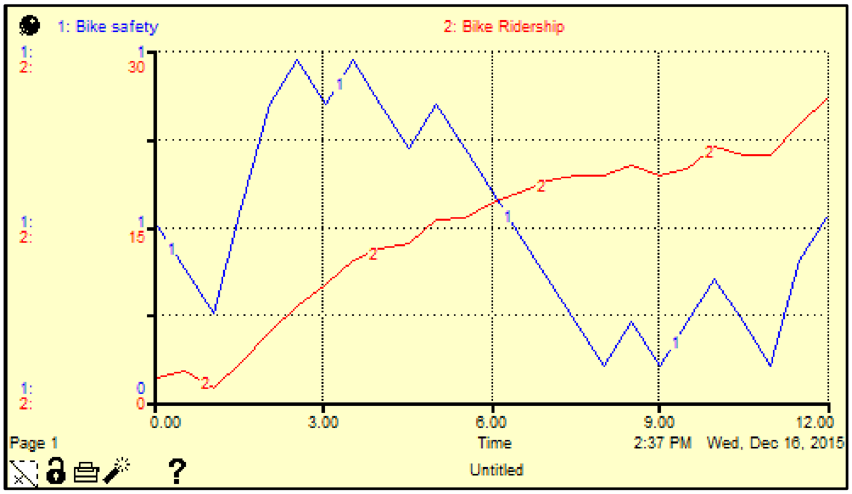

Fig. 36. Simulation results from Group 4's model.

The results of Group 4's model are shown above in **Figure 36**. Although bike safety has fluctuations, Group 4 assumed bike safety would be higher in the first half of the graph in response to the road diet, and then lower in the second half of the graph as Salinas expands and develops more roads to accommodate traffic. Bike ridership increases steadily to just under 30 bicyclists at the end of Group 4's simulation.

Traffic, Safety, and Alternative Transportation Model. Group 6 relied heavily on their causal loop diagram to construct a stock and flow model (shown in **Figure 37**) that showed how the road diet would affect traffic, safety, and use of alternative transportation. Their model was highly limited by arbitrarily assigned values.

- *Speed of traffic* had an initial value of 29.7 mph, but Group 6 found that a simpler calculation would have made the average speed of traffic 30 mph. This value was based on a 25 mph speed limit and a study that claimed two-thirds of drivers travel over the speed limit, and one-third of drivers travel 10 mph faster than other drivers.[20]
- *Fast driving (Inflow):*
  "IF Decrease_in_traffic>0 THEN .66*.01*speed_of_traffic ELSE 0"
  This function means that if there is a decrease in traffic, then two-thirds of drivers will drive 1% faster than the speed of traffic; the 1% was an arbitrary number.
- *Perceived safety* had an initial value of 53 out of 100 points, based on a walkability rating for Salinas, California.[21]
- *Safety risks (Outflow):*
  "SUM((IF Speed_of_traffic>27.5 THEN .005*Perceived_safety ELSE 0)+
  (IF Increase_in_traffic>0 THEN 5 ELSE 0))"

[20] Mannering, F. "Empirical analysis of driver perceptions of the relationship between speed limits and safety." *Transportation Research Part F* (2009): 99-106.
[21] "Cities in California," Walk Score. Accessed July 05, 2016 https://www.walkscore.com/CA/

This function means that as long as the speed of traffic was faster than 27.5 mph, then perceived safety would decrease by 0.5%; and if traffic was increasing, then perceived safety would decrease by 5 points. These numbers were also arbitrary.

- *Average number of people walking, biking, busing* had an initial value of 151 people based on Group 6's collected data.
- *Average number of cars backed up at stoplight* had an initial value of 3.12 cars based on Group 6's collected data.

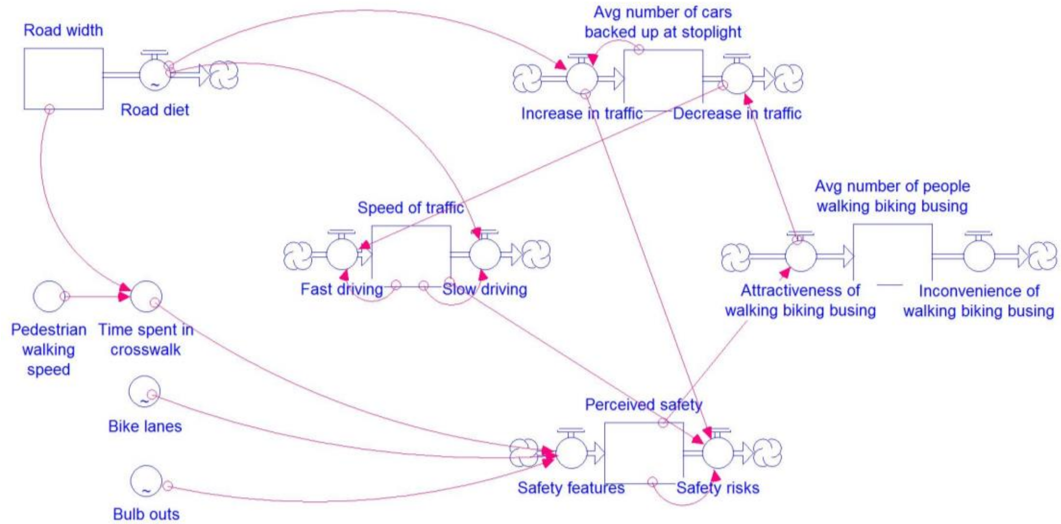

Fig. 37. Group 6's model on traffic, safety, and alternative modes of transportation.

Stock	Initial	Final
Road Width	62 ft.	52 ft.
Avg. Speed of Traffic	29.7 mph	26.3 mph
Perceived Safety	53.0 pts	70.4 pts
Avg. Number of People Walking, Biking, Busing	151 people	154 people
Avg. Number of Cars Backed Up at Stoplight	3.1 cars	5.3 cars

Table 3. Group 6's simulation results.

Group 6 ran their model to simulate a five-year period after the road diet. A decrease with the removal of a 10 foot late was reasonable since traffic lanes vary between nine and twelve feet.[22] Driving speeds may decrease between three and zero miles per hour for every foot of lane reduction[23], so a reduced traffic speed of 26.3 mph was plausible. The increase in perceived safety was highly limited because walkability does not necessarily represent safety, and variables

[22] Parsons Transportation Group. "Relationship Between Lane Width and Speed Review of Relevant Literature." 2009.
[23] Ibid.

such as environmental quality, crime, and rates of traffic accidents were not included in the model. The increase in the number of people walking, biking, and busing was smaller than expected due to conservative estimates of how people would respond to the road diet. Lastly, Group 6 made the error of assuming the number of cars backed up at the stoplight would double if a lane was removed because their units were in the number of cars backed up per stop and not per lane.

Conclusions

As with the CSUMB project, students noted that their models were greatly limited by small samples of data and estimated values. However, many groups gained useful knowledge about road diet through research and reviews of case studies. Even though Group 7 had some trouble with their temporary bus lane model, they spoke with MST bus drivers and found that traffic was not congested enough to warrant a temporary bus lane with the road diet. Group 1 recommended having buffer zones and bike lanes placed between street parking and the curb, similar to what was implemented at Golden Gate Park in San Francisco, California (shown in **Figure 38**). Group 4 found a case study on Santa Monica, California, where a road diet helped reduce vehicle collisions by 65%.[24] In another case study, Group 5 contacted the traffic safety office at Grand Rapids, Michigan and learned that travel times increased by 30 to 55 seconds, and the average speed of traffic decreased after a road diet. It is possible a road diet could also increase travel time on W. Alisal Street, but an extra minute of driving may be worthwhile if it means less traffic accidents and safer driving at slower speeds.

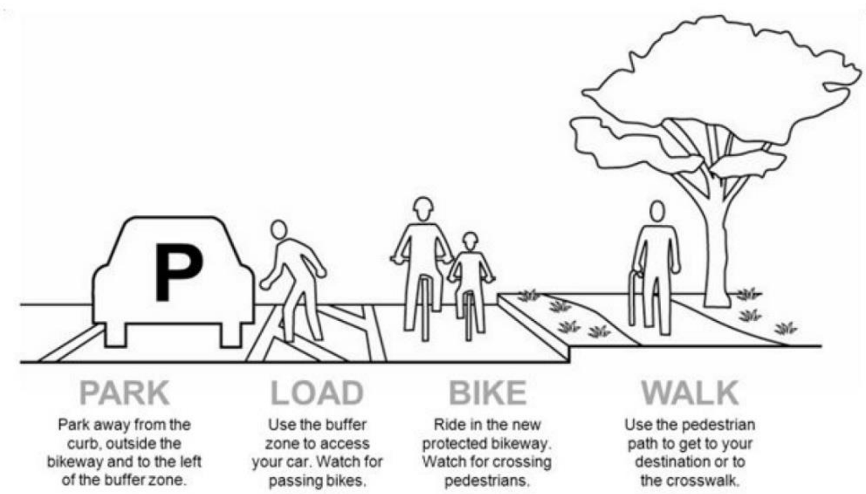

Fig. 38. Protected bike lane design. *John F. Kennedy Drive Separated Bikeways.* San Francisco Municipal Transportation Agency, accessed July 05, 2016. https://www.sfmta.com/projects-planning/projects/john-f-kennedy-drive-separated-bikeways

[24] U.S. Federal Highway Administration. "Road Diet Case Studies," last modified March 23, 2016, accessed July 05, 2016. http://safety.fhwa.dot.gov/road_diets/case_studies/