WELCOME TO THIS SEMINAR, ONE IN A SERIES OF SEMINARS WE'VE BEEN CONDUCTING THIS SEMESTER. MY NAME IS MAX DONATH, AND WE'LL HAVE A VERY INTERESTING PRESENTATION TODAY BY PROFESSOR JOHN HOURDOS. I WANT TO POINT OUT THAT THERE ARE AN AWFUL LOT OF PEOPLE OFF IN INTERNET LAND SO ALL QUESTIONS, YOU WILL HAVE TO USE A MICROPHONE, EVEN THOUGH THERE'S NO LOUDSPEAKER HERE IN THE ROOM SO THAT EVERYBODY OUT THERE CAN HEAR YOUR QUESTIONS, SO WE'LL DO THAT AFTER THE SEMINAR IS OVER RATHER THAN RUNNING AROUND IN THE MIDDLE. FOR THOSE OF YOU WHO ARE OFF-CAMPUS WATCHING THIS ON
ADAPTING ALGORITHM TO CHANGE THE SPEED LIMITS ON
SECTIONS ON THE ROADWAYS.
IT DOES THAT BY MONITORING THE SYSTEM FOR SIGNS OF
CONGESTION AND PREEMPTIVELY REDUCE THE UPSTREAM SPEEDS
TO LESSEN THE SHOCKS WITHIN THE TRAFFIC STREAM.
SO, TO MAKE THINGS SIMPLE, LET'S SAY THAT THIS IS THE
STRETCH OF THE FREEWAY, THESE DOTS REPRESENT THE LOOP
DETECTOR STATIONS THAT WE HAVE AND AT THE SECOND POINT
OF THE DAY, THE SECOND DOWNSTREAM LOACH DETECTOR IS
MEASURED IN VERY LOW SPEED AS COMPARED TO THE IMMEDIATE
ONE UPSTREAM.
THAT MEANS THAT SOMEWHERE IN HERE, THERE IS A
CONGESTION SPREADING BACKWARDS, CONGESTION IS BUILDING.
IT HAS PASSED THIS POINT BUT IT HASN'T PASSED THIS
POINT.
NOW, YOU UNDERSTAND THAT THE VEHICLES THAT ARE COMING
AT THIS POINT IN THIS SECTION, THEY WILL HAVE TO HAVE A
SHARP ACCELERATION BOTH IN THE SPEED OF 50 TO 60 MILES
AN HOUR TO AN AVERAGE SPEED OF 40.
NOW, WHAT THEY TRY TO DO IS DISPLAY MESSAGES ALONG THIS
AREA STARTING FROM THE POINT OF LOWEST SPEED AND SAY,
OKAY, WELL, RIGHT NOW YOU'RE FREE TO GO AT 65 MILES AN
HOUR BUT BECAUSE YOU'RE GOING TO ENCOUNTER THIS
CONGESTION, YOU SHOULD BETTER GO 55 AND THEN HALF A
MILE GO 45 AND THEN 35 IN ORDER TO MEET THIS BACKWARD
SHOCK WAVE AT A MUCH LOWER SPEED, AND THAT
THEORETICALLY AND PRACTICALLY REDUCES THE FRICTION AND
REDUCES THE AMOUNT OF CRASHES AND, IN SOME CASES, IT
CAN REDUCE THE RATE OF THE CONGESTION IS SPREADING
BACKWARDS.
NOW, THE FIRST IMPLEMENTATION OF THE SYSTEM -- AND
THAT'S WHERE THE PHOTO COMES IN WAS ON 35W NORTH AND
SOUTHBOUND SOUTH OF MINNEAPOLIS, AND THAT WAS
IMPLEMENTED IN 2010, AND AT THAT TIME, WE DID THE --
HAD THE PROJECT TO EVALUATE ITS OPERATION.
I GAVE A SEMINAR LIKE THIS ONE BUT WE WERE DEPENDING
ONLY ON MICROSCOPIC LOOP DETECTOR-BASEED INFORMATION OF
WHAT THE GENERAL OPERATION WAS.
NOW, WHEN THE I-94 SYSTEM WAS ACTIVATED IN SEPTEMBER,
2012, IT WAS ACTUALLY ACTIVATED, PART OF IT IS IN A
VERY SPECIAL LOCATION IN THE TWIN CITIES FREEWAY
SECTION, ONE OF THE HIGHEST CRASH LOCATIONS IN THE
STATE OF MINNESOTA.
IT'S EVERY DAY THERE'S SOMETHING GOING ON, SO ITS
APPLICATION HAS A LOT MORE INTEREST AND THAT'S WHY WE
SET UP SHOP THERE.
TO GIVE YOU A LITTLE IDEA OF WHERE THIS LOCATION IS,
THIS IS WAY ABOVE PICTURE OF DOWNTOWN MINNEAPOLIS.
YOU MAYBE SEE THE CONVENTION CENTER OVER THERE, AND
PARK AVENUE, SAYS PARK AVENUE, SO THIS IS BASICALLY A
SECTION FROM ABOUT RIVERSIDE ALL THE WAY TO THE LOWRY
HILL TUNNEL.
SPECIFICALLY, THE WEBSITE DIRECTION HAS TWO MAJOR
BOTTLENECKS.
ONE, AT THE INTERCHANGE WITH 35W BECAUSE SOMETIMES
CONGESTION IS SPREADING BACK FROM THE INTERCHANGE BUT
THE PRIMARY BOTTLENECK IS THIS ENTRANCE AROUND FROM
35W.
BASICALY YOU HAVE A FLEEWAY TO FREEWAY RAMP JOINING A
NORMAL ARTERIAL ROAD RAMP, AND BOTH OF THEM JOINING IN
AND SPILLING INTO 94 WESTBOUND.
THIS 35W RAMP IS VERY HIGHLY TRAVELED AND THIS Merging
BEHAVIOR THAT THE DRIVERS ARE SOMETIMES DANGEROUSLY
PERFORMING GENERATES SHOCK WAVES THAT STARTS GOING
BACKWARDS.
THIS ACTIVITY GOES BACKWARDS AND IT'S INTERESTING THAT
FOR THIS TRAJECTORY, VERY FEW CRASHES HAPPEN BUT AS
SOON AS THEY REACH THE POINT OF THE RAMP AT PORTLAND
AVENUE, THAT'S WHERE MOST OF THE CRASHES HAPPEN.
SO AS MAX SAID, IN 2002, WE DECIDED THAT THIS IS A VERY
INTERESTING LOCATION AND WE SET OUT TO COLLECT DATA.
WE PLACED OUR OWN SENSORS ON HIGH-RISE BUILDINGS.
SO IN TERMS OF THE FREQUENCY OF CRASHES, YOU CAN SEE
THIS IS THE CRASHES FOR ONE YEAR FROM SEPTEMBER 12 --
2012 -- NOT 2012, SORRY ABOUT THAT, BUT TO SEPTEMBER,
2013, THERE WERE 90 CRASHES TOTAL, WHICH BASICALLY SAYS
THAT YOU HAVE A CRASH EVERY THREE DAYS IF YOU EXCLUDE
WEEKENDS, AND YOU SEE THAT THESE BASICALLY CORRESPOND
EXACTLY WITH THE LOCATIONS ON THE PICTURES ABOVE.
SO YOU SEE THAT THIS IS DOWNSTREAM OF PORTLAND AVENUE
AND THIS IS THE AREA AROUND PORTLAND AND THEN THEY
DOUBLE UP IN TERMS OF NUMBERS AS HE YOU MOVE UPSTREAM.

SO THIS IS THE MOST IMPORTANT LOCATION.
The area of analysis that was done by us, we identified
that there are several causal factors for these crashes
but one of the major causal factors is the shock waves
that propagate back from the merge area.
so the new advisory variable speed limit system of
MnDOT is implemented in this very special location,
very difficult location.
The hope was to actually mitigate this problem and
reduce it, if not eliminate it but because it's a
special location, it was mutually agreed that we need
to monitor it in case unexpected things happen, so part
of the -- one of the project objectives was to utilize
the equipment that existed on the section to actually
watch for what happens on I-94 and if we detect any
abnormal situations, any abnormal increase in crashes,
MORE SHOCK WAVES, WE'LL INFORM MnDOT AND THERE'S
CHANGES.

THE SECONDARY OBJECTIVE WAS A STRAIGHTFORWARD, BEFORE
AND AFTER ANALYSIS, OKAY, SO DID THE SYSTEM ACTUALLY
SUCCEED IN SOMETHING.

DID IT REDUCE THE NUMBER OF CRASHES?
DID IT REDUCE THE NUMBER OF SHOCK WAVES.
DID IT REDUCE THE EXTENT OF THE CONGESTION?

THESE ARE THE QUESTIONS THAT WE WERE OUGHT TO ASK BUT
ALWAYS FOCUSING ON THIS PARTICULAR LOCATION.

I WANT TO STRONGLY EMPHASIZE THIS, THAT THE I-94
VARIABLE SPEED LIMIT SYSTEM IS ACTUALLY SPREADING BOTH
WAYS, EASTBOUND AND WESTBOUND FROM MINNEAPOLIS ALL THE
WAY TO ST. PAUL.

WE DON'T ANALYZE THE ENTIRE SYSTEM, WE FOCUSED ON THIS
HIGH-CRASH AREA, TYPICALLY FOR THE SAFETY AND BENEFIT
FROM THIS SYSTEM.

NOW, A LITTLE BIT INFORMATION ABOUT THE MINNESOTA
TRAFFIC OBSERVATORY AND FIELD LAB INSTRUMENTATION.
WE, BACK IN 2002, WITH THE ASSISTANCE OF THE ITS
INSTITUTE THEN, WE HAVE DEPLOYED OUR OWN EQUIPMENT ON
HIGH-RISE BUILDINGS THAT ARE OUTLINED IN THIS AREA.
WE WERE LOOKING -- THIS HIGH-RISE AREA IS RIGHT NEXT
DOOR AND ALSO OUTLINED BY VERY HIGH BUILDINGS SO WE PUT
OUR EQUIPMENT ON TOP OF THREE HIGH-RISE BUILDINGS, AND
SO --- BUT NOT ONLY DO WE HAVE CONTINUOUS COVERAGE OF
EVERY VEHICLE THAT'S COMING IN, GOING WEST ON 94,
PASSING ALL OF THESE CAMERAS, THE COLORS SIGNIFY
ROOFTOP LOCATION, BUT WE ALSO MANAGED TO DEPLOY A LARGE
NUMBER OF VISION SENSORS SO WE RECEIVE INDIVIDUAL
VEHICLE SPEEDS FOR ALL THE VEHICLES ON ALL THE LANES
THAT ARE TRAVELING WESTBOUND ON 94 IN THIS SECTION.
THIS IS A WEALTH OF INFORMATION THAT, AS MAX POINTED
OUT, I DON'T KNOW ANY OTHER PLACE THAT EXISTS, AND

WE'RE DOING THAT SINCE 2002 SO WE HAVE A REALLY BIG
DATABASE.
TO GIVE YOU AN IDEA OF THE THINGS THAT ARE HAPPENING,
THIS IS ONE OF THE -- ONE CRASH THAT ACTUALLY HAPPENED
DOWNSTREAM OF PORTLAND, IN THE IN-BETWEEN AREA.
YOU WILL SEE THAT THERE IS A SHOCK WAVE THAT HAPPENED
AND VEHICLES FAILED TO STOP, AND I THINK THERE'S GOING
TO BE A SECOND ONE.
NOW, MORE REGULARLY, THESE CRASHES THAT YOU SEE UP ON
THE RIGHT, WHERE A SHOCK WAVE HAPPENS ONLY IN THE RIGHT
LANE AND VEHICLES FAIL TO STOP WITH THE COLLISION.
ALSO HAVE TO EMPHASIZE THAT NONE OF THE CRASHES ARE
VERY SEVERE IN THEIR FORM.
THEY'RE REAR VEHICLE COLLISIONS, THERE HAS BEEN
INJURIES BUT THERE HASN'T BEEN ANY FATALITY.
WE BASICALLY BUILT IT, A PLOT OF THE SPEED IN THIS LOCATION, SHOWING THE VERTICAL AXIS IS THE TIME, THE SPACE, THE HORIZONTAL AXIS IS TIME AND YOU SEE THAT THE BREAKDOWN OF TRAFFIC IS HAPPENING SOMEWHERE AROUND STATION 50, AND THEN IT SPREADS ALL THE WAY BACKWARDS. NOW, EACH ONE OF THESE HORIZONTAL LINES REPRESENTS THE LOCATION OF A — THAT DISPLAYS THE SPEED LIMITS AND THE COLORS INSIDE THESE LINES IS THE SPEED THAT THE ALGORITHM THAT'S ELECTED TO DISPLAY FOR THAT PARTICULAR BOUNDARY OF A PARTICULAR TIME. WE DID THIS BECAUSE WE WANTED TO SEE IT AS A SET AND INVESTIGATE WHAT IS THE PATTERN AND HOW DO THEY ACTIVATE GIVEN THE DIFFERENT CONDITIONS. THE BLUE LINE REPRESENTS THE HYPOTHETICAL TRAJECTORY, A VEHICLE THAT KNOW THAT IN THIS CASE HAD A NEAR CRASH AT 5:12 AND 50 SECOND, AT A HIGH-CRASH LOCATION, AND ASSUMING THIS VEHICLE HAD COME FROM 94, UPSTREAM ON 94, BASED ON THE SPEED MEASURED BY THE DETECTORS, THIS WOULD HAVE BEEN ITS TRAJECTORY. AND WE DID THIS BECAUSE WE WANTED TO SEE HOW MANY SIGNS THIS DRIVER WAS EXPOSED TO. WHAT WAS THE LAST SIGN THAT THIS DRIVER SAW BEFORE IT HAD THE COLLISION. THE FOURTH AND FINAL ANALYSIS METHODOLOGY IS A LITTLE BIT MORE -- AND BEAR WITH ME WHEN I EXPLAIN THIS BECAUSE IT HAS... IT DEPENDS ON CROSS-CORRELATION AND ALLOWS US TO INVESTIGATE THE SPECIFIC SHOCK WAVE CHARACTERISTICS THAT WE ENCOUNTERED IN THIS LOCATION. NOW, WHEN YOU HAVE TWO SIGNALS THAT ARE COLLECTED AT DIFFERENT LOCATIONS, SIMULTANEOUSLY, YOU CAN CROSS-CORRELATION BASICALLY FINDS THE COMMON — THE TIME DIFFERENCE WHERE THESE TWO SIGNALS HAVE THE GREATEST COMMONALITY. SO IMAGINE THAT THERE ARE TWO DETECTORS HERE, ONE HERE AND ONE OVER THERE, AND I'M THE VEHICLE THAT IS TRAVELING OVER THERE, I SEE THE FIRST DIRECTOR FIRST, THAT IS RECORDED, THEN FIVE SECONDS LATER, I HIT THE SECOND DETECTOR. YOU WILL SEE IN THE RESULT OF THIS METHODOLOGY, YOU WILL SEE A SPIKE AT FIVE SECONDS SAYING THAT, OKAY, AT FIVE SECONDS, THESE TWO SIGNALS HAVE A VERY LARGE COMMON PATTERN. AND WE CAME UP WITH -- BECAUSE THIS IS -- THESE MEASUREMENTS ARE INDIVIDUAL SPEEDS PER LANE, WE CAME UP WITH A METHODOLOGY IN THE PROGRAM THAT ACTUALLY PRODUCES A TIME-SPACE ANALYSIS OF THE CORRELATION BETWEEN THE TWO SIGNALS. TO BRING IT UP TO REALITY, WHAT WE HAVE ON 94, THESE
ARE PICTURES THAT WERE TAKEN FROM ROOFTOP OF THIRD AVENUE. THIS IS THE OVERPASS THAT WE DON'T SEE ON THE PICTURE, IT'S PORTLAND AVENUE. THIS OVERPASS HERE WHERE YOU SEE A LITTLE BIT OF VEHICLES COMING BY, THAT IS THE RAMP FROM 35W GOING TO 94, AND THIS IS IN-BETWEEN, AND THIS IS IMMEDIATELY AFTER. AND YOU SEE THAT THE SHOCK WAVE IS PROPAGATING BACKWARDS, FIRST STOPPING AT THIS POINT, THEN THE STOP BEING GROUP OF VEHICLES GOING TO MOVE UPWARDS WHILE THESE UP IN FRONT ARE GOING TO START MOVING AGAIN, AND IT'S GOING THAT WAY UNTIL VEHICLE MAYBE FAILS TO STOP. SO WE HAVE PLACED OUR OWN MOTION DETECTORS IN THESE TWO LOCATIONS. THEY'RE APPROXIMATELY 750 FEET APART SO A VEHICLE THAT IS -- A GROUP OF VEHICLES THAT IS COMING BY, FIRST IS GOING TO BE DETECTED ON THE UPSTREAM DETECTOR AND THEN A FEW SECONDS LATER IS GOING TO BE DETECTED AT THE DOWNSTREAM STATION. AND THIS CREATES THIS VERY COLORFUL GRAPH. NOW, THIS GRAPH HAS THE ABILITY TO DESCRIBE ALSO ALL MODES OF TRAFFIC, ALL STATES OF TRAFFIC IN ONE VERY PRETTY IMAGE. SO I THINK THIS TIME WE ARE AROUND 10:00 IN THE MORNING. AT THAT TIME, APPLICATION IS UNCONTESTED. SO WE SEE THERE IS A HIGH CORRELATION OF THESE SIGNALS ON A NEGATIVE LINE OF ABOUT TEN SECONDS. WHAT THAT MEANS, THAT MEANS THAT THE PRACTICE TOONS OF VEHICLES THAT ARE MOVING AT FREE-FLOW SPEED ARE FIRST KEEPING THE UPSTREAM DETECTOR. THEN TEN SECONDS LATER, THEY'RE HITTING THE DOWNSTREAM DETECTOR. THE DISTANCE IS NOT LARGE ENOUGH FOR THE PLATOONS TO HAVE CHANGED SHAPES SO WE DETECT FOR EACH ONE OF THESE PATTERNS, WE DETECT A HIGH LEVEL OF CORRELATION AT ABOUT TEN SECONDS. AND THIS IS THE SIGNATURE OF UNCONGESTED TRAFFIC. NOW, AS SOON AS THE BREAKDOWN HAPPENS, THIS PATTERN REVERSES BECAUSE THE CONGESTION HAPPENS FIRST DOWNSTREAM AND IT SPREADS OPPOSITE THE TRAFFIC, UPSTREAM, WHICH MEANS THAT THE SLOWDOWN IN THE SPEED OF THE CONGESTION FIRST IS GOING TO BE DETECTED AT THE DOWNSTREAM STATION AND A FEW SECONDS LATER, WHEN THE SHOCK WAVE REACHES THE UPSTREAM, THEN IT'S GOING TO BE DETECTED ON THE UPSTREAM. SO NOW YOU SEE THAT IN THE CONGESTED CONDITIONS, THE PATTERN FLIPS AND YOU HAVE A HIGH CORRELATION RATE AT
ABOUT 60 SECONDS, 50 TO 60 SECONDS, AND THIS IS THIS TIME DIFFERENCE GIVEN THE SPEED THAT WE HAVE ALSO GIVES US THE SPEED OF THE SHOCK WAVE THAT MOVED BETWEEN THOSE TWO DETECTORS.

NOW, THE LINES THAT WE HAVE HERE SIGNIFY NEAR CRASHES, AND THE BLUE LINES, ONES HERE, SIGNIFY THE VERSIONS OF THE -- NO, I'M SORRY, THESE ARE THE NEAR CRASHES. HERE YOU SEE THE ACT WAYS OF THE LAST VSL BOUNDARY, THE ONE THAT IS ON PARK AVENUE, SO YOU SEE THAT THERE'S BEEN A CRASH THAT HAPPENED ALMOST AT THE FIRST, VERY FIRST SHOCK WAVE THAT APPEARED DURING THAT DAY AND THE ALGORITHM DID NOT HAVE TIME TO REACT TO IT BECAUSE IT NEEDS TO FIND THE SHOCK WAVE AND RESPOND TO IT. SO THAT GUY WAS UNLUCKY, ANYWAY.

ANY QUESTIONS ON THIS? NO?

ALL RIGHT.

SO LET'S BEGIN A LITTLE BIT ON THE RESULTS.


SO AS YOU CAN SEE, THERE ARE A LOT MORE NEAR CRASHES THAN CRASHES BUT THE PATTERN REMAINS THE SAME.

AND IF YOU TAKE ANY LOCATION OF ANY FREEWAY, YOU WILL BASICALLY SEE THAT THESE FREQUENCY THAT WE SEE HERE IS A NORMAL FREQUENCY OF CRASHES AND NEAR CRASHES THAT YOU ENCOUNTER IN ANY FREEWAY AREA.

SO CONSIDER UP TO THESE LEVELS NORMAL BACKGROUND CONDITIONS.

AS SOON AS YOU HIT THE OVERPASS ON PORTLAND, THERE IS A HUGE SPIKE IN FREQUENCY WHICH IS WHAT THE ABNORMAL CONDITIONS IN THIS LOCATION ARE.

SO LOOKING AT IT PURELY THROUGH NUMBERS, WE HAVE A -- THESE ARE THE TOTAL NEAR CRASHES -- CRASHES IN TOTAL THAT WERE DETECTED BY OUR STUDENTS FOR EVERY MONTH BETWEEN SEPTEMBER -- WE HAD TWO MONTHS IN 2008, VERY SPECIAL MONTHS BECAUSE THERE WERE TWO MONTHS AFTER THEY IMPLEMENT THE RETURN OF 35W BRIDGE ON THE SYSTEM, AND THEN -- BUT LATER ON, WE HAVE EVERYTHING FROM APRIL, 2012, ALL THE WAY TO SEPTEMBER, 2013.

THESE ARE THE NUMBERS, AND YOU SEE THAT THE -- I DON'T KNOW IF YOU NOTICED, SUMMER MONTHS REPRESENT A SPIKE IN CRASHES.

WINTER MONTHS ARE ACTUALLY HAVING A LOT LESS.

TO GO EVEN FURTHER FROM PRIOR ANALYSIS THAT HAVE BEEN DONE, DAY AND GOOD WEATHER REPRESENT AN INCREASE IN
CRASHES WHILE NIGHT AND BAD WEATHER REPRESENT A SAFER CONDITION.
ANECDOΤALLY, THE ONLY WAY THAT I CAN ANSWER THAT IS DURING NIGHT AND DURING BAD WEATHER CONDITIONS, PEOPLE PAY ATTENTION BECAUSE NO MATTER WHAT HAPPENS IN THIS SITUATION, NO MATTER THE SHOCK WAVES, THE SPEED DIFFERENTIAL OR THE DIFFERENT CAUSAL FACTORS THAT ARE PRECIPITATING OR GENERATING THE CRASH, 80% RESPONSIBILITY FOR THAT CRASH IS ON THE DRIVER WHO WAS NOT PAYING ATTENTION OR WAS DRIVING TOO CLOSE TO ANOTHER VEHICLE FOR SAFETY.
BECAUSE IF YOU PAY ATTENTION AND YOU KEEP -- EVERYBODY KEEPS ITS DISTANCES, MOST OF THE TIMES, CRASHES ARE VERY, VERY RARE.
SO WHAT HAPPENED BEFORE AND AFTER?
IF WE LOOK AT IT IN PURELY RATES BEFORE AND WE ALSO COUNTED THE VOLUME OF VEHICLES THAT PASSED THROUGH THIS AREA, IN THE BEFORE PERIOD FROM APRIL, 2012, TO SEPTEMBER, 2012, AND WE HAVE EXCLUDED 2008, WE SEE THERE WERE 4258 INCIDENTS OVER A 4.5 MILLION VEHICLES PASSING THE LOCATION WHICH RESULTS IN ABOUT 116 INCIDENTS PER MILLION VEHICLES TRAVELED.
AFTER, WHICH YOU TAKE THE ENTIRE YEAR AFTER, YOU END UP WITH A SLIGHTLY LOWER RATE OF 106 INCIDENTS PER MILLION VEHICLES TRAVELED.
NOW, SO THAT'S NOT A VERY FAIR COMPARISON BECAUSE AS I SAID, WE OBSERVED THAT THE WINTER MONTHS HAVE A COMPLETELY DIFFERENT FREQUENCY PATTERN AS THE SUMMER MONTHS, SO IF WE EXCLUDE THE WINTER MONTHS FROM THE AFTER LOCATION, SO WE ONLY MATCH THE SAME MONTHS THAT WE HAD AFTER WITH THE SAME MONTHS THAT WE HAD BEFORE, THEN YOU SEE THAT ACTUALLY THE RATE OF CRASHES INCREASED TO 131 INCIDENCES PER MILLION VEHICLES TRAVELED.
SO, UNFORTUNATELY, FROM PURELY COUNTING EVENTS, UNFORTUNATE EVENTS, THERE WAS NO REDUCTION.
THE INCREASE OF ABOUT 20 VEHICLES — 20 INCIDENTS PER MILLION VEHICLES TRAVELED IS NOT A BIG INCREASE TO ACTUALLY CALL IT THAT BUT, FOR SURE, THERE HASN'T BEEN

AN IMPROVEMENT IN ACTUAL NUMBERS OF CRASHES AND NEAR CRASHES THAT ARE APPEARING IN THESE LOCATIONS.
NOW, WE LOOKED A LITTLE BIT CLOSER, WHAT HAPPENS TO THE ACTUAL SHOCK WAVES THAT CREATE SOME OF THESE INCIDENCES, AND THE BLUE LINE, THE FIRST — THE LEFT-MOST PICTURE IS THE TIME IN THE DAY THAT THE FIRST SHOCK WAVE APPEARED IN THIS SECTION.
THE PLOT IMMEDIATELY TO ITS RIGHT IS THE TIME THE SECOND SHOCK WAVE HAPPENED IN THIS LOCATION AND THE PLOT ON THE BOTTOM IS THE TIME THE THIRD SHOCK.
SO THIS ESSENTIALLY IS THE TIMES AND THE FREQUENCY DURING THE TIME OF THE DAY OF THE FIRST, SECOND AND THIRD SHOCK WAVE IN A DAY.
AND WE SEE THAT THE PATTERN HASN'T CHANGED MUCH.
THERE'S BEEN AN INCREASE OF SHOCK WAVE ACTIVITY AT AROUND 1:00, 12:30, ACTUALLY, SO YOU SEE THIS SPIKE WHICH OF COURSE IN THE FIRST SHOCK WAVE HAPPENS EARLIER, THEN THE SECOND AND THIRD PRETTY MUCH FOLLOW THE SAME WAY, SO FOR SOME REASON, WHICH IS NOT EXACTLY CLEAR, IN THE AFTER PERIOD, CONGESTION AND TROUBLE STARTED EARLIER THAN LATER.
NOW, I WOULD LIKE TO DRAW YOUR ATTENTION THAT THIS DOESN'T TELL US ANYTHING ABOUT THE OPERATION OF THE SYSTEM BECAUSE THE SYSTEM IS REACTING.
THE ALGORITHM REQUIRES A NUMBER OF SPEED MEASUREMENTS IN ORDER TO DECIDE THAT THERE IS INDEED A SLOWDOWN AND WE HAVE TO ACTIVATE THE SIGNS.
SO THE FIRST AND SECOND SHOCK WAVE USUALLY ARE NOT ENOUGH, THEY'RE BUILDING TOWARDS THE SYSTEM'S REACTION BUT THEY'RE NOT PART OF THE SYSTEM'S REACTION.
SO THIS TYPE OF CONGESTION IS MORE OF A PATTERN OF THE TRAFFIC IN THE AFTER PERIOD RATHER THAN A CAUSE OF THE ALGORITHM.
NOW, AT THE TIME OF THE THIRD SHOCK WAVE, THE ALGORITHM HAS ALREADY REACTED BECAUSE IT'S USUALLY ABOUT TWO OR THREE MINUTES LATER, THE ALGORITHM IS APPROXIMATELY NEEDS ABOUT A MINUTE AND A HALF OF COLLECTED DATA IN ORDER TO ACTIVATE, SO IF THE ALGORITHM WAS WORKING IMMEDIATELY, WITH SUCCESSFUL -- QUICKLY, WE WOULD HAVE SEEN A DROP IN THE TIME DIFFERENCE BETWEEN THE SECOND AND THE THIRD SHOCK WAVES BECAUSE THE ALL BEING RHYTHM KICKED IN AND IT WOULD HAVE PREVENTED THAT THIRD SHOCK WAVE TO HAPPEN AS SOON AS POSSIBLE.
AND ACTUALLY, THROUGH, WE SEE IT'S SLIGHT INCREASE. SO THE THIRD SHOCK WAVE, MOST OF THE THIRD SHOCK WAVES HAPPENED FASTER WHEN THE VSL SYSTEM WAS ACTIVATED
RATHER THAN LATER.
AND OVERALL, NOW, IF WE GO AND WE COUNT ALL THE SHOCK WAVES THAT HAPPENED DURING THE TIME OF OBSERVATION, WHICH IS FROM 10:00 IN THE MORNING TO 8:00 AT NIGHT, WE SEE AND WE PLOT THE BEFORE AND AFTER NUMBERS, WE SEE THAT THERE IS A SLIGHT DECREASE LATER ON, SO IN THIS LOCATION, ABOUT 3:00 p.m., HEAVY CONGESTION HAS SET IN.
THE ALGORITHM HAS NOW SIGNS HAVE ACTIVATED FARHTER
UPSTREAM ON HURON AND 280 AND RIVERSIDE, AND IT SEEMS THAT THERE'S FEWER SHOCK WAVES HAPPENING WITH THE ALGORITHM OPERATION AT THE HIGH-CRASH AREA THAN HAPPENED WHEN IT WASN'T THERE.
SO THIS IS A SMALL POSITIVE EFFECT BECAUSE EVERY SHOCK WAVE IS A CAUSE — COULD BE A CAUSE FOR A CRASH, SO IF YOU HAVE FEWER OF THEM, EVEN IF THEY ARE DURING CONGESTED CONDITIONS, THAT'S BETTER.
NOW, IF WE LOOK AT THE PROGRESSION OF CONGESTION...
NOW, HERE WE HAVE THE PLOTS ON THE LEFT, WE HAVE THE PLOTS OF LOOP DETECTOR SPEED AVERAGED EVERY FIVE MINUTES AND THE DIFFERENT LINES CORRESPOND TO ALL THE DETECTORS ON THE RIGHT-MOST LANE STARTING FROM PARK AVENUE, GOING BACKWARDS ALL THE WAY TO RIVERSIDE.
SO YOU WOULD -- AND THE PATTERNS ARE ALIGNED TO MATCH THE TIME THAT THE BREAKDOWN HAPPENED.
WELL, THE BREAKDOWN DOESN'T HAPPEN THE SAME TIME EVERY DAY BUT IN ORDER FOR US TO MEASURE THIS, FOR EVERY DAY, WE TOOK ALL THE DAYS WORTH OF DATA AND WE ALIGNED ALL THE BREAKDOWNS TO BE AT THE SAME TIME AND WE MEASURED THE AVERAGE SPEED ON EACH ONE OF THE UPSTREAM DETECTORS FROM ZERO TO FIVE MINUTES AFTER THE BREAKDOWN, TEN TO 15 — FIVE TO 10 MINUTES, 15 TO 20 MINUTES AND SO ON, AND BASICALLY, WE RUN A STATISTICAL ANALYSIS TO SEE IF THERE WAS SIGNIFICANT DIFFERENCE IN THE PROGRESSION OF CONGESTION BEFORE AND AFTER.
NOW, WHEN WE COMPARE DATA FROM 2011 WITH DATA IN 2013, WE SEE THAT THERE'S ACTUALLY A VERY LARGE DROP, SO AS COMPARED TO A YEAR BEFORE IT WAS ACTIVATED, THE SYSTEM SEEMS TO HAVE A STATISTICALLY SIGNIFICANT REDUCTION IN SPEEDS UPSTREAM OF THE CONGESTION, WHICH IS THE DESIRABLE EFFECT.
NOW, BUT WHEN WE GO — 2011 WAS A YEAR FARTHER AWAY. WHEN WE COMPARE IMMEDIATELY AFTER, SO WE COMPARE 2012 WITH 2013, TWO CONSECUTIVE YEARS, WE SEE THAT THERE WAS SOMETHING ELSE THAT HAPPENED BETWEEN 2011 AND 2012 THAT ACTUALLY CAUSED THE SPEED REDUCTION, AND IT WAS NOT THE VARIABLE SPEED LIMIT SYSTEM.
SO WHEN WE LOOK AT THE TWO CONSECUTIVE YEARS, THERE IS NO STATISTICALLY DIFFERENCE BETWEEN THE AVERAGE SPEEDS UPSTREAM OF THE CONGESTION BETWEEN THE TWO YEARS.
THERE IS A LITTLE BIT OF SPEED DROP SO THE VARIABLE SPEED LIMIT MIGHT BE DOING SOMETHING BUT IT'S NOT ENOUGH TO REGISTER AS A SIGNIFICANT EFFECT.
FINALLY, WE LOOKED AT — SO WE DID THE CROSS-CORRELATION ANALYSIS AND WE PERFORMED — DEVELOPED THE CRASH CORRELLOGRAMS FOR BEFORE AND AFTER THE IMPLEMENTATION OF THE VARIABLE SPEED LIMIT SYSTEM AND ALTHOUGH ANECDOTALY WE DETECTED THAT THE DURATION
OF CONGESTION IN THE PERIOD AFTER THE VSL WAS IMPLEMENTED IS ACTUALLY GENERALLY SHORTER, SO CONGESTION OVERALL LASTS LESS, THE CHARACTERISTICS OF THE SHOCK WAVES, SO THE HEIGHT OF THAT LINE IS THE SAME.

SO THE EXTENSIONS TO THE INSTRUCTIONS TO THE DRIVERS DID NOT SUCCEED IN HAVING THEM SLOW DOWN AS THEY APPROACHED THE PROBLEM SO THE SHOCK WAVE DID NOT CHANGE THE PROPAGATING SPEED UPWARDS.

FINALLY, WE HAVE -- WE LOOKED AT SORT OF THE HUMAN FACTOR ASPECT OF THE VARIABLE SPEED LIMIT SYSTEM. OKAY, WHO ARE THE PEOPLE WHO SAW IT AND HOW OFTEN DID THEY SEE.

SO, BASICALLY, WE COUNTED THE NUMBER OF TIMES THAT A VEHICLE WAS INVOLVED, AND IT MEANS THAT — IN THIS PARTICULAR CASE IS A CRASH, SO THIS VEHICLE WAS ACTUALLY ON THE 10TH — ON THE 9th OF OCTOBER, 2012, WAS INVOLVED IN A CRASH AT AROUND 3:30, AND IF IT HAD COME FROM 94, IT WOULD HAVE ENCOUNTERED AN ACTIVE VSL TELLING IT TO SLOW DOWN ON RIVERSIDE.

THEN ANOTHER VSL ON 11th — ON CEDAR, BUT THE 11th AND PARK AVENUE GANTRIES WERE OFF.

THEY HAD ACTIVATED EARLIER BUT BY THE TIME THIS WAS PASTED, THEY WERE OFF.

THIS IS A CHARACTERISTIC OF THE ALGORITHM THAT IN THIS PARTICULAR LOCATION IS WORKING NEGATIVELY BECAUSE THE ALGORITHM, THE WAY IT’S WORKING, IS DESIGNED TO CHASE OFF THE CONGESTION.

SO IT TRIES TO REDUCE THE SPEED OF THE VEHICLES ENCOUNTERING THE TAIL OF THE CONGESTION.

SO FOR EVERY STATION THAT THE TAIL OF THE CONGESTION HAS PASSED, IT SAYS, THERE IS NOTHING I CAN DO HERE, THE TAIL IS GONE.

BETTER I DON'T TELL THEM ANYTHING, I SWITCH MYSELF OFF.

WHAT HAPPENS IN THIS LOCATION, THOUGH, THE TRAFFIC CONDITIONS HAPPEN THAT INSIDE THIS CONGESTED REGION, THERE ARE TIME AND LOCATIONS WHERE SPEEDS ARE INCREASING, TEMPORARILY.

SO GROUPS OF VEHICLES ARE RELEASED FROM CONGESTION ONLY TO ENCOUNTER FEW THOUSAND FEET ENCOUNTER ANOTHER SHOCK WAVE.

AND IN THOSE CASES, THE ALGORITHM IS DEACTIVATED SO THERE IS NO WARNING.

BUT WE CAN SEE THAT IN THE CASE OF AT LEAST NEAR CRASHES, AT LEAST HALF OF THE VEHICLES HAVE ENCOUNTERED VSLs JUST BEFORE THEY HAD THE CRASH, SO THE INFORMATION IS THERE.

IT WAS NOT THAT IT WAS PASSED BUT IT WASN'T NOTICED.

SO, IN CONCLUSION, WE BASED OUR ANALYSIS ON SEVERAL
DIFFERENT EVIDENCE AND OVERALL, DOESN'T SEEM SO THAT THE VARIABLE SPEED LIMIT SYSTEM IS HAVING ANY POSITIVE INFLUENCE ON THE CAUSAL FACTORS THAT ARE BEHIND THE CRASHES ON 94.
THE FLOW BREAKDOWN AT THE MERGE HAPPENS WITH SIMILAR FREQUENCY.
THE SPEED DIFFERENTIAL BETWEEN THE LANES REMAINS THE SAME.
AND THE TRAFFIC DENSITY AND HEADWAYS ON THE RIGHT LANE WHERE MOST OF THE CRASHES HAPPEN REMAIN THE SAME.
WE DETERMINED THAT THE SYSTEM IS VISIBLE TO DRIVERS LATER INVOLVED IN THE INCIDENTS, SO INCIDENTS DON'T ONLY HAPPEN AT THE BEGINNING OF THE CONGESTION BUT ALSO HAPPENS DURING FLUCTUATIONS INSIDE THE CONGESTED PERIOD, AND FOR THOSE, THE SIGN IS VISIBLE, AT LEAST IN MORE THAN HALF OF THE CASES.
WHICH UNFORTUNATELY BRINGS US TO THE REALIZATION THAT THE DRIVERS ARE IGNORING THE SYSTEM BECAUSE IF THEY WERE NOT Ignoring THE SYSTEM, THAT BEHAVIOR SHOULD HAVE CHANGED.
IN SEVERAL CASES, NEAR CRASHES AND CRASHES ARE HAPPENING TOO EARLY FOR THE SYSTEM TO BE EFFECTIVE.
BY CONSTRUCT, BY DEFINITION, THE WAY THAT IT IS DESIGNED, IT HAS AN INHERENT DELAY TIME WHERE IT'S GOING TO ACTIVATE AND THERE IS A CONSIDERABLE AMOUNT Of CRASHES THAT ARE HAPPENING ON THIS VERY FIRST SHOCK WAVES THAT THE SYSTEM HASN'T HAD ENOUGH TIME TO ACTIVATE.
ONE OF THE REASONS THAT THIS HAPPENS IS IT'S DESIGNED TO BE DEPLOYED ANYWHERE IN THE TWIN CITIES. THEREFORE, IT'S DESIGNED TO USE LOOP DETECTOR DATA. LOOP DETECTOR DATA IN THE TWIN CITIES PRODUCE ONLY ESTIMATED SPEED WITH A LOT OF NOISE.
ONE 30-SECOND SAMPLE OF THAT SNEAD IS NOT TRUST-WORTHY. YOU NEED TO GET A NUMBER OF THEM TO REALIZE THAT, OKAY, YES, CON GUESS HIT IN THIS LOCATION, IT WASN'T JUST A BIG TRUCK PASSING BY ONCE.
SO WITH BETTER DETECTION, MORE ACCURATE DETECTION LIKE MICROWAVE DETECTION THAT IS MORE TRUST-WORTHY, THIS DELAY CAN BE REDUCED.
AND AS I SAID FOR HALF OF THE CASES, THE SYSTEM WAS VISIBLE, IT HAD DEACTIVATED IMMEDIATELY UPSTREAM LOCATION WHERE THE CRASHES HAPPENED.

SO THAT IS ANOTHER, AGAIN, INHERENT OPERATION OF THIS PARTICULAR ALGORITHM THAT CAN CHANGE, THAT TO ACTUALLY NOT BE PREVENT THE REACTIVATION OF SOME OF THE SIGNS, EVEN IF THEY ARE INSIDE THE CONGESTED REGION.
SO THAT WAS MY PRESENTATION.
I I'M OPEN TO ANY QUESTIONS YOU MAY HAVE.
I HAVE A MICROPHONE AND I WILL BRING IT AROUND TO ANYONE WHO HAS A QUESTION. JUST RAISE YOUR HAND. WELL, LET ME ASK A QUESTION. JUST BECAUSE YOU'RE PASSING UNDER THE SIGN DOESN'T MEAN THAT YOU'RE ACTUALLY LOOKING AT IT. AND EVEN IF YOU LOOK AT IT, THAT DOESN'T MEAN YOU SEE IT. ENGINEERED, I'M DRIVING ALONG, PAYING ATTENTION TO THE CARS IN FRONT OF ME, THAT DOESN'T MEAN I AM ACTUALLY READING THE NUMBERS OVERHEAD. WELL, HUMAN FACTOR STATUS OF VSL MESSAGE SIGN READABILITY HAS SHOWN THAT DRIVERS, IF YOU PROVIDE THEM WITH A SIGN OF THE RIGHT SIZE AND THE RIGHT COLOR AT THE RIGHT LOCATION, THEY WILL SEE IT. AND THESE SIGNS WERE DESIGNED THAT WAY. BUT I'M IN THE MIDDLE OF ALL THIS CONGESTION WHERE I REALLY NEED TO PAY ATTENTION TO THE CARS IN FRONT OF ME, CAN I REALLY BE, YOU KNOW, ABLE TO PERCEIVE -- I'M NOT A HUMAN FACTORS ENGINEER BUT HUMAN FACTORS ENGINEERS HAVE SHOWN THAT, YES, THE SIGNS ARE SEEN. NOW, THAT DOESN'T MEAN THAT THEY'RE OBEYED OR HAVE INFLUENCE ON THE DRIVER BEHAVIOR BUT THEY'RE DEFINITELY SEEN. SOME OF THEM ARE LOOKING AT THEM AND THINKING WHAT THE HECK IS IT SAYING. THAT IS ANOTHER PROBLEM, COMPREHENSION, SEEING DOESN'T EQUAL COMPREHENSION AND, ANECDOTALLY, I'VE READ COMMENTS ONLINE OF PEOPLE THAT HAVE COMMENTED ON THE SYSTEM AND THERE WERE AT LEAST 12 COMMENTS AND HALF A DOZEN DIFFERENT OPINIONS OF WHAT DO THEY MEAN, WHAT DOES THIS NUMBER MEAN. SOME OF THEM THOUGHT THAT IT IS THE SPEED AT THAT LOCATION, WHICH IS NOT CORRECT. SOME OF THEM THOUGHT IT WAS THE SPEED DOWNSTREAM SO IT IS ALERTING THEM OF WHAT IS GOING TO HAPPEN, WHICH AGAIN IS WRONG. FEW ACTUALLY UNDERSTOOD THAT THIS IS A DIRECT COMMAND TO THEM TO ADJUST THEIR SPEEDS ALTHOUGH THEY DON'T HAVE TO AT THAT LOCATION. SO THERE IS AN EDUCATION ELEMENT IN THIS. IN YOUR OPINION, THEY HAVE A SPEED LIMIT WITH A WHITE BACKGROUND WITH A RED CIRCLE AROUND IT. IN EUROPE, TYPICALLY, THERE IS A CAMERA GIVING TICKETS RIGHT UNDERNEATH EACH ONE OF THESE SIGNS. IT IS THE OFFICIAL SPEED LIMIT OF THE ROAD AND YOU HAVE TO OBEY IT. UNFORTUNATELY, IN MINNESOTA, IT IS AN ADVISORY SPEED
LIMIT.
WE HAVEN'T -- THE WASHINGTON, SEATTLE SYSTEM WHICH IS THE SAME ALGORITHM AS OURS, I BELIEVE, THEY HAVE PASSED LEGISLATION TO MAKE IT ENFORCEABLE.
SO IT'S NEARING ITS FIRST YEAR OF OPERATION SO WE'RE GOING TO FIND OUT IF THAT ACTUALLY MAKES A DIFFERENCE.
>> ANY OTHER COMMENTS, QUESTIONS?
WELL, IF NOT, I COULD PROBABLY GENERATE MANY MORE BUT I DON'T THINK PEOPLE WANT TO SIT AND LISTEN, SO, ANYWAY, WITHOUT ANY FURTHER ADO, PLEASE JOIN ME IN THANK ENGINE PROFESSOR HOURDOS FOR HIS PRESENTATION.
THANK YOU.
BY THE WAY, BEFORE I FORGET, NEXT WEEK I BELIEVE THERE IS NO PRESENTATION -- THERE IS NO SEMINAR HERE NEXT WEEK.
THAT'S THE WEEK WHERE THERE WILL BE THE TZD CONFERENCE IS BEING HELD IN DULUTH SO THERE IS NO PRESENTATION.
TWO WEEKS FROM TODAY, THERE WILL BE A PRESENTATION BY PROFESSOR BILL SCHNEIDER FROM THE UNIVERSITY OF AKRON, THE OFFICIAL TITLE OF HIS TALK ASK THE EVOLUTION OF HOT SPOT MAPPING, PAST, PRESENT AND FUTURE.
HE IS DOING A LOT OF RESEARCH ON THE DEPLOYMENT OF SQUAD CARS AND HOW YOU OPTIMIZE WHERE YOU LOCATE THEM TO CATCH D.W.I. DRIVERS, DRIVING WHILE INTOXICATED.
SO HE HAS BEEN WORKING WITH THE OHIO STATE PATROL, THE UNIVERSITY OF AKRON, AND HE'LL BE COMING HERE TO PRESENT TWO WEEKS FROM TODAY AT 3:00.
SO IF YOU ARE INTERESTED, PLEASE COME BACK AGAIN.
THANK YOU.

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