The ITS Berkeley Online Magazine ***Winter 2005: Volume 1, Number 2***

FEATURES:

X Marks the Spot

Many Disciplines Team Together for Intersection Safety

In an effort using researchers from PATH and the Traffic Safety Center, encompassing human factors, wireless communications, epidemiology, and optometry—among other research disciplines—intelligent solutions are being brought to bear on traffic safety problems. More...

ALSO:

- ### MVP Air

  A Niche Airline for Student Athletes Starts to Take Shape as a Result of NEXTOR Research. More...

- ### The Beer Game and the Bullwhip

  Astonishing Results When Carlos Daganzo Applies Traffic Flow Theory to Supply Chains. More...

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Welcome to the second issue of NewsBITS, the magazine of the ***Berkeley Institute of Transportation Studies****. It is published four times a year by the BITS Publications Office. Your comments are welcome. Address them to the editors listed below.*

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Fall 2005, Vol. 1, No. 1
The Women of ITS

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Many Disciplines Team Together for Intersection Safety

The sedan pulls up to a red light in Richmond, CA, near the offices and experimental facilities of the UC Berkeley Institute of Transportation Studies' **Partners for Advanced Transit and Highways** (PATH) program, and the driver waits for a green light in order to make a left turn. Because there is no arrow, the maneuver will be solely up to the driver.

This is among the most dangerous situations on the road: roughly 25 percent of all crashes happen at intersections and another 20 percent are **"intersection-related."** Crashes are twice as likely to occur at intersections where there is a signal compared to those with no controls (no signs nor signals) at all.

The statistics argue strongly for some kind of system beyond traditional signal lights and arrows that will support the driver's decision when to execute the maneuver, which is the basis for the **Intersection Decision Support** (IDS) project, launched in 2002 by the Federal Highway Administration and Caltrans. Researchers affiliated with **ITS Berkeley**, **PATH**, and the **Traffic Safety Center** (TSC) have been working over the last five years to make situations like these safer by developing intelligent warning and detection systems that could aid drivers in these circumstances.

The undertaking has brought together engineers, psychologists, epidemiologists, computer scientists, modelers, systems designers, and communications experts, among others, to provide the technical underpinning for future intersection safety improvements.

Already, at the Richmond Field Station, not far from the real-world intersection where the sedan's driver waited to turn left, researchers have built an instrumented intersection and automated alert system prototype for the next phase of development, part of a broader federal effort to develop networks of communications between vehicles and transportation infrastructure. These efforts are expected to carry on through 2011 and possibly beyond.

Intersection Crashes Have Their Own Taxonomy

While the hazardousness of intersections makes intuitive sense, given the increased likelihood of conflicts between vehicles wherever they have the potential to cross paths, much remains to be understood about the finer details

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of these crashes. Traffic Safety Center researchers undertook a closer examination of the phenomenon and created a more detailed taxonomy of these crashes, building on earlier work. That enabled them to match up details like type of intersection, type of crash, nature of the signals or signage, posted speed limit, and age and gender of the driver. They then analyzed the data to guide suggestions for potential countermeasures using intelligent technologies.

The high crash rates at traditional red-yellow-green (three-phase) signal intersections suggested that an alternative would be a system that "could provide information to drivers when risk is high, but it would allow optimum traffic flow at all other times," according to TSC Director David Ragland and an author on a number of studies related to this complex problem.

Sensors monitoring oncoming and lateral traffic could activate a warning for the driver of the left-turning vehicle if they determined that a left turn was not safe to execute at that time. The problem is complex.

In the left-turn maneuver, a number of outcomes are possible:

- the sedan could start on a left turn path and encounter a pedestrian in the crosswalk, which could lead it to hit the person on foot,
- the sedan could be forced to slow down or stop, which could lead to a crash with oncoming traffic,
- the crosswalk could be clear, but the sedan's driver could misjudge the amount of time and space available in the face of oncoming traffic and start out on the left turn path and crash into approaching traffic,
- the turning driver could delay the maneuver until after the light had turned red and crash into traffic approaching laterally.

The consequences of intersection crashes tend to be more severe since 75 percent of them involve vehicles that are crossing paths, not sideswiping or rear-ending each other. Ragland stated that they killed 9,000 people a year and injured 1.5 million.

Learning How a Driver Thinks

To begin to understand the type of warning device that would work well, researchers needed to understand how drivers behave at such intersections.

- How far ahead does the driver of the sedan look to see if there is a potential conflict?
- What are the visual cues that the driver of the sedan uses to determine how fast approaching traffic is moving toward the car?
- Are there elements such as roadway lighting, or shape or size of any approaching vehicles that might make it harder for the driver to anticipate conflicts?
- If a driver does judge the speed of the approaching traffic correctly, how does the driver determine the amount of time needed to clear the intersection safely?
- How is this "gap acceptance" affected by drivers' personal attributes such as age, experience, perceptiveness, and so on?
- How can a system incorporate these elements into some kind of warning or perhaps guidance device?

Keeping an Eye on the Eyes on the Road: 350 Left Turns

To discover more about cues to driver behavior, PATH researchers devised instruments that were mounted inside a car to observe test subjects as they executed left turns at intersections like the one in Richmond.

Researchers Delphine Cody and Christopher Nowakowski did much of the work on these "**human factors**" observations and analysis, which combine psychology with engineering. Cameras recorded actions as minute as the changes in focus from one moment to the next in the driver's eyes. In one study, nine drivers made more than 350 left turns in the instrumented car that were recorded for later analysis. This data was used to quantify factors involved how a driver approaches an intersection and to develop a timeline of a crossing. The car's operating systems were monitored at the same time, so connections between braking, signaling, acceleration, and the like could be determined. A driver's pattern of acceleration proved to be a significant factor in indicating whether a driver intended to make a turn or wait.

Optometry researchers Theodore Cohn and Daniel Greenhouse expanded on their work on **visual perception**. They incorporated previous findings that have determined that perception is affected by the type of light, and that certain light signals travel more rapidly to the brain, enabling more time to avoid conflicts.

They have also studied the complex associations and calculations human observers make when trying to make sense of the range and velocity of **approaching objects**. For example, a landmark effort showed that lights that are illuminated in a sequence literally are seen more rapidly because they travel a shorter path to the brain and are processed more rapidly. Optometry research also contributed to the design of the LED pattern for the alert sign that was ultimately tested at the Richmond Field Station testbed.

Use Only When Needed

Of course, a warning system must not only be understandable and usable by the driver, it must also be accurate and timely. A major concern is fear that false positives will cause drivers to eventually disregard signs, or false negatives will cause drivers to proceed in error and risk a crash. That is where the **sensors** come in. A key distinctive element of IDS is the fact that, unlike traditional traffic signals, these alerts are only activated when they are needed, in order to permit unimpeded traffic flow in low-traffic and low-danger settings.

PATH engineers began by examining the usefulness of commercially available devices, in the hope that something ready-made could be deployed more quickly. They began by evaluating sensors at the Richmond Field Station, creating a testbed which was overseen by PATH engineers Ashkan Sharafsaleh and David Marco They created the prototype IDS intersection using infrared, inductive loop, radar, millimeter wave radar and other detection devices capable of determining the presence and speed of vehicles. PATH software team leader Sue Dickey enabled the **intersection processor** to work with these devices, and several PATH researchers—Xiao-Yun Lu, Ashkan Sharafsaleh, and Christopher Nowakowski—conducted research. The studies ascertained the timing necessary to warn driver and showed that current sensors were not adequate for such a safety-critical use.

All of this complexity needs to be reproducible in mathematical terms, in the form of a model, to allow detailed theoretical testing, study and validation of various systems. PATH researchers Steven Shladover, TSC director Ragland, PATH Researcher Xiqin Wang, and PATH engineer Joel VanderWerf teamed to design algorithms for various aspects of the models, and Joel VanderWerf built the computer model.

Determining alert criteria was done in part by Shladover, who found that providing vehicle location and speed far from the intersection were two of the more important alerts drivers would need.

What the Future Holds

This year, as the IDS project's first phase concludes at PATH, several parallel efforts are continuing on into 2011 and possibly beyond. One component of the US DOT's **Cooperative Intersection Collision Avoidance System** (CICAS) project begins in early 2006, and it is a five-year program to develop a left turn-assist sign at intersections that will tell drivers when it is unsafe to make a left turn across oncoming traffic. The project will involve a pilot test of a more evolved version of the prototype intersection at the Richmond Field Station testbed.

Because it uses communication between infrastructure and vehicles, the collision avoidance project will have a place in the **Vehicle Infrastructure Integration** (VII) California project, funded through the Caltrans and the US DOT, for which PATH has recently completed the first year of a three-year, $1.7 million contract. One of the key technologies is direct short range communications (DSRC) systems linking vehicles and infrastructure, and by extension an entire region's traffic on a virtual grid of congestion, speeds, and other information to boost capacity and safety.

Engineering faculty member Raja Sengupta, who is also a researcher at the UC Berkeley Center for Future Urban Transport, A Volvo Center of Excellence, has worked extensively on DSRC architecture and functionality. One element of this network system is the "state map," which would contain all the pertinent details about an intersection's state and be available to cars and other intersections.

"What makes this a little bit of an art is you have to bring on other disciplines to measure and understand really what the interaction is, and it's a lot different than what you would think," explained Jim Misener, PATH Transportation Safety Research Program Lead and head of PATH's CICAS and VII California efforts. "We have a basic understanding of how everything works as drivers go through intersections; a really nice model. We've involved a lot of investigators from various walks to include people from the Traffic Safety Center, some computer vision people, people who understand pedestrians, to people who understand kinematics to understand how a human interacts with cars," Misener says. "The fact is, this is soup to nuts."

Some Helpful Links for Further IDS Inquiries:
(more recent nearer the top)

Intersection Decision Support Project Seeks to Prevent Broadside Crashes, by James A. Misener, PATH Traffic Safety Program Leader, an overview of the project. (128 K PDF).

California Intersection Decision Support: A Systems Approach to Achieve Nationally Interoperable Solutions, PATH Research Report by Ching-Yao Chan. (UCB-ITS-PRR-2005-11). (6.1 MB PDF).

Experimental Evaluation of Commercial Off-the-Shelf Sensors, by Ashkan Sharafsaleh and Ching-Yao Chan. Presented at the 2005 ITS World Congress in San Francisco. (1 MB PDF).

Effects of Traffic Density on Communication Requirements for Cooperative Intersection Collision Avoidance Systems (CICAS), by Steven Shladover, PATH. Presented at the 2005 ITS World Congress in San Francisco. (228 K PDF)

Cooperative Collision Warning: Enabling Crash Avoidance with Wireless Technology, by James A. Misener, Raja Sengupta, PATH, and Hariharan Krishnan General Motors Research and Development. Presented at the 2005 ITS World Congress in San Francisco. (600 K PDF).

Intersection Decision Support Project: Taxonomy of Crossing-Path Crashes at Intersections Using GES 2000 Data, by David Ragland and A. Zabyshny, U.C. Berkeley Traffic Safety Center. (link to eScholarship repository).

Impact of Pedestrian Presence on Movement of Left-Turning Vehicles: Method, Preliminary Results & Possible Use in Intersection Decision Support, by Ipsita Banerjee, Steven Shladover, James Misener, Ching-Yao Chan, and David Ragland, U.C. Berkeley Traffic Safety Center (link to eScholarship repository).

False Alarms and Human-Machine Warning Systems, by David Ragland and A. Zabyshny, U.C. Berkeley Traffic Safety Center. (link to eScholarship repository).

A timeline of progress on IDS, VII, and CICAS projects newsletters from PATH: http://www.path.berkeley.edu/PATH/Intellimotion/

"**IDS demonstrated successfully in Washington DC's FHWA Turner-Fairbank Research Center**", story from PATH Web site.

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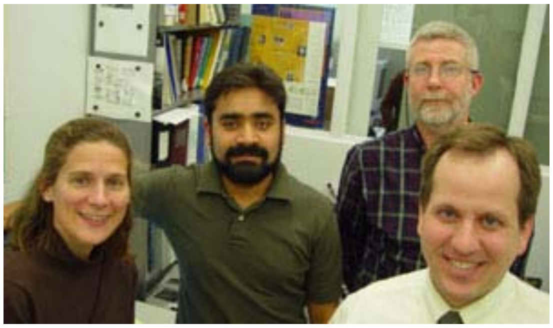

MVP Air

NEXTOR Researchers Help in Creating a Niche Airline for Student Athletes

(NEXTOR's Anne Goodchild, Gautam Gupta, Mark Hansen and Scott Simcox.)

For years as he hurried through airline terminals across the country, pilot Jack Hareland couldn't help noticing groups of college athletes—teams of basketball, soccer, volleyball, baseball players—waiting, sometimes for hours, for flights to games at other campuses or for flights home. Poor commercial airline connection schedules meant certain student athletes in the PAC 10—for instance those flying between Pullman, Washington , home of Washington State University, and University of Arizona in Tucson—might be gone for three days in order to play one game.

Hareland thought there must be a better way to get student athletes to and from games more efficiently and quickly so they could spend less time in terminals and more time in class. He realized that using smaller aircraft would eliminate the need to go through long security lines; a bus could drive the team right up to the airplane, which would save time. And if athletes could get to and from a game in one day it would eliminate hotel bills. But the logistics of providing enough flights to carry each school's 20 or so teams —from baseball and basketball to water polo and wrestling—to all their games confounded him.

A Happy Coincidence

Then last November, Hareland happened to sit next to **NEXTOR's Scott Simcox** on a commercial flight between Los Angeles and San Francisco. Simcox noticed Hareland's flight bag and realized the two shared an interest in aviation. "We struck up a conversation, and the next thing I knew, Scott suggested I talk to some people at ITS,"said Hareland.

Simcox spoke to **ITS Professor Mark Hansen** who thought the problem might be an interesting challenge for students in his air transportation (CE 260) class. **Gautam Gupta**, a PhD student in the class, developed more than a passing interest and kept working on it long after the course finished. He was joined by another PhD student, **Anne Goodchild**, who has an interest in aviation logistics. "The students were just great. They understood the idea and the problems it presented right away," Hareland recalls.

In fact, the problems were numerous and complex. The most easily solved was the choice of aircraft: Dornier 328 jets filled the bill for several reasons.

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They were comfortable, the price was right, they have an exemplary industry safety record, and they had room for 30 passengers: large enough to carry all PAC 10 teams except football, which requires significantly more seats. Yet the Dornier was small enough to be exempt from TSA security at airports, which meant a bus could pull up to the aircraft, unload the athletes and the plane could take off—a considerable time saver. (Aircraft carrying 30 passengers or less are exempt from certain security rules, although the airline will conduct security checks.)

The remaining problems were tougher to solve. In some cases, athletes flying between certain cities, such as Los Angeles and the Bay Area, could fly just as conveniently commercially. A small charter operation like the one Hareland envisioned would have a harder time competing on routes with numerous daily flights. And when USC plays UCLA, or Stanford plays Cal, teams travel by bus.

Team schedules were also an important part of the equation. Most games are played Thursday through Monday, and more heavily concentrated on the weekends. How many planes would be needed, and what would planes and pilots do during the middle of the week or the summer months when no games are scheduled?

"To make this a money-making enterprise, we needed to be efficient in how we scheduled the airplanes," explained Goodchild. "We don't want to fly lots of empty planes. So if you're just taking one team, say to Seattle, and then you wait to bring them back, that's like chartering an aircraft. But you have to charge more because there are no efficiencies in your scheduling."

"But," she continued, "if USC's men's basketball team is playing in Berkeley, and the Berkeley women are playing at USC—which is what happens with the basketball schedule—there are efficiencies already built in that allow you to shuttle the plane and have it full."

Another important variable was the amount of time students would need to wait between arriving at their destination and the start of the game, as well as the time spent waiting to leave after the game is over. After all, the big selling point Hareland wanted to make to college athletic departments was that his fledgling airline could save time for student athletes--time that could be better spent in class or studying. "Student athletes really want to be able to leave as soon as the game is over—especially if they lose," added Gupta.

> ***Most of the time savings will come from being able to deliver the team closer to the event and to bring the team home quickly after the game...***

"Most of the time savings will come from being able to deliver the team closer to the event than with commercial travel, and being able to bring the team home quickly after the game. So, we needed to make sure students didn't get there too far in advance, while recognizing one hour beforehand is not enough time to prepare." explained Goodchild. "In addition, scheduling flexibility allows us to serve more demand. If a team requires we deliver them exactly at six p.m., we can't serve as many teams as if they allow us to deliver them between three and six p.m. We needed to know how much that flexibility increased our efficiency."

Balancing Cost, Fleet Size and Demand

Goodchild and Gupta took the PAC 10 schedule off the Internet and put the information into a database. Then they formulated a problem that tried to minimize the cost of serving the demand with either commercial flights or the new airline.

“We knew we couldn’t serve all ten schools in the PAC 10, so we chose those that would derive the most benefit--which turned out to be what we called ‘schools in the middle of nowhere,’” explained Gupta. Those included the University of Oregon in Eugene, and Oregon State in Portland, Washington State in Pullman, and the University of Arizona in Tucson. Currently, teams flying from Washington State to University of Arizona typically have to make two connections, for example with flights from Pullman to Seattle, Seattle to Los Angeles, and Los Angeles to Tucson.

With flight information pulled from online travel sites, the team formulated and built a computer model to see how the proposed airline compared in terms of time and cost to commercial flights serving the same four universities. The researchers plotted the trade-off between fleet size and the percentage of the demand that could be served. “If we have three planes, how many of those games can we serve? If we have four planes, how many?” asked Goodchild.

What they found pleased Hareland. In this very small market, his niche airline could compete financially, and outperform the commercial airlines in terms of time saved—up to 500 hours per team—and still make a profit while exceeding current corporate or commercial aviation company safety standards.

In September, Goodchild and Gupta flew to Jackson Hole, Wyoming to explain how they’d arrived at their conclusions to potential investors. The meeting went well, and if all continues to go well, the new company—now called MVP Air—may be in business by spring.

There are still some kinks to be worked out. “We realized there’s really no room on these planes for the cheerleaders,” said Goodchild. “But usually the home team provides the entertainment.”

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The Beer Game and the Bullwhip

Astonishing Results When Carlos Daganzo Applies Traffic Flow Theory to Supply Chains

Ordinarily, serendipity and supply chains are not compatible; supply chains at their best are idealized expressions of order and predictability; serendipity is just the opposite. However, a moment of serendipity has led to a revolution in understanding how supply chains work. The serendipitous moment occurred when Carlos Daganzo, ITS Berkeley traffic flow theorist and professor of civil engineering, analyzed supply chain behavior using traffic flow theory and found a solution to the vexing phenomenon known as "the Bullwhip Effect," first described in the early 1960s. But because the breakthrough came from someone outside the specialized world of supply chains, it has created little more than a ripple.

The story starts with the Beer Game, a well-known simulation tool used to teach how supply chain theory works in the real world. A professor places orders for beer, and a chain of suppliers—the students in his class—place orders with one another to fill his requests, from the hops grower down to the bottling plant and wholesaler. Because the suppliers don't know when or how much the professor will order, they have to order enough supplies from each other to cover the highest demands, which "costs" them money for extra storage, extra employees and the like.

Having taught logistics and having written a textbook on it, Daganzo was familiar with the Beer Game, but had never run it in a class. One of Daganzo's former students, Al Erera (Berkeley Ph.D. 2000), had just started teaching a course in supply chains at Georgia Tech, where he is an assistant professor. Because his class was more applied, he was using the Beer Game to illustrate the Bullwhip Effect in a concrete manner.

"When the Bullwhip Effect arises," Daganzo explains, "the farther away a supplier is from the consumer, the more variable the orders that that supplier receives become. Even if I order very regularly, and the person on the supply chain next to me is very happy, the last person in the supply chain won't be happy because things will fluctuate for that person tremendously."

> ***The Bullwhip Effect is so prevalent, so costly to society, that some people think it could be a contributor to business cycles...***

The phenomenon was named the Bullwhip Effect because the wide fluctuations experienced by the supplier who is farthest away, e.g., the person supplying hops for the beer, are similar to the wide fluctuations at the end of a long whip. (To complete the analogy, the retail customer would be the equivalent of the handle.) "The thing is so prevalent, so costly to society, that some people think it could be a contributor to business cycles," Daganzo

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explains.

As Erera described the outcome of the Beer Game in his class, Daganzo realized that "the Bullwhip Effect happened even when the students were not given any directions or rules to follow. Al let them act according to their own devices. That sounded like traffic to me, because in traffic we can't tell drivers how to drive. They drive pretty much the way they want, within the parameters of what is safe."

Furthering the traffic analogy, the oscillations in the supply chain sounded to Daganzo like the oscillations that happen to traffic upstream of a bottleneck. The drivers upstream of a bottleneck typically experience much wider oscillations in traffic speeds, more stop-and-go driving, than those who are passing through.

"It sounded just like traffic entering and leaving a bottleneck. You have cars going down toward the bottleneck, and they're discharging out of the bottleneck at a pretty steady rate. But if you look at traffic data upstream of the bottleneck, you see it is more variable. The farther away from the bottleneck you are, the more variable it is." Daganzo saw the customer at the end of the supply chain as the bottleneck, dictating how many orders will have to pass through. "Upstream of the customer, among your suppliers, it's getting crazier and crazier, just like traffic. I wondered if people in supply chains understood things in the same way."

There is a large body of literature on the Bullwhip Effect, and Daganzo undertook to review it (enlisting the aid of a number of Ph.D. students). "The typical paper would say, 'Let's assume that the customer places these orders with these properties, seasonal, whatever,' and they would give some mathematical properties to the customer orders. Then they would assume that the suppliers replenish their inventories according to some rule, for example, when an inventory is down to a certain level. All the papers assumed that the Bullwhip Effect was a combination of something the customer did and something the suppliers did."

Using that assumption, any method for smoothing out the flow of goods and eliminating the Bullwhip Effect would have to be able to anticipate the customer's behavior all of the time, but that is not possible. Daganzo sought to develop methods that do not require knowing what the customer is going to do. Surprisingly, this line of reasoning had never been pursued, he found.

He used traffic flow theory to analyze the Bullwhip Effect and started by searching for conditions under which the Bullwhip Effect would always arise, no matter what the customer does. He found that when suppliers tended to keep higher inventories during periods of higher demand, the Bullwhip Effect resulted. "Always. No matter what the customer does. That is a powerful result. Now we know something that is very generic, a root cause, and we can attack it."

Removing Uncertainty and Spreading the Gains

The key he found to smoothing out the flow of goods and eliminating the Bullwhip Effect's oscillations is to introduce commitments into the process, "information from the future," as Daganzo describes them. "They are used all the time, by the way," he says. "Just-in-time inventory that automobile companies use is a type of commitment. The automaker knows what he is going to produce, and he tells the seller upstream to begin producing this now because he's going to need it next month. The only way they'll do that is if the car maker commits to taking that order."

And why aren't all supply chains run that way? Because of how the rewards and risks of the current system are distributed, Daganzo explains.

And why aren't all supply chains run that way? Because of how the rewards and risks of the current system are distributed, Daganzo explains. "The people who are suffering are the people way upstream. If you introduce commitments, who suffers? The customer. He has to commit. Who gets the benefits? The people higher up." To induce the customer to change, a mechanism needs to give each occupant on the chain some of the value gained by eliminating the Bullwhip Effect, "so that every supplier wins, and the customer wins, and society wins."

While the analysis is revolutionary, it is an orphan academically, Daganzo notes, possibly because he is a newcomer to the supply chain world, but also for other reasons. After getting his work published as an ITS Research Report (*A Theory of Supply Chains*, 2001), he went public with his theory, starting with four lectures at UC Berkeley in the fall of 2001. He also went on a tour of other universities in the U.S. and Europe. "When I talked to them, many of them could see the value," he recalls, noting that his audiences were more diverse and included people from other fields outside of supply chains.

One of his hosts, Paul Zipkin, a leading authority in inventory theory at Duke University, saw the value of it. But Daganzo suspects that general acceptance will be slow to come in large part because of a natural inertia and resistance to what is in essence a paradigm change in thinking about supply chains.

A monograph outlining his theory, *A Theory of Supply Chains*, was published in 2003 by Springer-Verlag, where Daganzo has also published his logistics textbook, *Logistics Systems Analysis* (link to preface 90K PDF). He also published a shorter version in *Operations Research*, the flagship of the field (Volume 52, No. 6, Nov.-Dec. 2004).

Daganzo figures it will take a generation of students to effect a broader impact, but he may be proven to be too pessimistic. The seeds for change have already been sown, with Daganzo having enlisted current or recently graduated Ph.D. students Alejandro Lago, Anne Goodchild, Jorge Laval, Juan Carlos Munoz, Yuwei Li and Yanfeng Ouyang in his work. (He thanks them in the preface to his supply chains book.) To date, two of them, Lago and Ouyang (both of who now hold faculty positions) are working on refinements of the theory.

Carlos Daganzo's ITS Berkeley Publications Related to Supply Chains:

A Theory of Supply Chains, UCB-ITS-RR-2001-07 (link to catalog results page).

On the Stability of Supply Chains, Daganzo, UCB-ITS-RR-2002-02 (684 K PDF).

Some Properties of Decentralized Supply Chains, Yanfeng Ouyang and Carlos Daganzo, UCB-ITS-RR-2005-3 (454 K PDF).