

FUNDAMENTALS: ONE-TO-MANY CONGESTION

BOTTLENECKS AND ZIPPER MERGE

Usually one-to-many congestions happen at bottlenecks, such as Istanbul's bridges on the right. If **zipper merge** is not maintained, the bottleneck may generate congestions, especially long in rush hours.

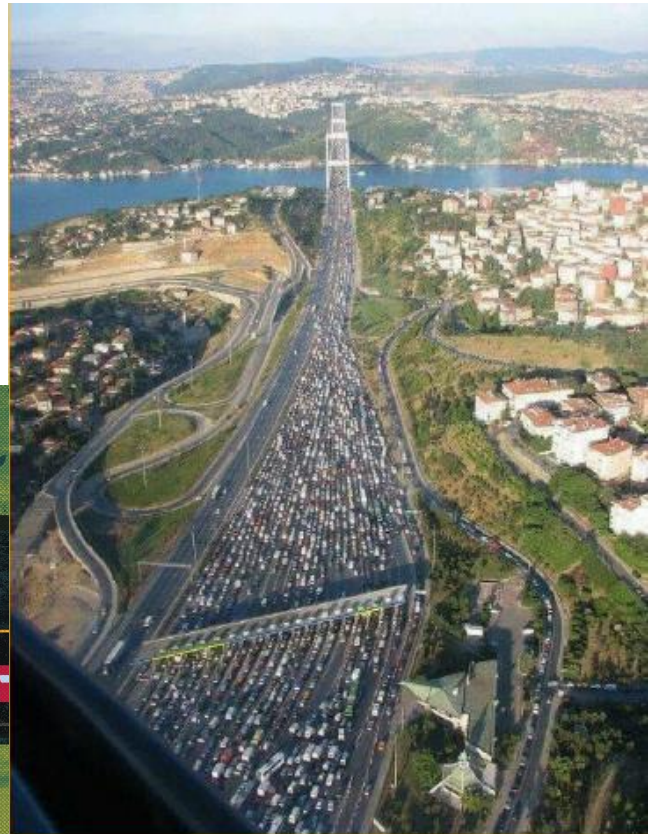


Image 1 - <https://twitter.com/erikwest73/status/1031842127918125057>

Netherlands Enterprise Agency Report: - <https://www.rvo.nl/sites/default/files/2018/08/Who-need-cars-anyway.pdf>

Image 2 - <https://amain insider.com/zipper-merge/>

FUNDAMENTALS: ONE-TO-MANY CRASHES

REAR-ENDING: SUDDEN BREAKING AND ACCELERATION

Behind bottleneck congestions, if the incoming flow is high speed, rear-end collisions are commonplace.

On the other end of the congestion, once the road is cleared, the irritated drivers stomp their feet on the gas, causing disruption. Erratic driving of autonomous vehicles is the dominant cause of humans rear-ending them.

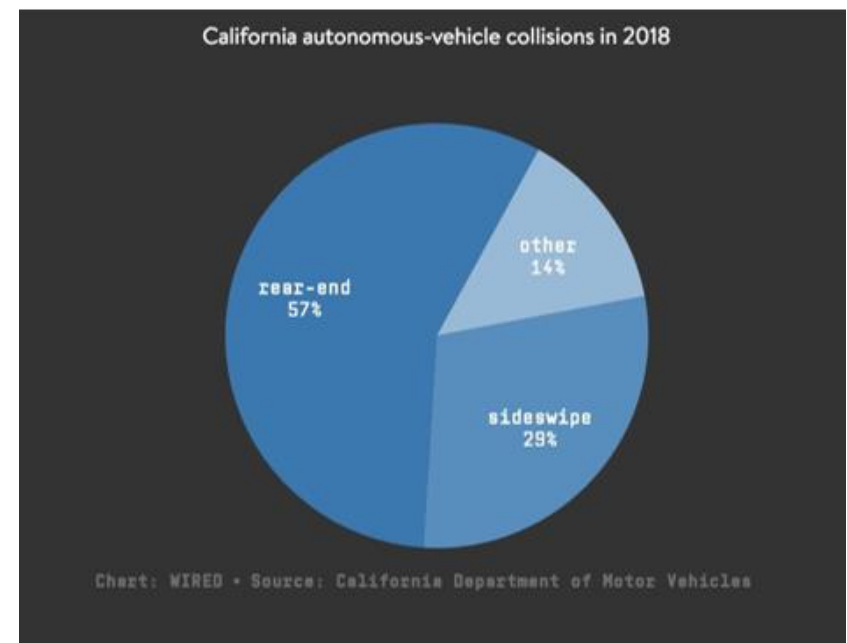


Image - <https://www.wired.com/story/self-driving-car-crashes-rear-endings-why-charts-statistics/>

FUNDAMENTALS: MANY-TO-MANY CONGESTION

CONGESTION (in my terms)

When in one time frame, if two vehicles attempt to pass through a road section able to accommodate one vehicle at that one time frame, congestion occurs if one of the vehicles **fall in queue**. This queue may extend backwards depending on other vehicles joining the road.

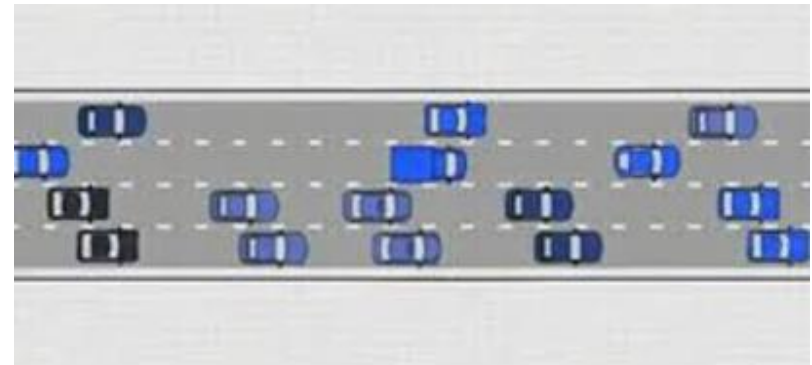


Image: Traffic jams created by merging – <https://www.youtube.com/watch?v=2Loi9YyOz4k>

FUNDAMENTALS: MANY-TO-MANY CRASHES

CRASHES (between two vehicles)

When in one time frame, if two vehicles attempt to pass through a road section able to accommodate one vehicle at that one time frame, a crash occurs if one of the vehicles **end up on sharing the same road space at the same time**, stopping, blocking the road passage.

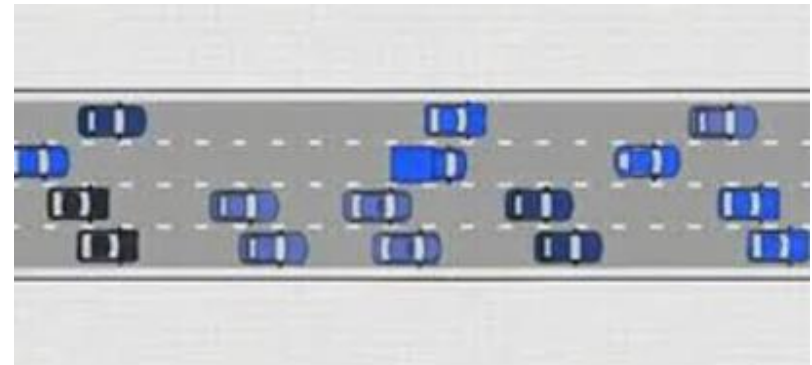


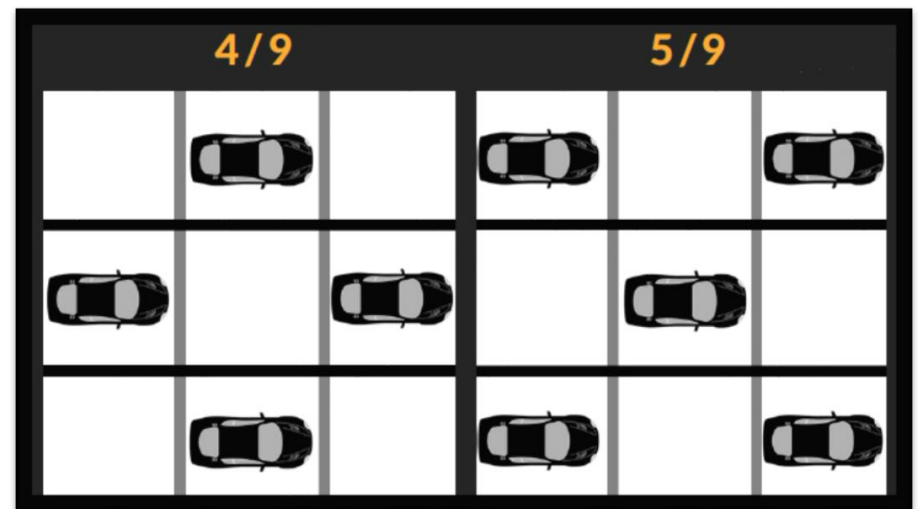
Image: Traffic jams created by merging – <https://www.youtube.com/watch?v=2Loi9YyOz4k>

METHODOLOGY: TRAFFIC FORMATION

Hypothetical optimal traffic formation: **continuous zipper merge or, checkerboard**

Allowing vehicles to move forward and merge sideways, causing no disruption to the traffic flow.

Physics of formation is presented at NECSI ICCS 2020¹, NERCCS 2021^{2 3} conferences on complex systems.



1 - https://www.researchgate.net/publication/348521157_A_2D_Ising_Model_Cellular_Automaton_Mapped_onto_Catenary_Involute

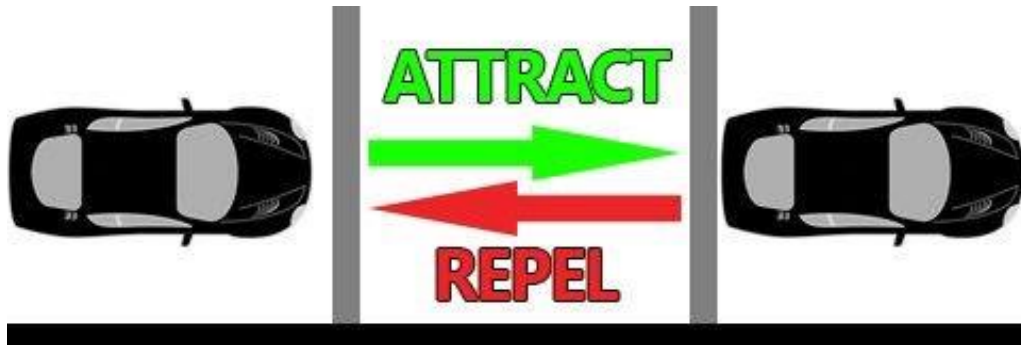
2 - <https://github.com/goktu/ADama>

3 - https://goktu.github.io/ADama/pdf/GoktugIslamoglu_NERCCS2021_Presentation.pdf

METHODOLOGY: ZIPPER FLEXIBILITY

Continuous zipper merging can form one empty lane on demand.

This use is reserved for emergency vehicles. Vehicles in side demagnetize the flow: physics in the previous slide.



ONE-TO-MANY, MANY-TO-MANY: ISTANBUL

Crash focus Istanbul D100 Roadway:

- ↳ Spans from European to Asian side, connected by 1st Bridge of Istanbul
- ↳ Surrounded by very dense population
- ↳ Formerly E-5 highway, lost highway status :
 - ↳ Bus-Rapid Transit (Metrobüs) protected road built in 2011, both shrunk the lane width and occupied one lane on each direction
 - ↳ Entry into highway not managed exclusively through access roads, especially near airport
 - ↳ Highway travel speeds not maintained

Dataset: Istanbul Municipality's Transport Management Center
Twitter: Dec 2016 - Mar 2017¹

Outdated Data: In the above time period, Istanbul Ataturk Airport was still operational. On April 2019, the decommissioning of Ataturk Airport greatly altered the traffic conditions.

1 - <https://twitter.com/4444154>, Twitter API

ONE-TO-MANY: MONDAY MORNING CRASHES

D100 KUCUKCEKMECE BOTTLENECK CRASHES ON MONDAY MORNINGS

Hour Range	Mon
3	1
5	2
7	4
8	4
10	1
11	1
12	4
13	2
14	1
15	1
16	1
18	2
19	2
20	1

Insurance Information and Monitoring Center (SBM):
In 2014, highest number crashes happened on Mondays in Istanbul¹.

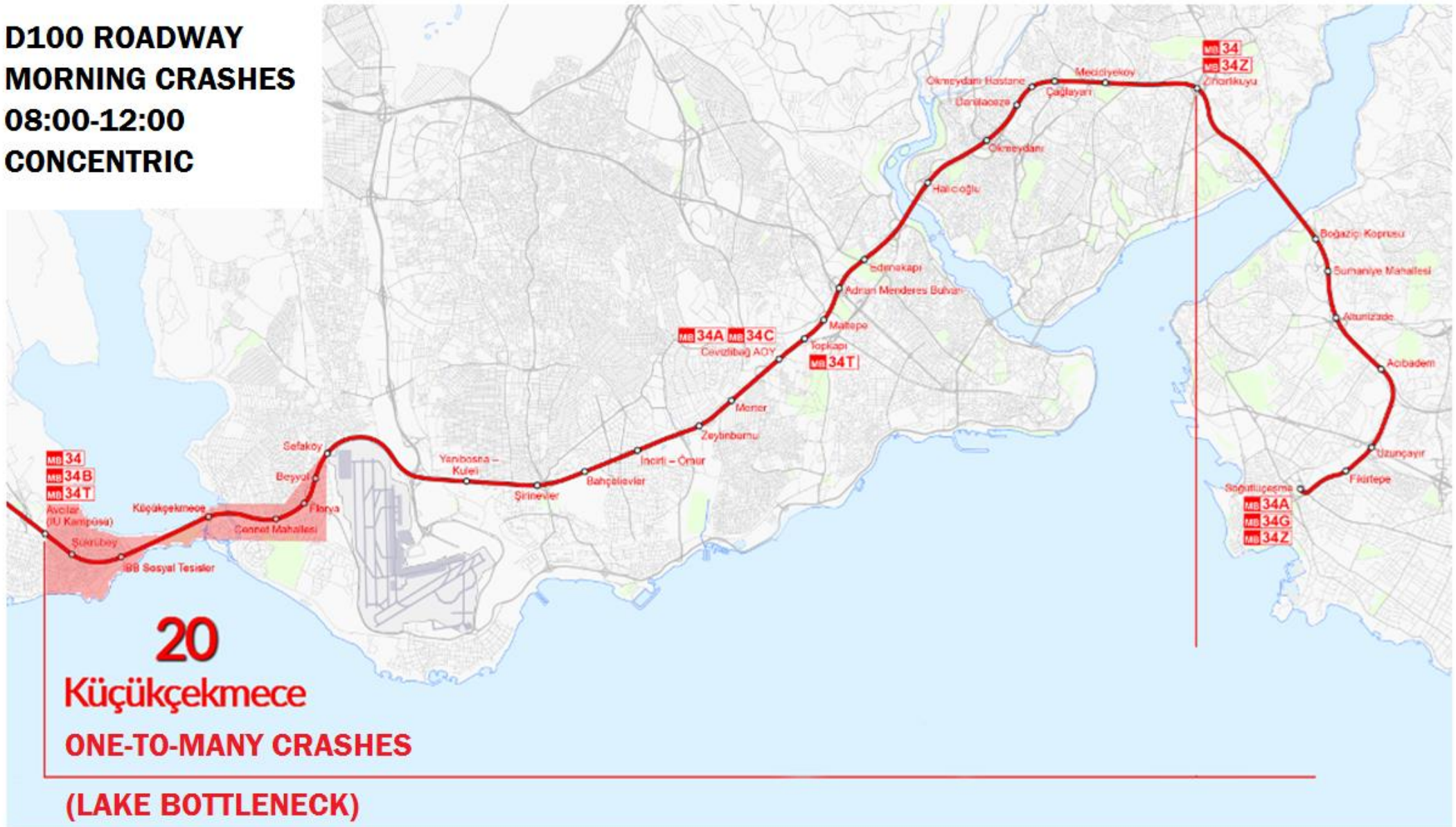
REST OF ISTANBUL PROPER CRASHES ON MONDAY MORNINGS

3	2
4	4
5	7
6	9
7	13
8	5
9	6
10	7
11	3
12	5
13	9
14	1
15	4
16	3
17	5
18	3
19	1
20	1

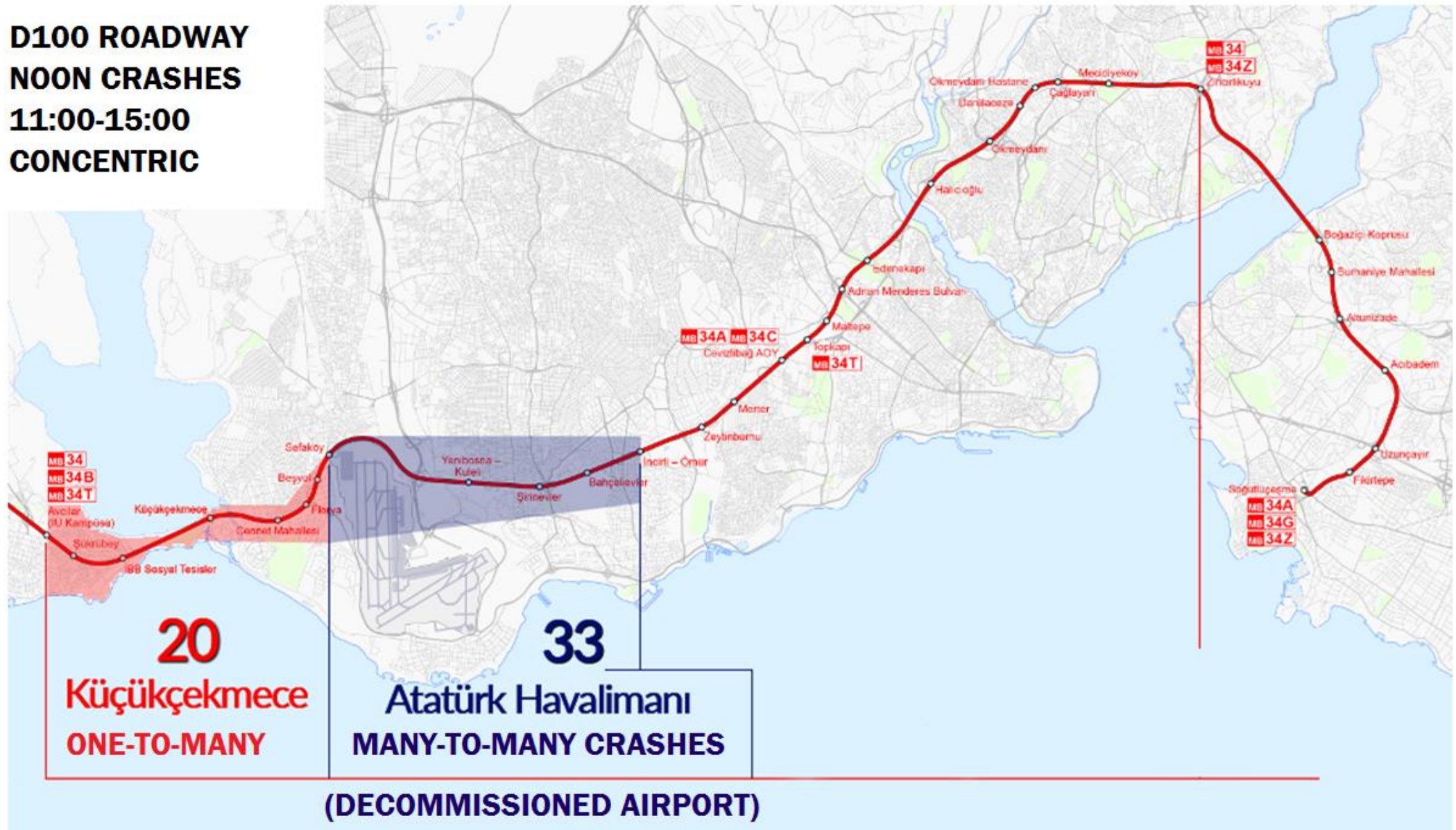
D100 Küçükçekmece crashes on **Monday**
08.00 and **12.00** are **disproportionately high** compared to the rest of three-months dataset.

¹ - <https://www.wsj.com/articles/trafikte-pazartesi-sendromu-1405253239>

**D100 ROADWAY
MORNING CRASHES
08:00-12:00
CONCENTRIC**



**D100 ROADWAY
NOON CRASHES
11:00-15:00
CONCENTRIC**



**D100 ROADWAY
DAY-LONG CRASHES
11:00-22:00
SPREAD-OUT**



BAD ROAD DESIGN: AMPLIFYING CRASHES

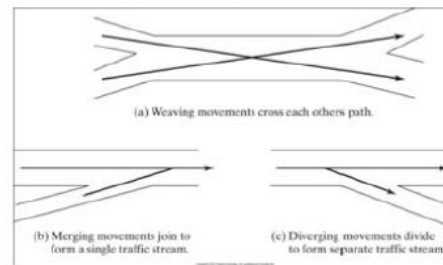
D100 roadway in the now decommissioned Ataturk Airport area:

- ↳ Squeezed by BRT road on one side
- ↳ Squeezed by side road on the other side
- ↳ No access road to former highway D100, weave lane



15.1 Turbulence areas on freeways and multilane highways

- Turbulence as characterized by the additional lane-changing these maneuvers cause: i.e. one movement must make at least one lane change.
- Other elements: the need for greater vigilance on the part of the driver, more frequent changes in speed, and average speeds that may be somewhat lower than on similar basic sections.



The maximum length over which weaving movements are defined varies (2,500ft in HCM 2010). Beyond that, analyze as separate ramps.

The maximum length over which merging and diverging movements are defined is 1,500 ft.

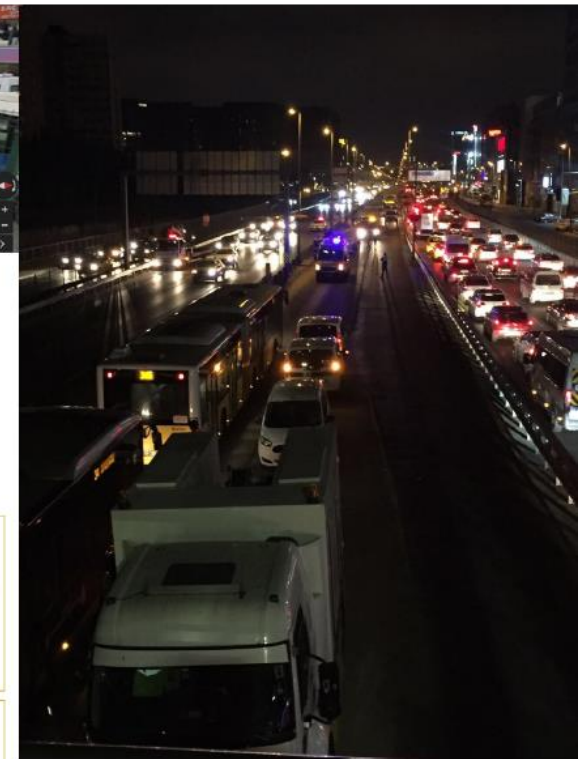


Photo 1 - Google Maps Street View – Şirinevler D100 Roadway and Side Road, Joining Ahead Without Access Road

Photo 2 – Goktug Islamoglu, Taken en Route to Airport, Şirinevler Metrobüs Stop. BRT Operations Stopped Due to Car Entering Protected Road

Image 1 - Traffic Engineering, Roger P. Roess / Elena S. Prassas / William R. McShane, Prentice Hall, Pearson .

BRT CRASHES: VEHICLE ENTRY INTO ROAD

Kadıköy accident is the lone outlier, which was a cement truck crashing into BRT road barriers.

DURAK	1	8	13	17	22	Total
Atakoy	1					1
Bahçelievler				1		1
Cevizlibağ Sefaköy	1					1
İncirli	1					1
Kadıköy		1				1
Küçükçekmece Sefaköy			1			1
Merter				1		1
Total	1	2	1	1	1	7

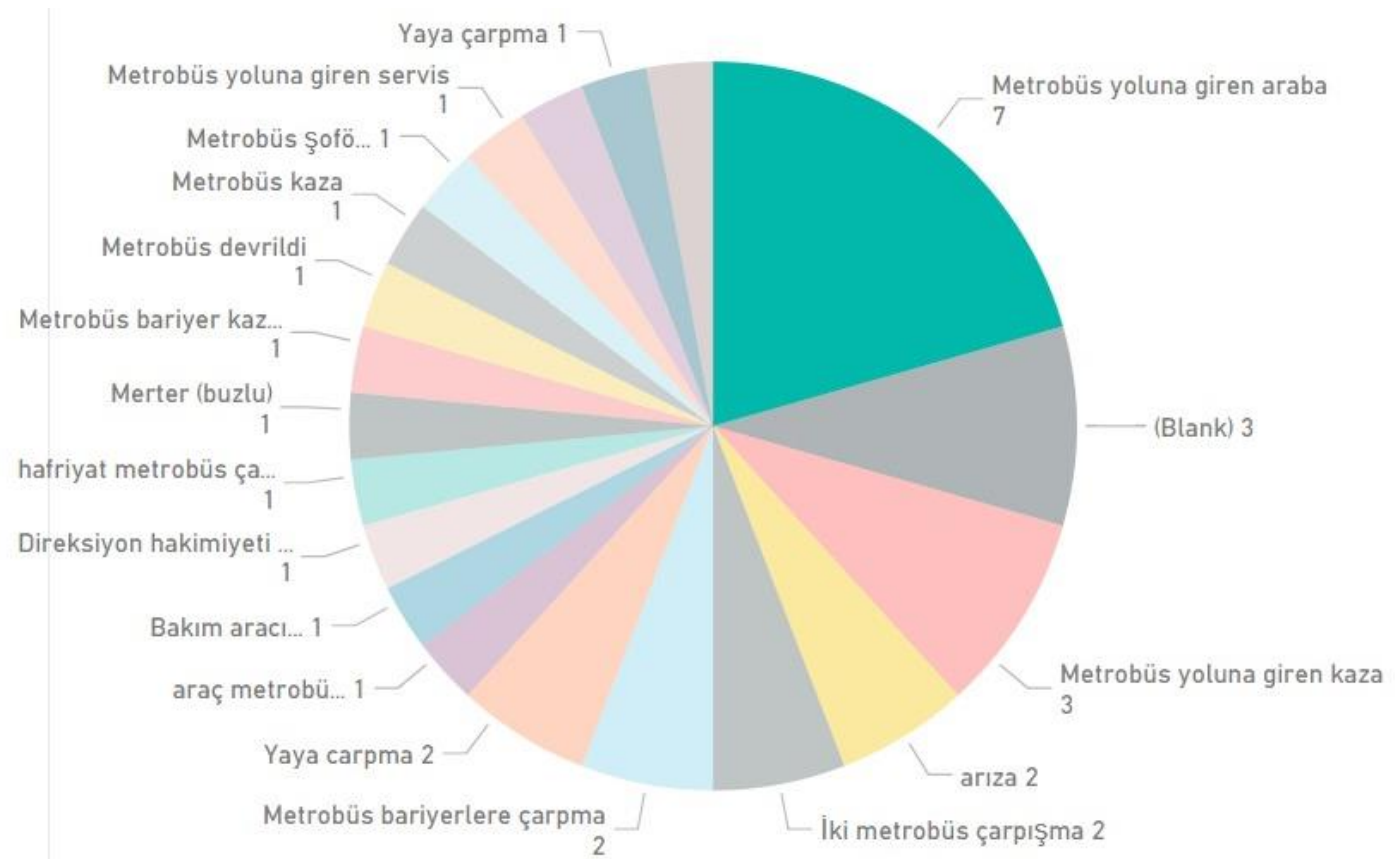


Image 1, 2 – Twitter Search Results for Istanbul Metrobus Line Accidents, 2017

MANY-TO-MANY: FRIDAY EVENING CRASHES

İncirli lies within Merter-Sefaköy section of D100 roadway. In the 3 month dataset, Friday evening crashes concentrated in D100 İncirli, almost as dense as the rest of the city roads combined.

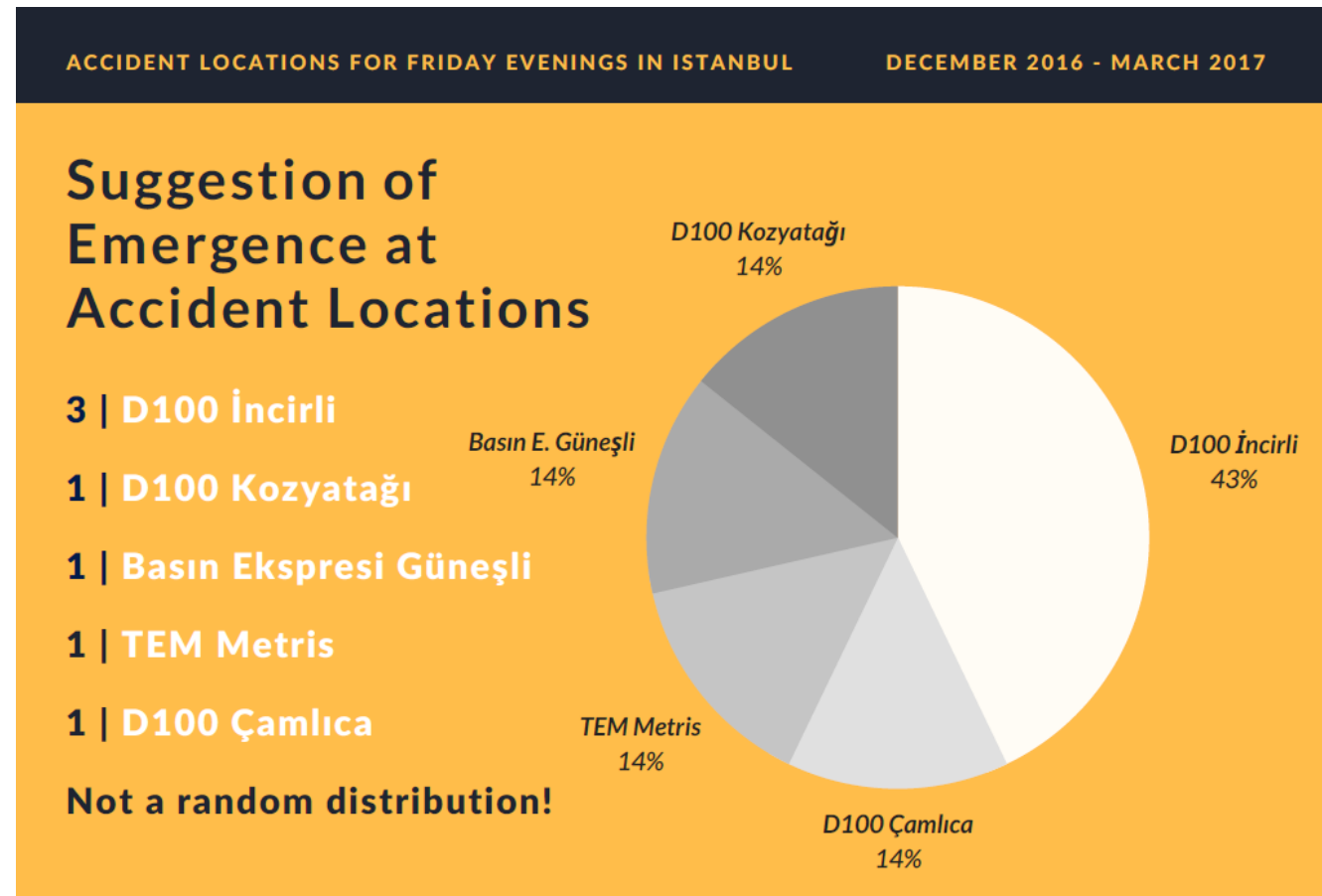


Image 1 – Istanbul Municipality Transportation Management Center Twitter Announcement, Twitter API, December 2016 - March 2017

CRASHES: PRODUCT OF AIRPORT DEMAND

D100 İNCİRLİ PRE-DECOMMISSIONING CRASHES AND CONGESTION ALERTS

Three weeks before:

29 traffic congestion alerts

13 crash alerts

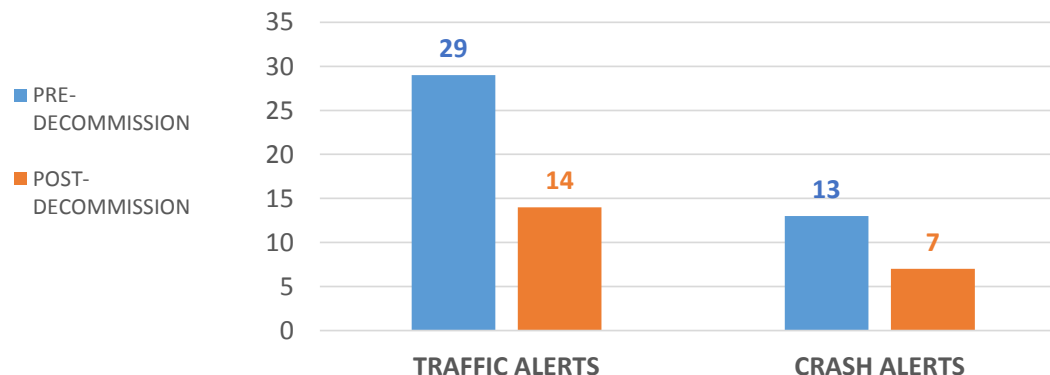
D100 İNCİRLİ POST-DECOMMISSIONING CRASHES AND CONGESTION ALERTS

Three weeks after:

14 traffic congestion alerts (-52%)

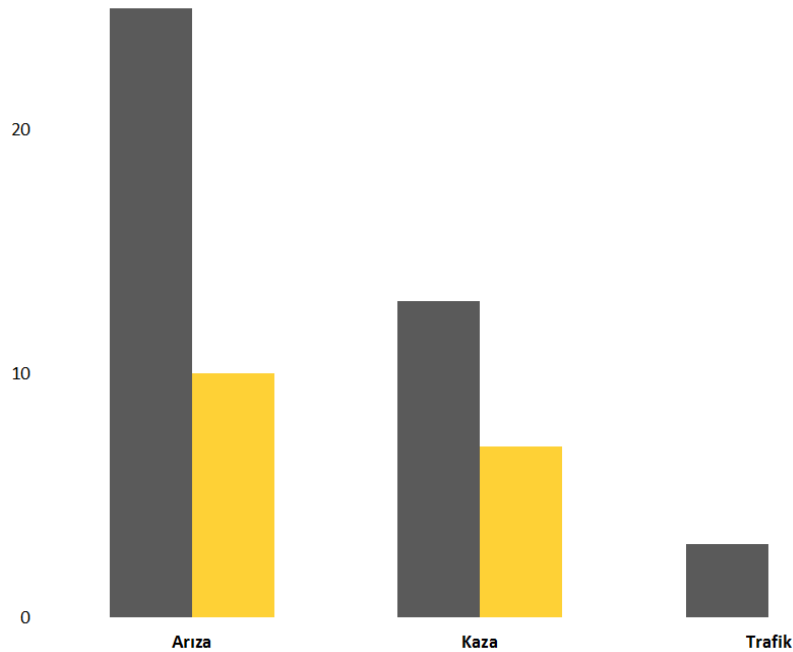
7 crash alerts (-46%)

PRE- VS POST- AIRPORT DECOMMISSIONING EFFECTS OVER
CONGESTION AND CRASHES

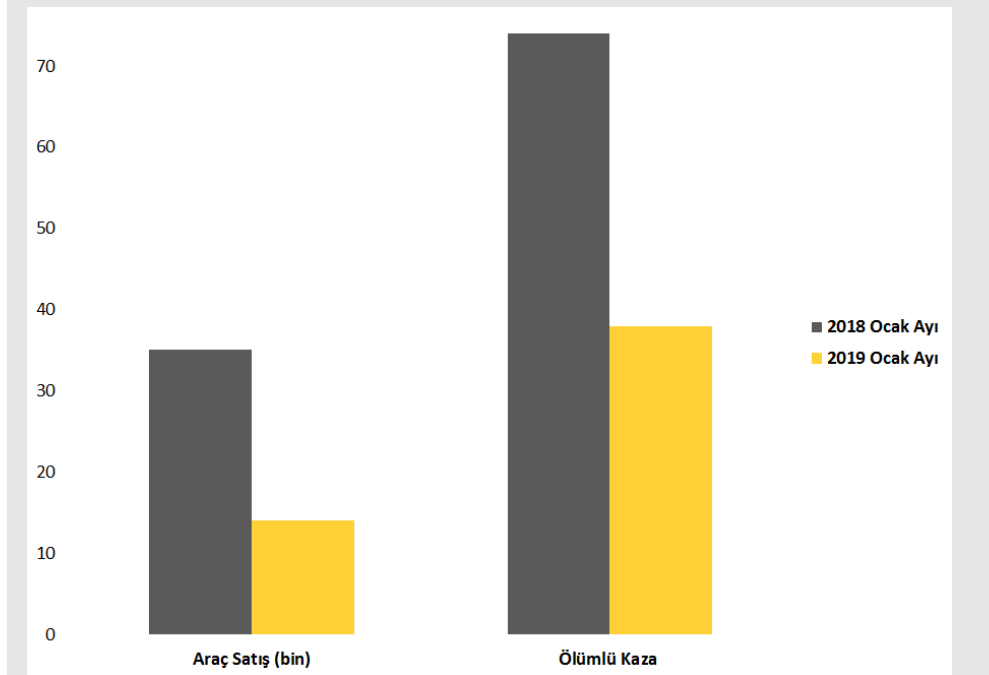


DEMAND-CRASHES: LINEAR RELATIONSHIP

2018-19 JANUARY VEHICLE SALES DROPS IN CRASHES AND BREAKDOWNS



2018-2019 JANUARY VEHICLE SALES DROPS IN SALES AND FATALITIES

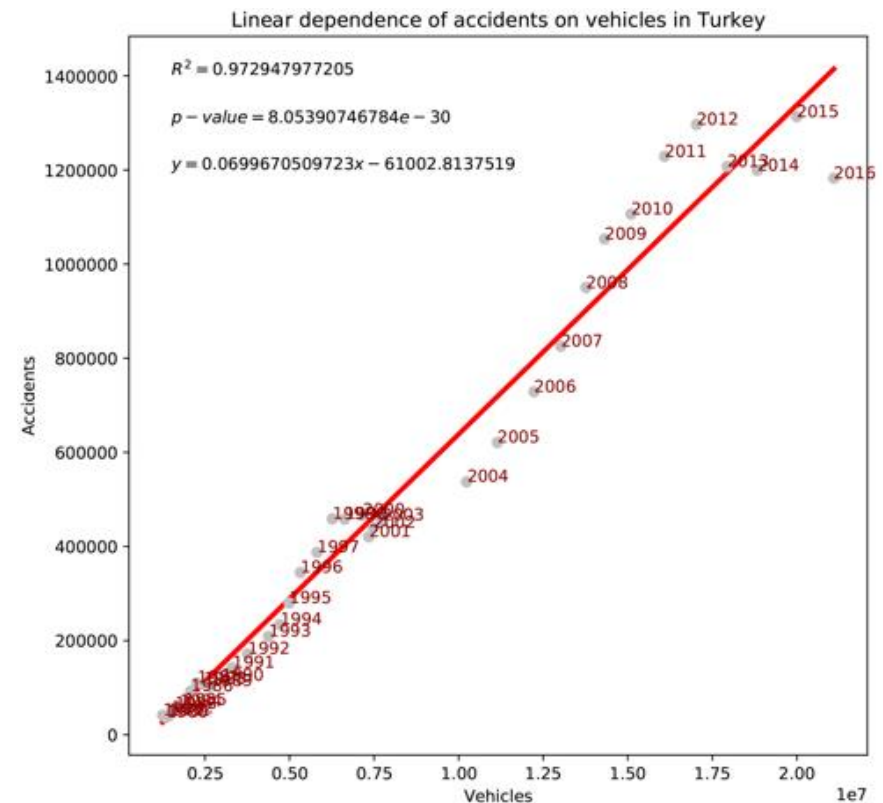


Alerts – Istanbul Municipality Transportation Management Center Twitter Announcement, Twitter Search, January 2018; January 2019
Drops in Automobile Sales in January 2019 - <https://alemicihan.com/post/182556630096/2019-ocak-ayi-otomobil-satislarinda-buyuk-dusus-yasandi>

VEHICLES VS CRASHES: TURKEY GRAPH

As registered vehicles have risen annually in Turkey, crashes have also risen proportionally. The 0.97 R^2 value is the indicator of this linearity.

However, there is also an expanding spiral that shows there is an additional property beyond linearity.



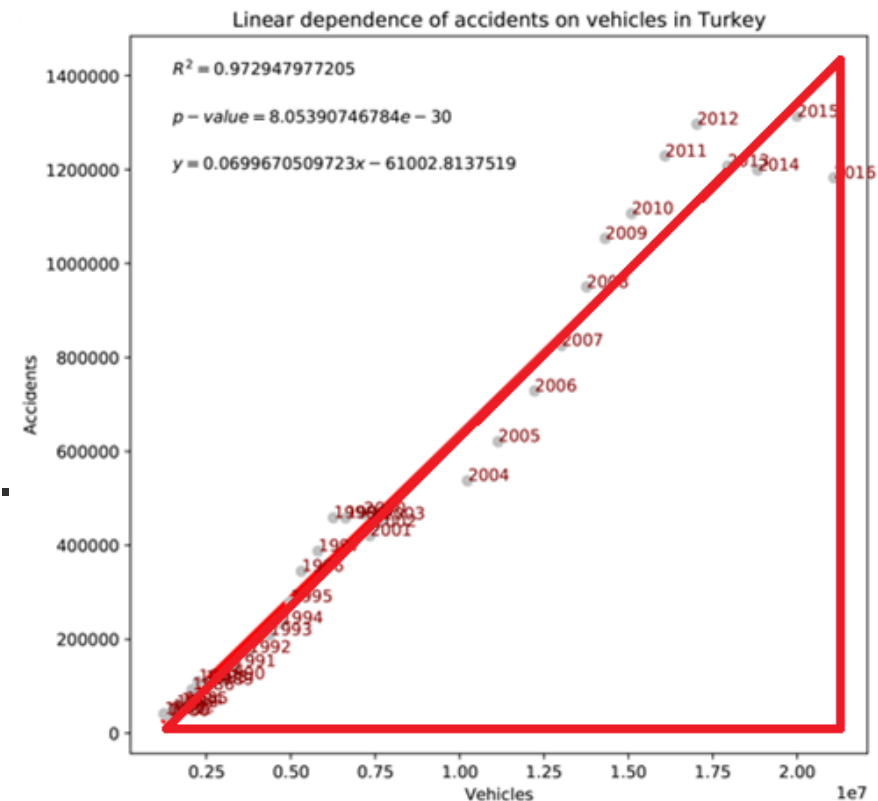
Data: Turkish Statistical Institute (TÜİK) - Annual Traffic Crash Report, 1988 - 2016

ONE-TO-MANY CRASHES: TURKEY GRAPH

LINEAR CRASHES

More vehicles causing more crashes is a counterintuitive property of traffic flow. More vehicles should lead to congestion, which should decrease crashes. Yet, as explained before, the opposite is the case.

One-to-many corresponds with linearity. Early morning crashes at bottlenecks is a clear indicator of heavy traffic demand.



Data: Turkish Statistical Institute (TÜİK) - Annual Traffic Crash Report, 1988 - 2016

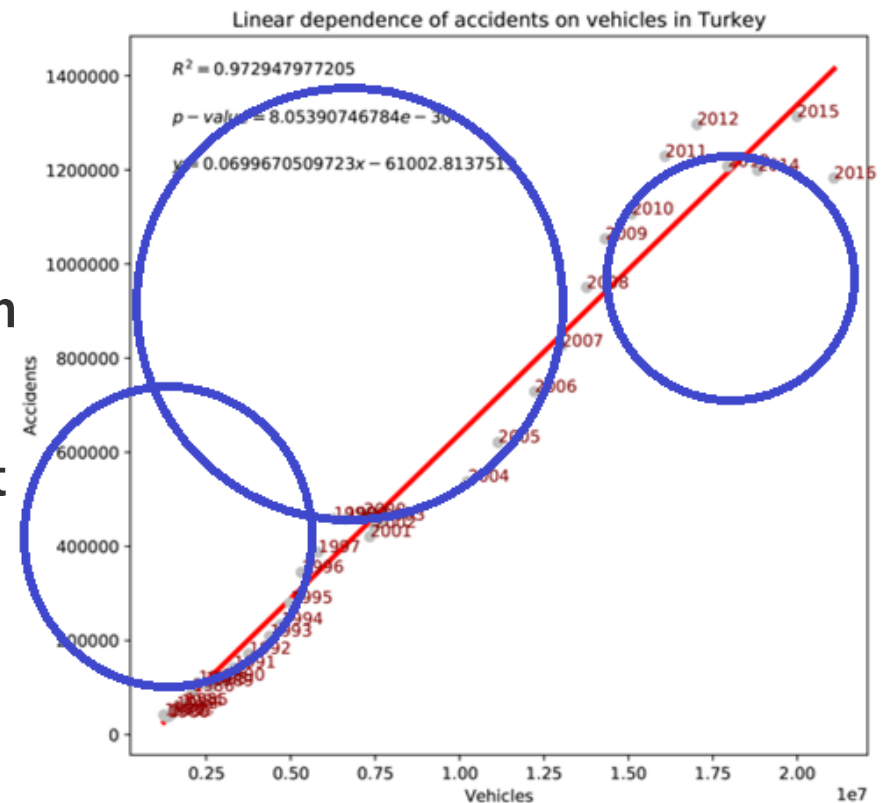
MANY-TO-MANY CRASHES: TURKEY GRAPH

NONLINEAR CRASHES

The spiraling distribution of accidents is not very easy to quantifiably explain.

Although certain economic downturns can be pinpointed (2001 economic crisis), the overall behavior of the graph is at the first glance not clearly visible.

To capture the driving force, a breakdown will be applied on city and vehicle scales.



Data: Turkish Statistical Institute (TÜİK) - Annual Traffic Crash Report, 1988 - 2016

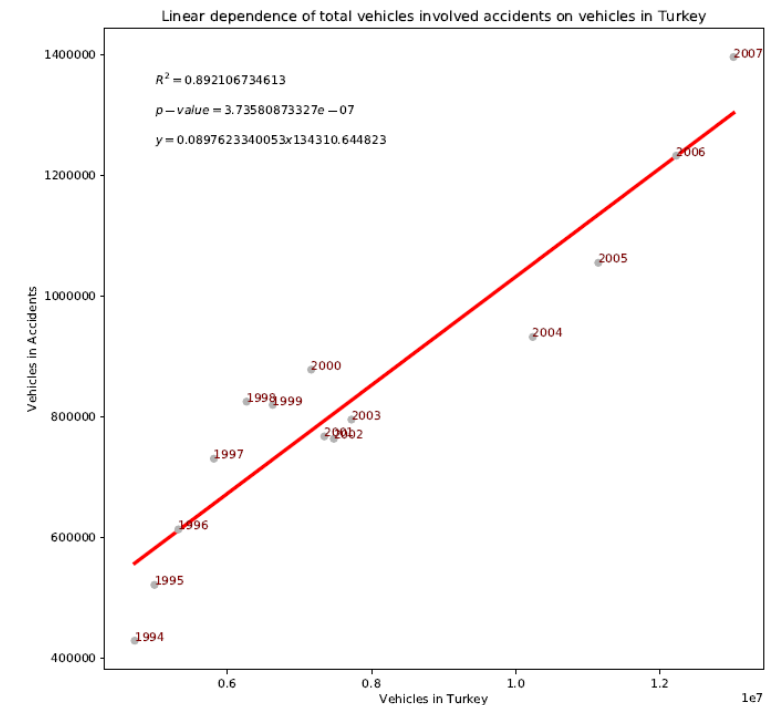
NONLINEAR CRASHES: VEHICLE TYPE

CITY AND VEHICLE SCALE DOWN

Turkish Statistical Institute's crash data per vehicle type and city is limited to 1994-2007. For total crashes, graph on the right is given.

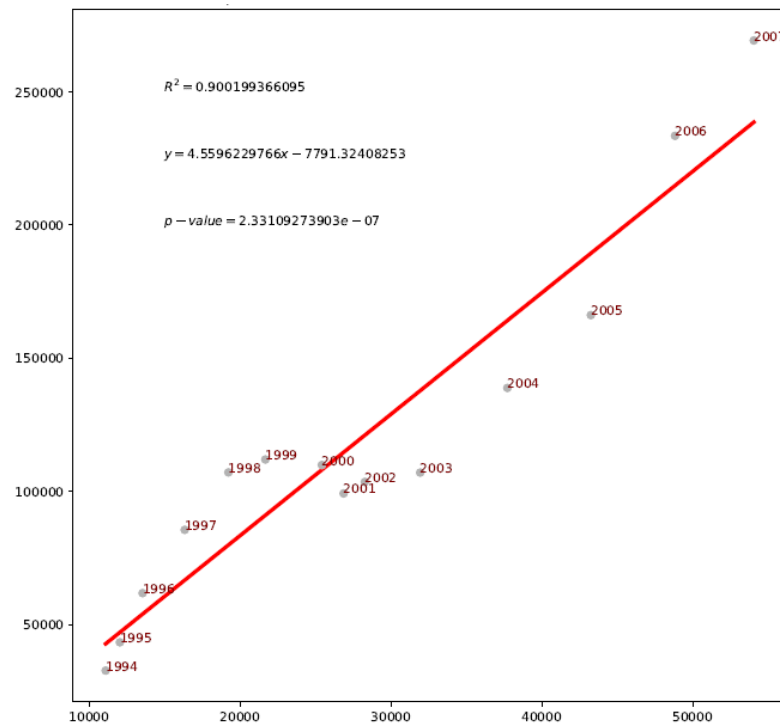
I have first scaled down crashes by municipal metropolitan cities, then by vehicle types.

Only vehicle type to maintain this symmetry must be the driving force behind crashes.

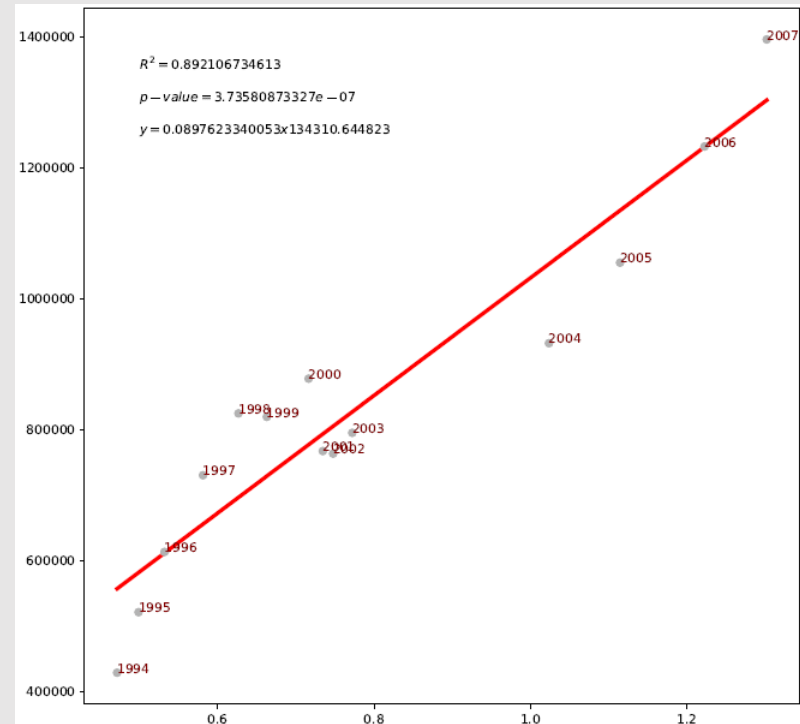


EMERGENCE: LIGHT TRUCKS / LCVs

LCV SYMMETRY IN ADANA



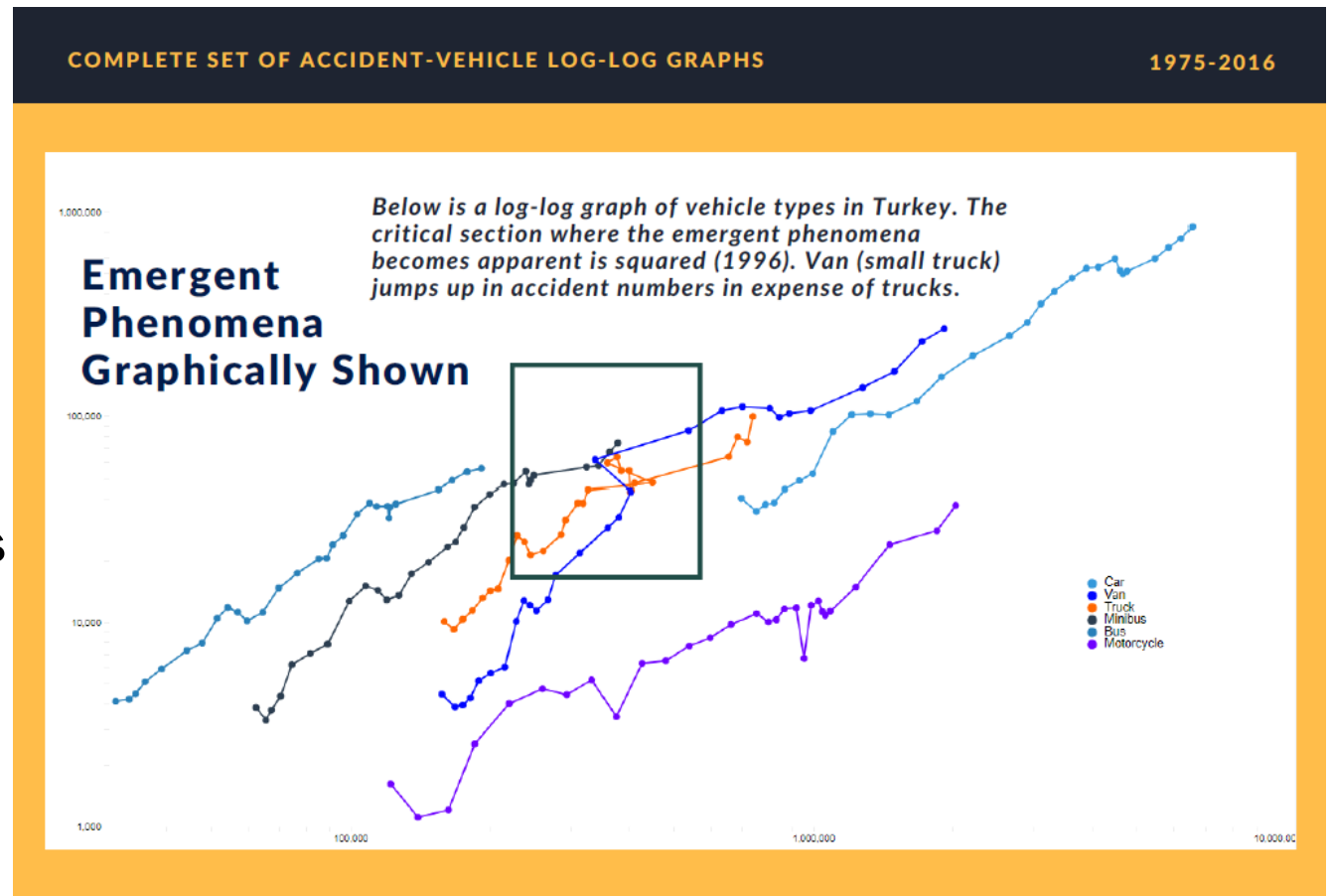
TOTAL VEHICLES SYMMETRY IN TURKEY



Data: Turkish Statistical Institute (TÜİK) - Annual Traffic Crash Report, 1994 - 2007

CRASH WEIGHT: LCVs INCREASING

On the log-log graph of all vehicle types in Turkey, vans (LCVs) appear to take over the trucks in the year 1996. This is in fact in the narrow streets of Turkish cities, LCVs are more maneuverable and better suited for the SME dominant Turkish market.



Data: Turkish Statistical Institute (TÜİK) - Annual Traffic Crash Report, 1994 - 2007

CURRENCY CRISIS: CAR IMPORTS HALT

CURRENCY CRISIS OF TURKEY

USD/TRY parity skyrocketed from 2.8 in 2016, to 8.1 in 2021, called **2018 Turkish currency and debt crisis**¹. Majority of vehicles are imports, and the currency rates crashed sales in 2018 and 2019.

TURKISH LIRA CRASH: DROP IN VEHICLE SALES 2018-2019

2016	1.214.610
2017	1.247.449
2018	903.274
2019	671.131
2020	1.038.905

2020: Government stimulus packages

METRO ISTANBUL NEW LINES: SURGE TO PUBLIC TRANSIT IN 2018 AND 2019

TOTAL DAILY TRANSIT RIDES:

2017: 12,939,000²
2018: 13,898,470³ +7%
2019: 15,148,333⁴ +9%

2020 not included due to pandemic lockdowns and travel restrictions.

More Istanbulites turned to public transit as their primary mode for commute.

Image 1: Turkish Statistical Institute (TÜİK) Biruni Central Distribution System <https://biruni.tuik.gov.tr/>

1 - https://en.wikipedia.org/wiki/2018_Turkish_currency_and_debt_crisis

2 - <https://www.gzt.com/jurnalist/istanbulda-toplu-tasimanin-sayisal-verileri-2798866>

3 - <https://www.ibb.istanbul/News/Detail/36320>

4 - <https://www.iETT.istanbul/tr/main/pages/istanbulda-toplu-ulasim/95>

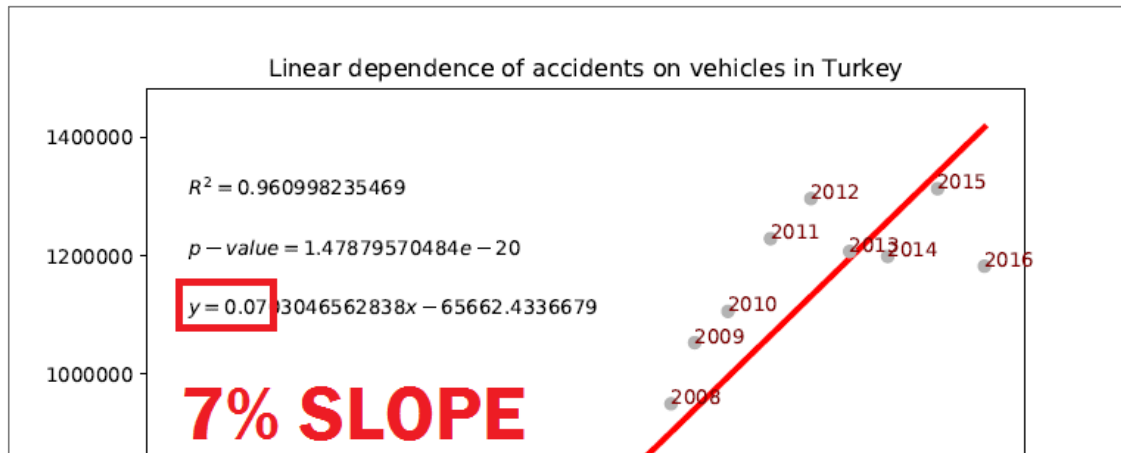
UNIVERSALITY: LADDERING OF SCALES

7% CRITICAL SYMMETRY

7% HEAVY VEHICLES IN D100 İNCİRLİ

7% HOURLY TRAFFIC IN D100 İNCİRLİ

Sales dictate on macro scale, black spots on micro. Critical micro-macro laddering is: **scale-free behavior**



Universality: The emergence of 7% in the **crash-vehicle graph's slope**, the **many-to-many black spot heavy vehicles distribution** and its **hourly traffic ratio** is a universal pattern.