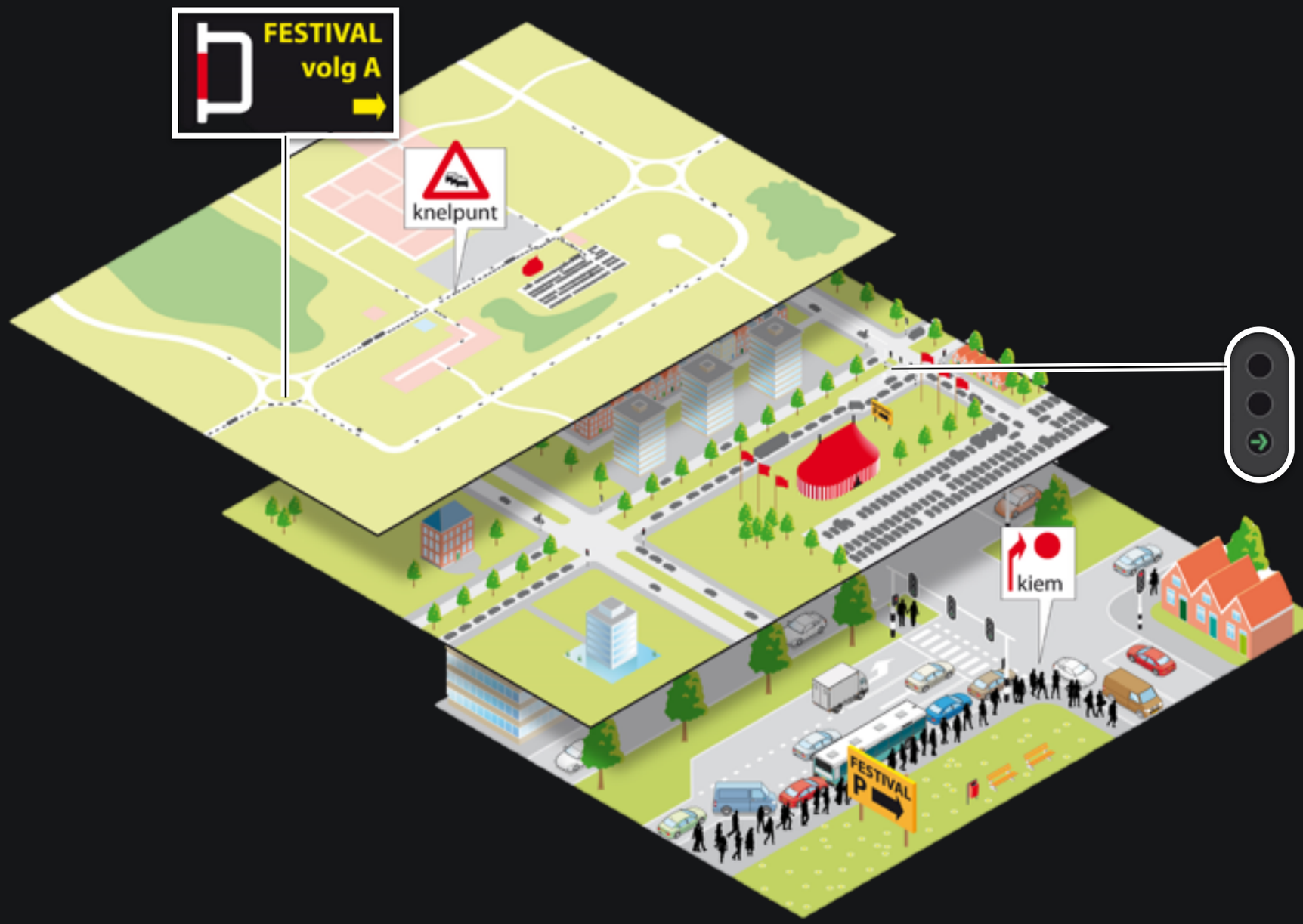



# Rule based approach

## to traffic management

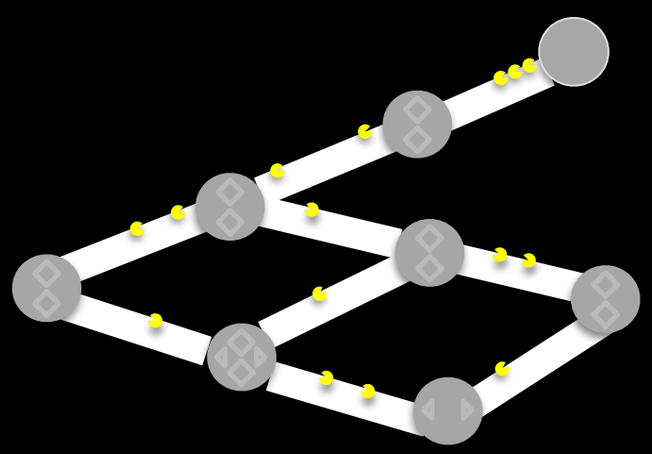
# It's all about ...

… the road user's experience who is driving a smarter car with more technology.

# SUMMERY

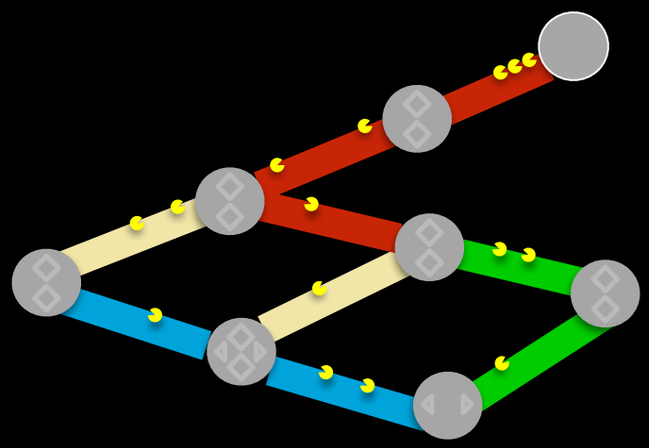
**NETWORK:**

- **Flow control points: {$A_n$}**
- **Decision points: {$B_n$}**
- **Link: {Ln($A_n$, $A_m$)}**
- **RouteSegment: {$RS_n$($B_n$, $B_m$)}**



**POLICY**

- **ROAD PRIORITY: P($L_n$)**
- **CAPACITY NORM: N($L_n$) -> #**
- **TRAVELTIME NORM: T($RS_n$) -> #**
- **Services: {$S_n$($A_n$), $S_m$($B_n$)-> PO, DI, RR}**
- **Restrictions: R($S_n$) -> 0,1**

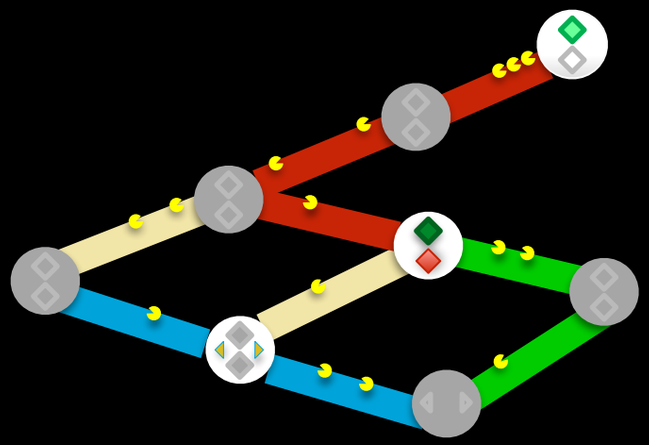


**DECISION**

- **SELECTION: D($S_n$, N($L_n$), A($L_n$) )-> 0, 1**
- **AVAILABLE: R($S_n$, T($RS_n$), A($RS_n$)) -> 0, 1**
- **CONFLICTS: C(A($S_n$), A($S_m$)) -> 0, 1**

where

the actual status of a link, route segment er service is represented by the function A()



download proceedings paper at: ceur-ws.org/Vol-1875/paper8.pdf




# Silvie Spreeuwenberg

road user
background in AI
expert in business rules
professional in IT
designer of controlled languages

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# The road user is not the only stakeholder.

Each road authority balances safety, air quality and economical factors in it's policy.

Custumer: LVMB

collaboration of all road authorities in the Netherlands

Assignment

Collaborate and standardize the operation,

… such that the road network is used in an optimal way.

**Technology may change but policy and responsibility will not change.**

Which roads must have good traffic flow?

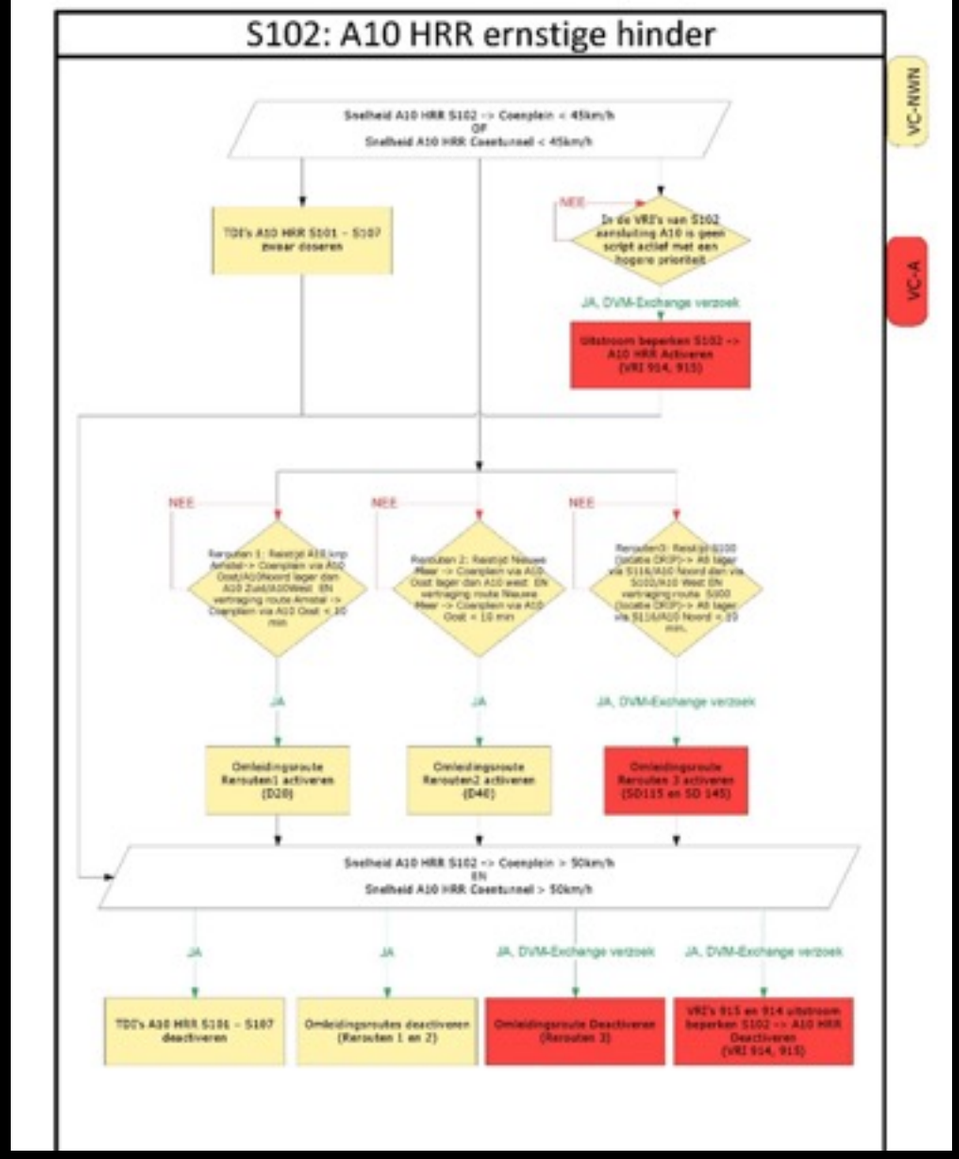
Where may traffic delays occur.

Is a detour allowed when the school go out?


Reference:
www.rijkswaterstaat.nl/english

# practical issues with response plans





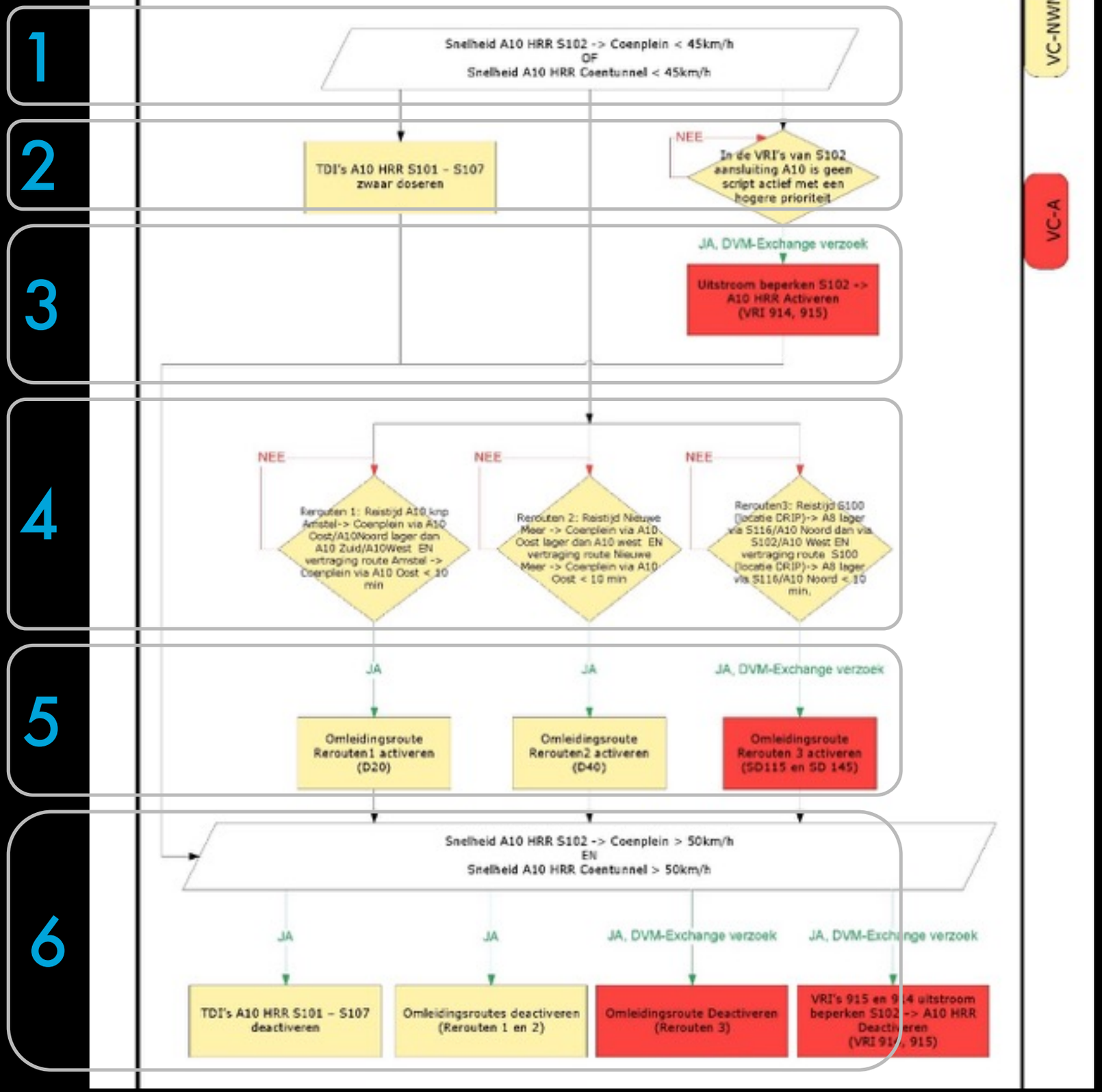

PDF document

20 - 30 pages

protocol

# what are we doing ?

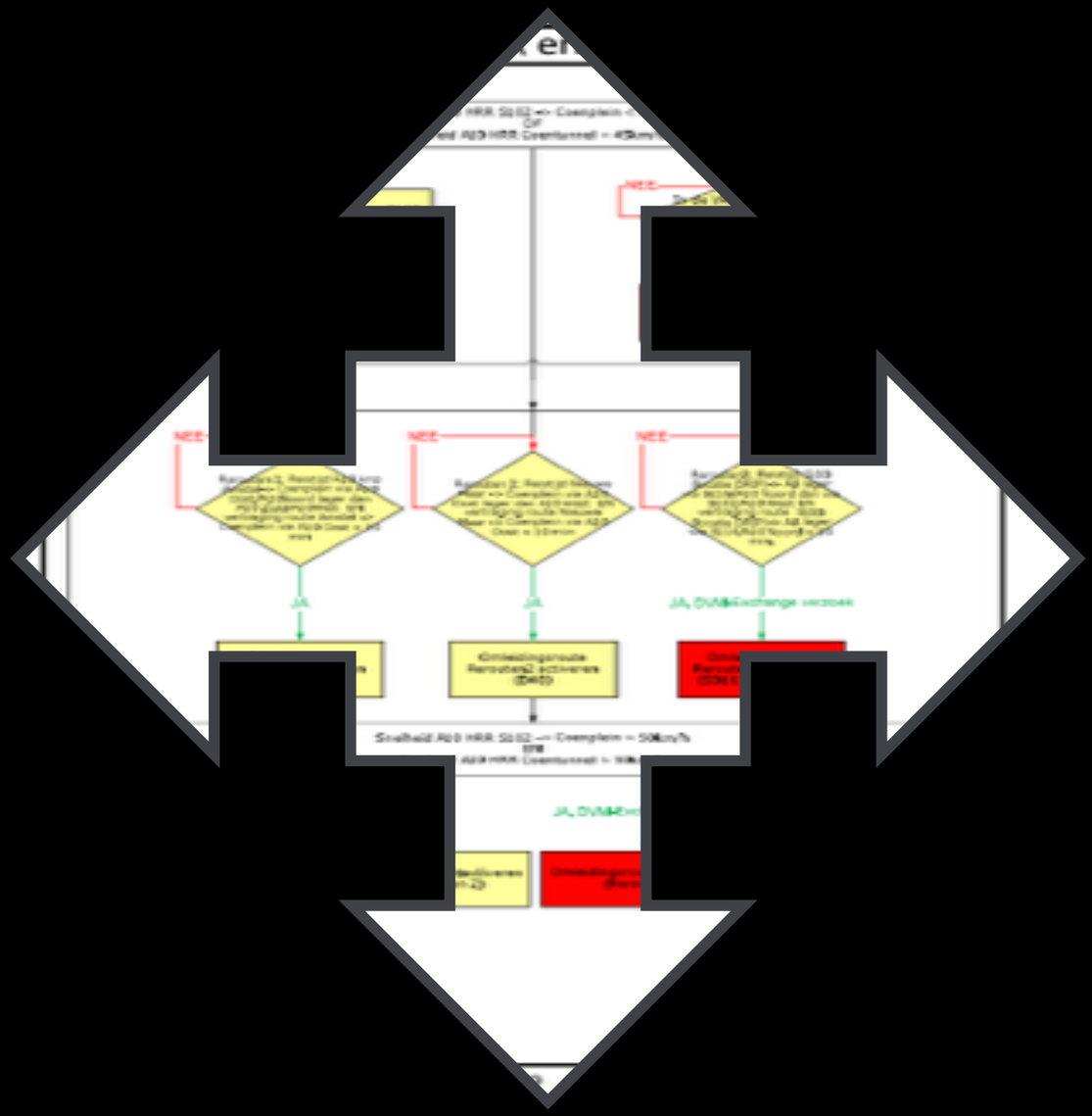
1. Determine traffic situation
2. Handle conflicts
3. Optimize road capacity
4. Check restrictions
5. Inform road user about reroute
6. Back to normal



# too many, too complex and difficult to automate

Detect problem

Restrictions



Conflict handling

Problem solution

**Define once …**

**… use in multiple situations**

# IF [1] THAN [2] UNLESS [3] & [4] UNTILL [5]

1. **Turn on condition** → • MUST, GOAL — OBLIGATION -
   Based on the policy and agreements between all road authorities

2. **Services**
   Offered by a road authority

3. **Restriction on service** → • MAY NOT, NOT PERMITTED
   Based on the policy and agreements between all road authorities

4. **Confict detection** → • CAN NOT, NOT POSSIBLE
   Instrument is in use by service with higher priority.

5. **Turn off condition** → • MUST, OBLIGATION
   Based on the policy and agreements between all road authorities

# Policy

No delays allowed on city ring

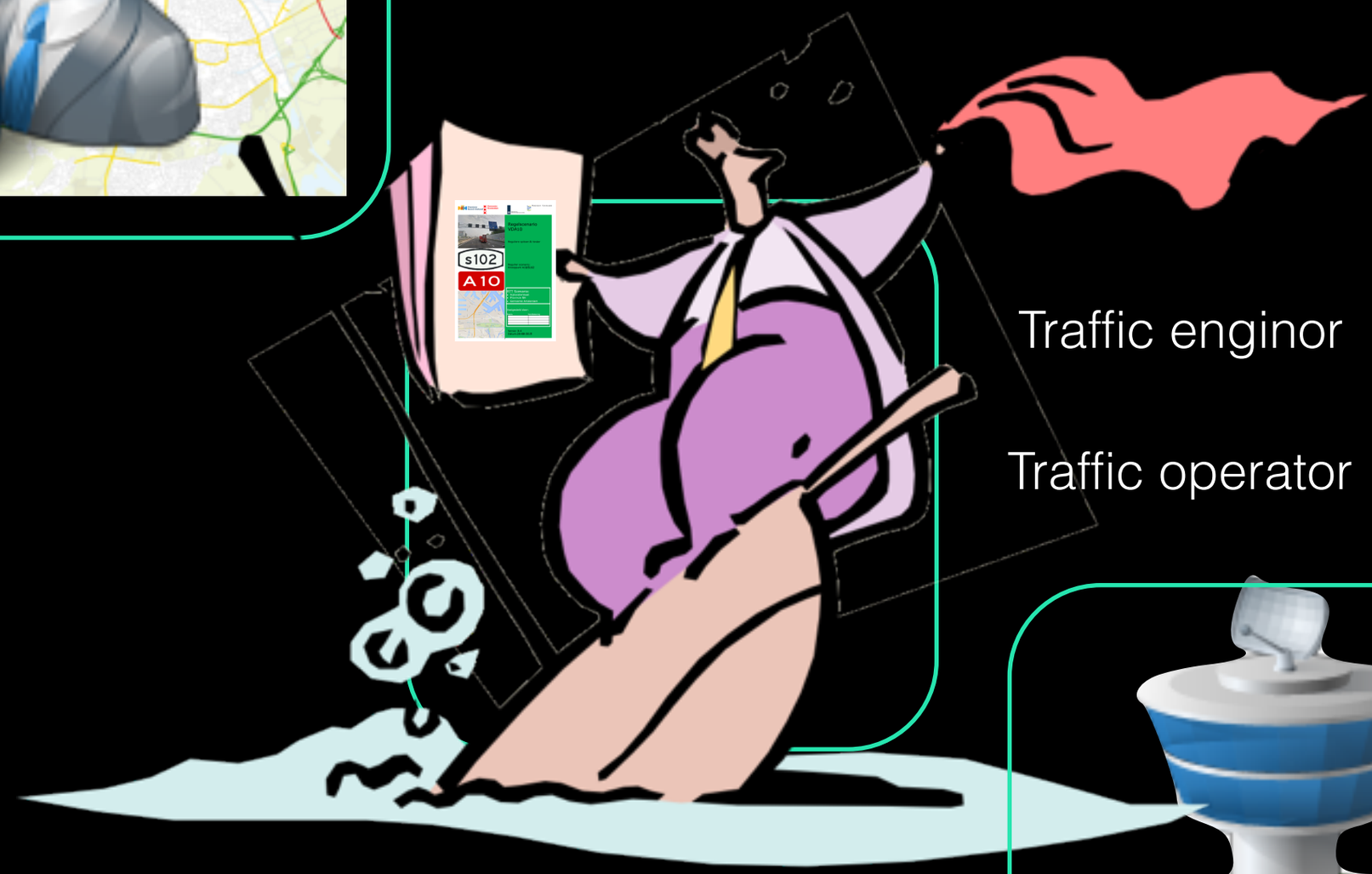
# Rules

Reroute traffic when
traffic time drops


# Operational execution

After a football match turn on reroute
U2 on display D25

# People make things work




Traffic enginor

Traffic operator

Rule based traffic management

**Why?**


**RBTM**

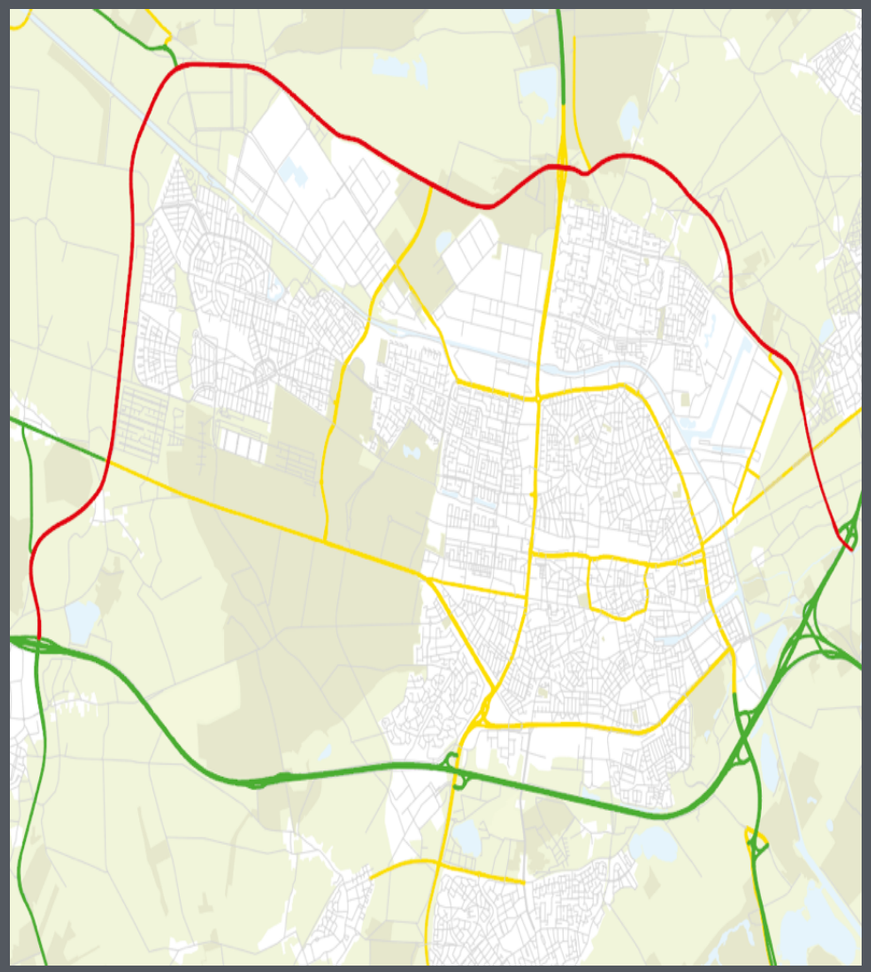
**How?**

…. connects policy to operations

# ingredient 1: policy

## Joint vision road authorities

### Road priority map



### Traffic management norms

| Kind of road | Speed limit | Optimal speed | Norm |
|---|---|---|---|
| Highway | 100 | 85 | 65 |
| Provincial highway | 100 | 85 | 50 |
| Provincial road | 80 | 65 | 40 |
| City road | 50 | 35 | 20 |
| City inner ring | 50 | 35 | 20 |
| City connection road | 70 | 60 | 40 |

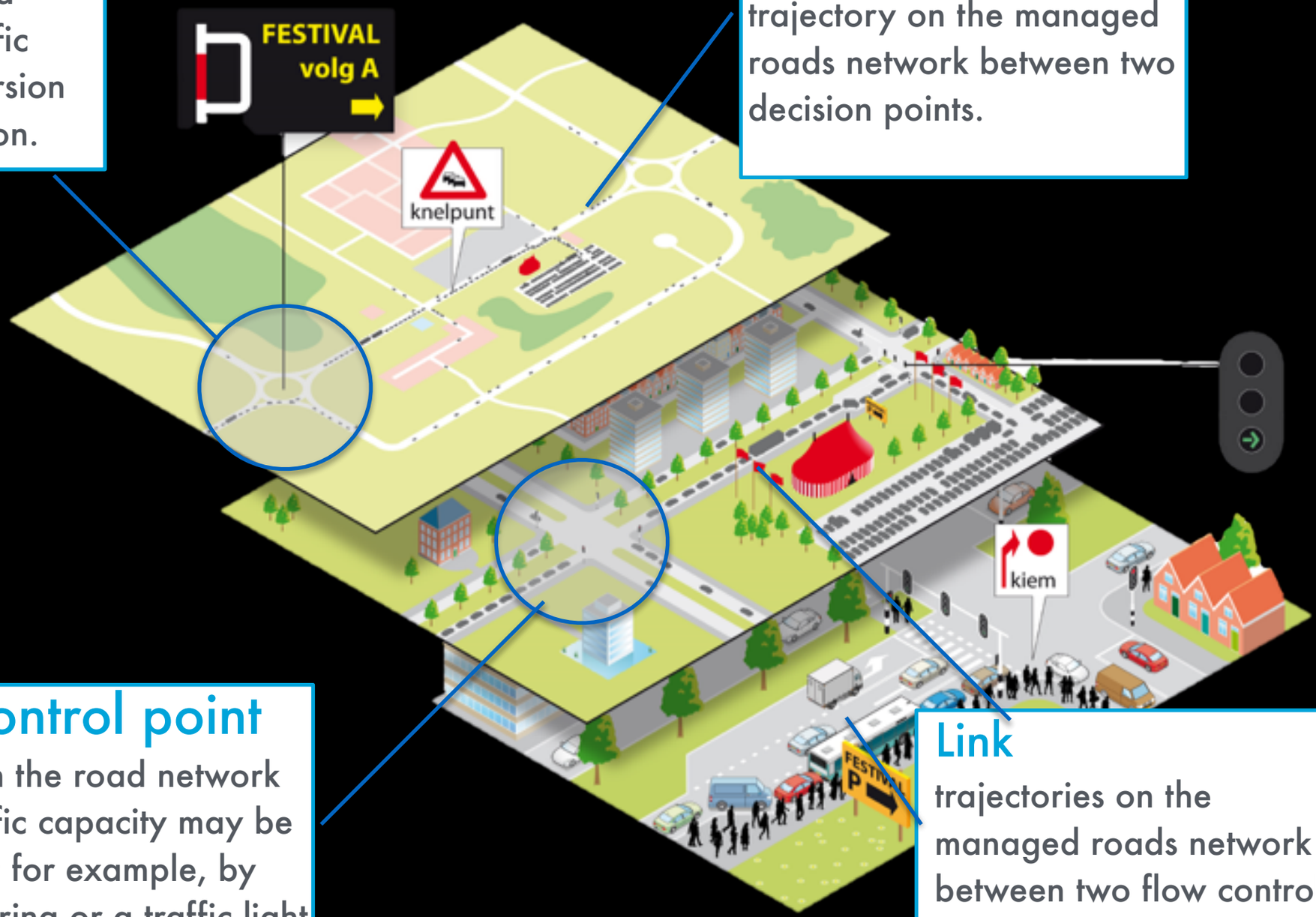
# ingredient 2: network

## Decision point

location on the road network where traffic may choose a diversion route to a destination.

## Route segments

trajectory on the managed roads network between two decision points.




## Flow control point

location on the road network where traffic capacity may be influenced; for example, by ramp metering or a traffic light system.

## Link

trajectories on the managed roads network between two flow control points for each driving direction

# ingredient 3: services

Three **standard** services define what we do:

1. Increase outbound flow
2. Decrease inbound flow
3. Reroute


Service = Setting for traffic control device + Restrictions

# ingredient 4: decision logic

The rule based traffic management (RBTM) has four principles that determine which service must be requested.

I. Prevent saturation on a link by early detection of bottlenecks and capacity services.

II. Optimize travel time on route segments by reroute services.

III. Turn down a service request when traffic conditions violate the policy constraints.

IV. Manage conflicting service requests by turning down the service requested from the least severe traffic situation.

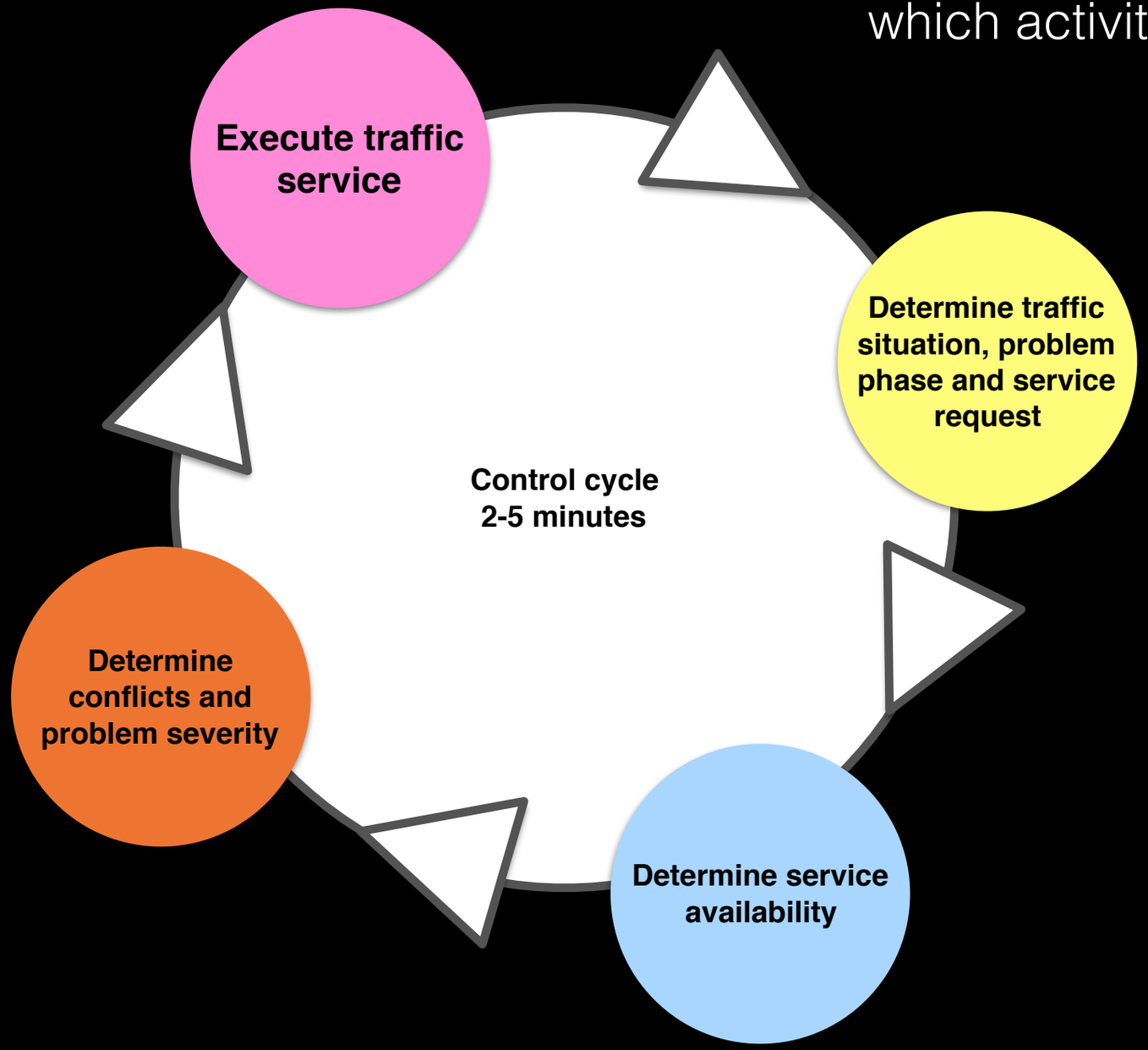
Hmm… work by principle, sounds good.

What should I do ?!?!

**Each principle translates to a set of generic business rules.**

# decision logic to control the order of activities

Answer the question:
which activity should be executed ?



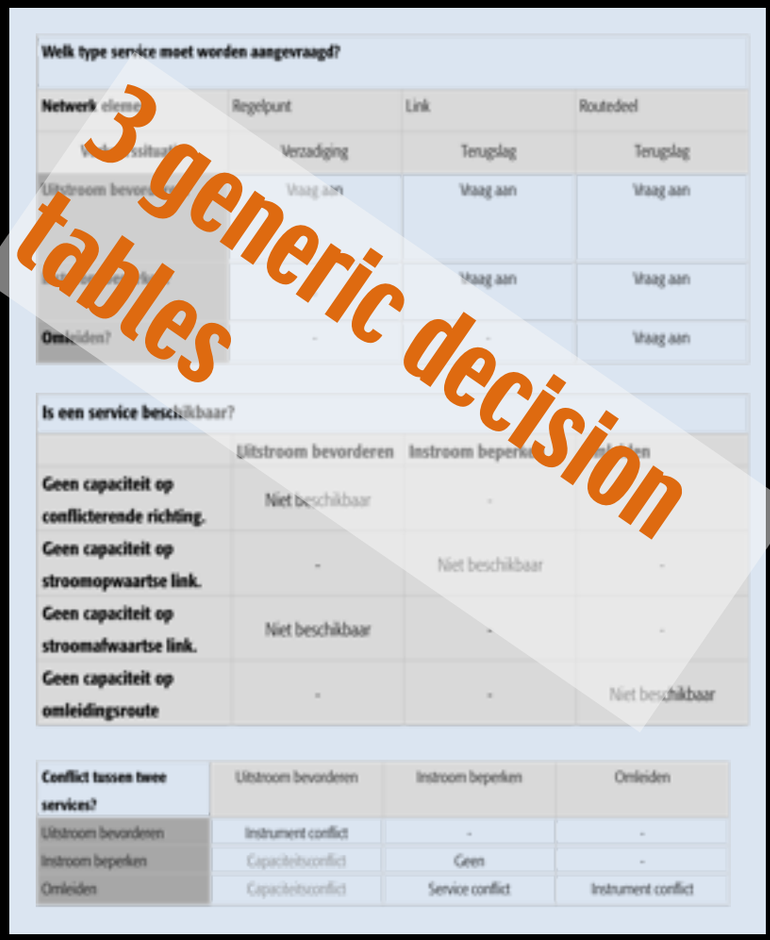

This process is normally implemented in an advanced traffic management system.

# decision logic to request a service

Answer the question:
which kind of service should be executed
and is that allowed ?

- Request a service
- Define restrictions
- Detect a conflict

The decision tables follow the standard ‘Decision Model Notation’ (OMG , 2014) as ‘rules as cross-tab’ or ‘rules as columns’, tables are complete and single hit.



# decision table to request a service

| Which kind of service to request? | | | | |
|---|---|---|---|---|
| | | | **Problem phase:** | |
| | | Saturation | Congestion | Gridlock |
| **Service** | **Promote outbound?** | Request | Request | Request |
| | **Limit inbound?** | - | Request | Request |
| | **Reroute?** | - | - | Request |

DMN: ‘rules as cross-tab’, complete, unique hit policy.

- : means that there is no outcome hence the service is not requested

# decision table to define restrictions

| Is a service available? | | | |
|---|---|---|---|
| | **Promote outbound** | **Limit inbound** | **Reroute** |
| **No capacity on conflicting direction.** | Not available | - | - |
| **No capacity on upstream link.** | - | Not available | - |
| **No capacity on downstream link.** | Not available | - | - |
| **No capacity on diversion route.** | - | - | Not available |

If the restrictions of a service are not satisfied, then the service is not available and will not be executed.

DMN: ‘rules as cross-tab’, complete, any hit policy.

# decision table to detect a conflict

| | | **Kind of service:** | |
|---|---|---|---|
| **Are two services conflicting?** | Promote outbound | Limit inbound | Reroute |
| Promote outbound | Instrument conflict | - | - |
| Limit inbound | Capacity conflict | No | - |
| Reroute | Capacity conflict | Service conflict | Instrument conflict |

Conflict resolution strategy: when a conflict is detected the service requested by the road with highest priority is executed.

Capacity conflicts are not solved, both services are executed.

DMN: ‘rules as cross-tab’, complete, unique hit policy.

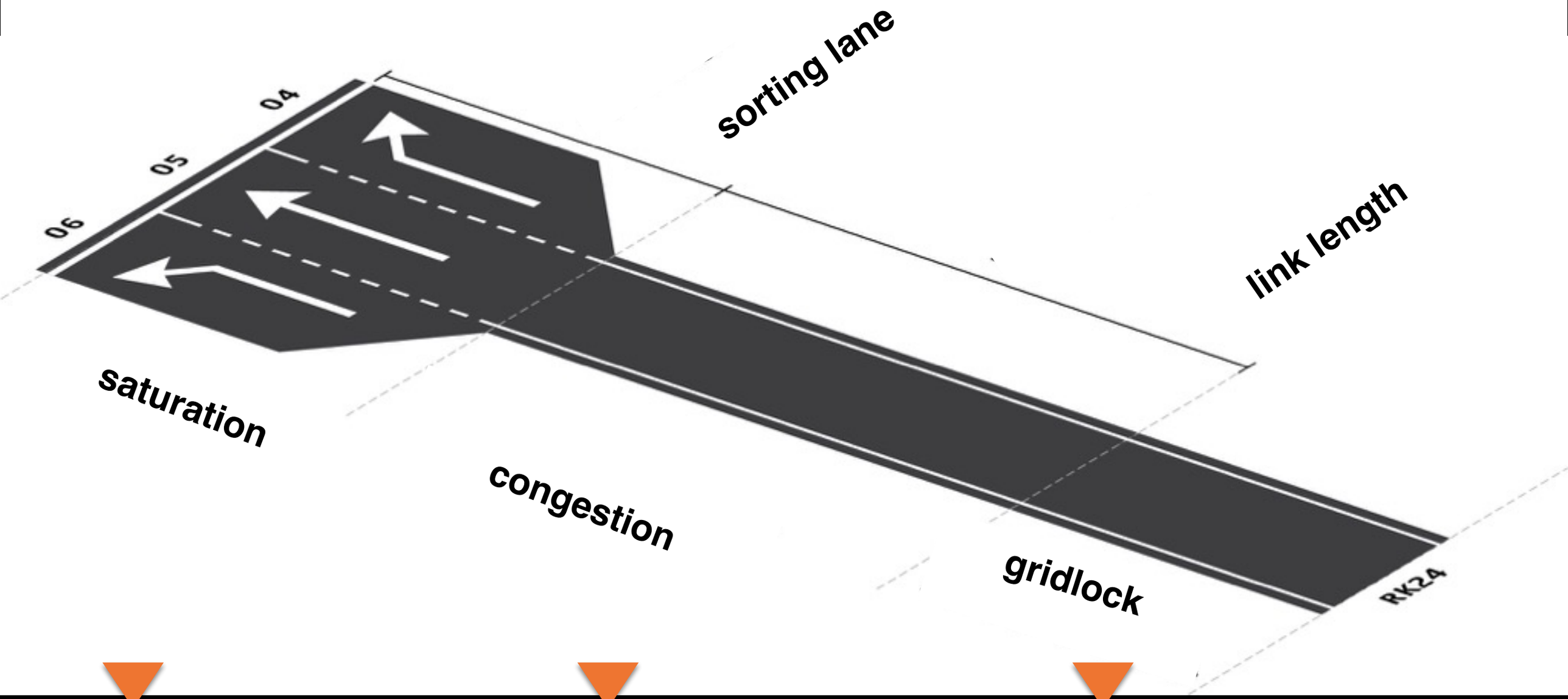
# decision logic to categorize traffic situation

Answer the question:
is a traffic situation undesired and
how severe is the situation?

| **What is the problem phase?** | | | |
|---|---|---|---|
| **Topology:** | Link | Link | Route segment |
| **Waiting queue:** | >90% of sorting lane length | >90% of link length | - |
| **Travel time:** | - | - | > 90% of travel time norm |
| **Saturation?** | Yes | - | - |
| **Congestion?** | No | Yes | - |
| **Gridlock?** | No | No | Yes |
| priority | 1 | 2 | 3 |

DMN: ‘rules as columns’, priority hit policy.

# example link

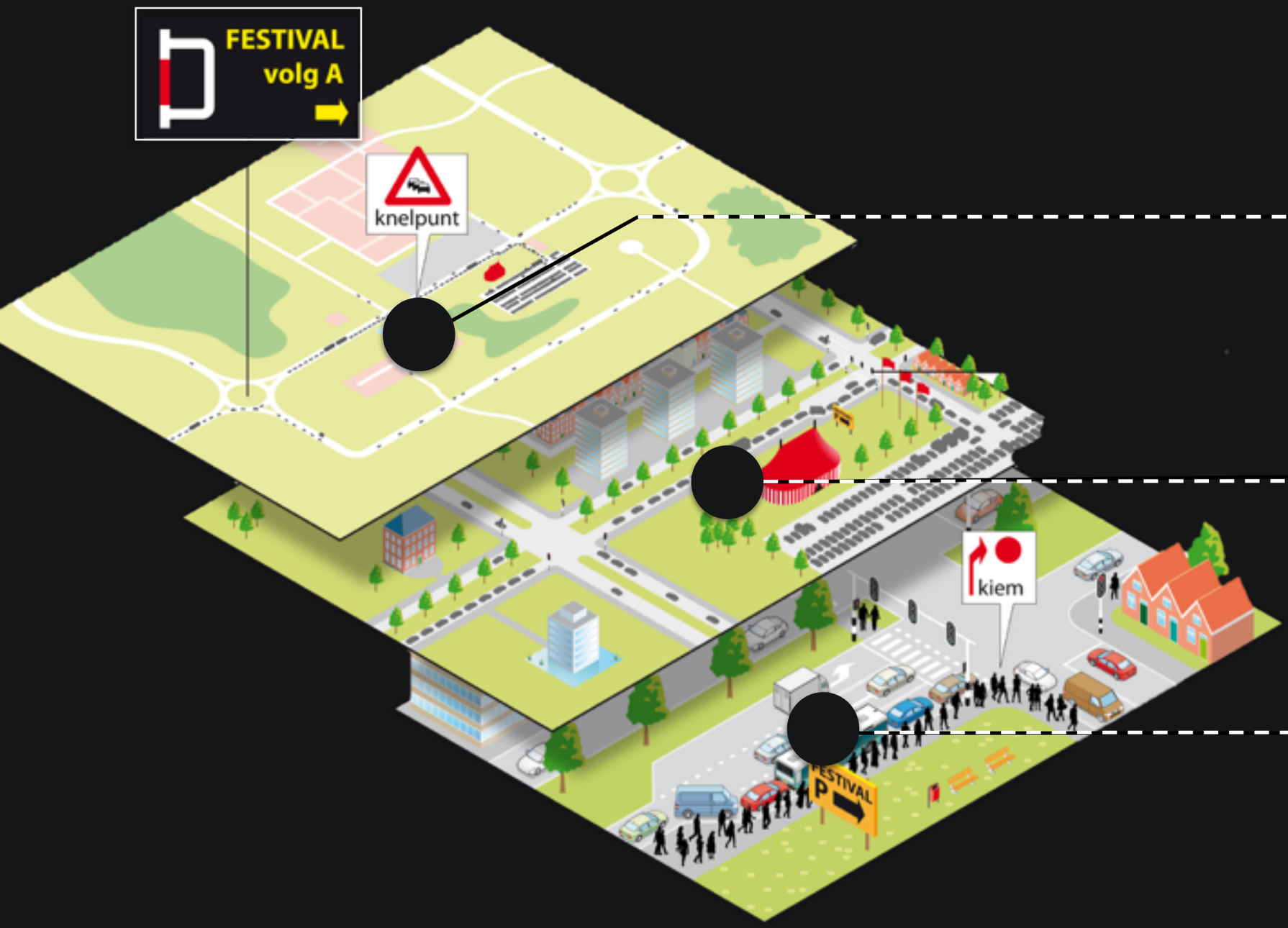



Reroute

Limit inbound

Promote outbound

# each link is a sensor



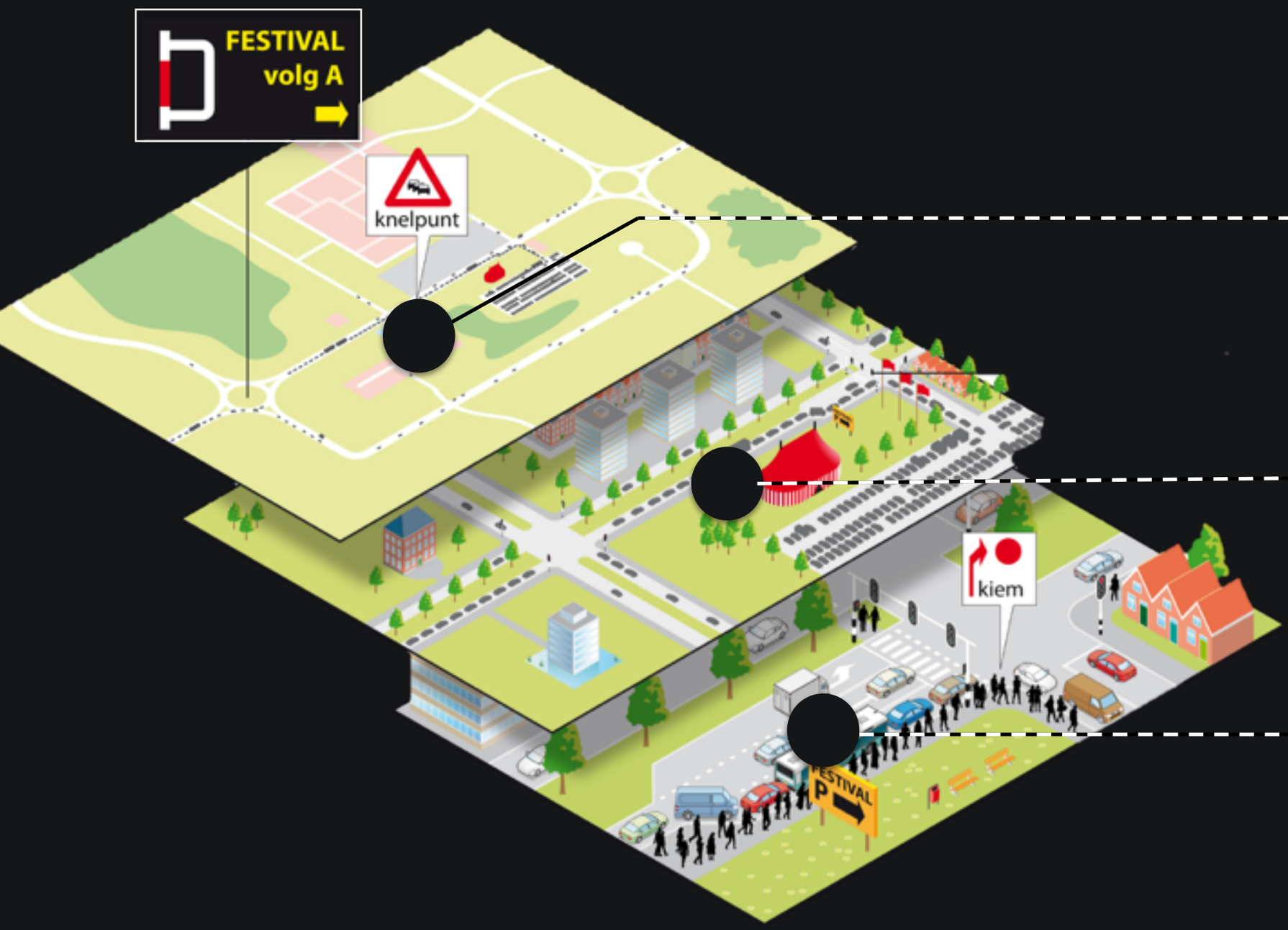

3 standard problem phases:

Gridlock

Congestion

Saturation

# actions on network nodes




3 standard services

Reroute

Limit inbound

Promote outbound

# overview on a map

*Legenda:*

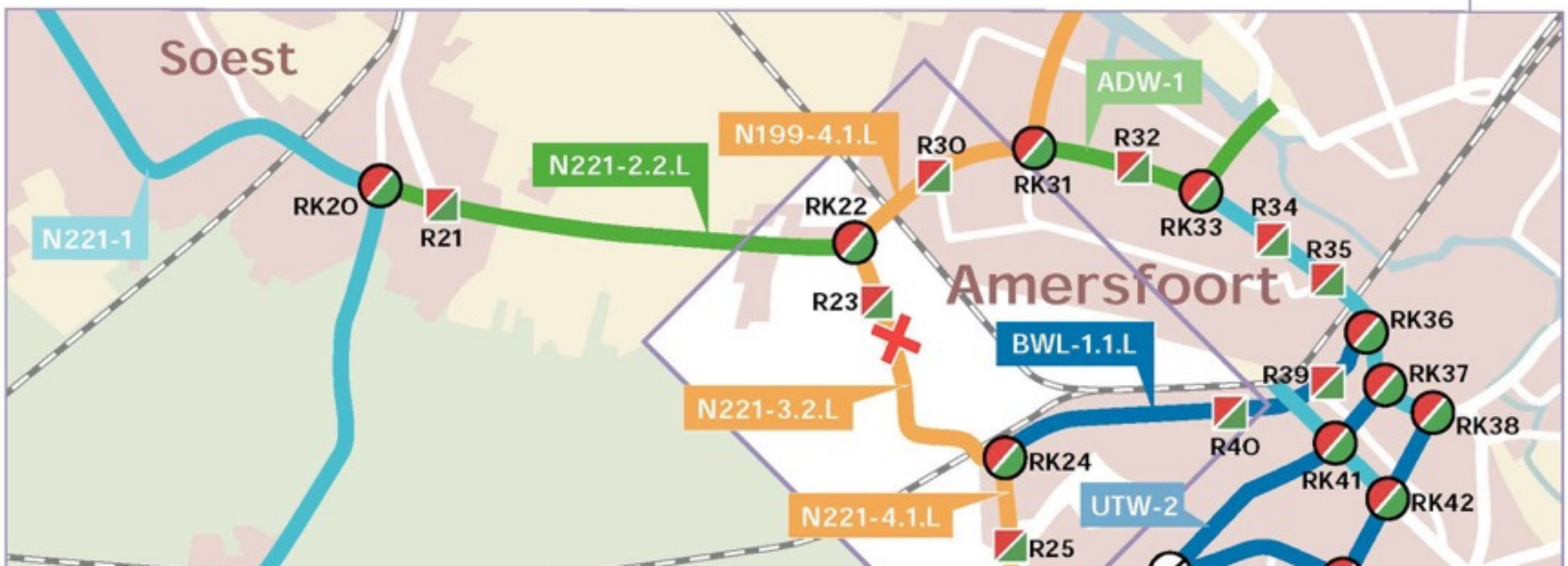
| | | |
|---|---|---|
| | | Kiem |
| | R | Regelpunt |
| | K | Keuzepunt |
| | RK | Regel- en keuzepunt |
| | RK | Regel- en keuzepunt met informatieservice |
| | RK | Samengesteld regel- en keuzepunt |

Prioriteit weg

1
2
3
4
5

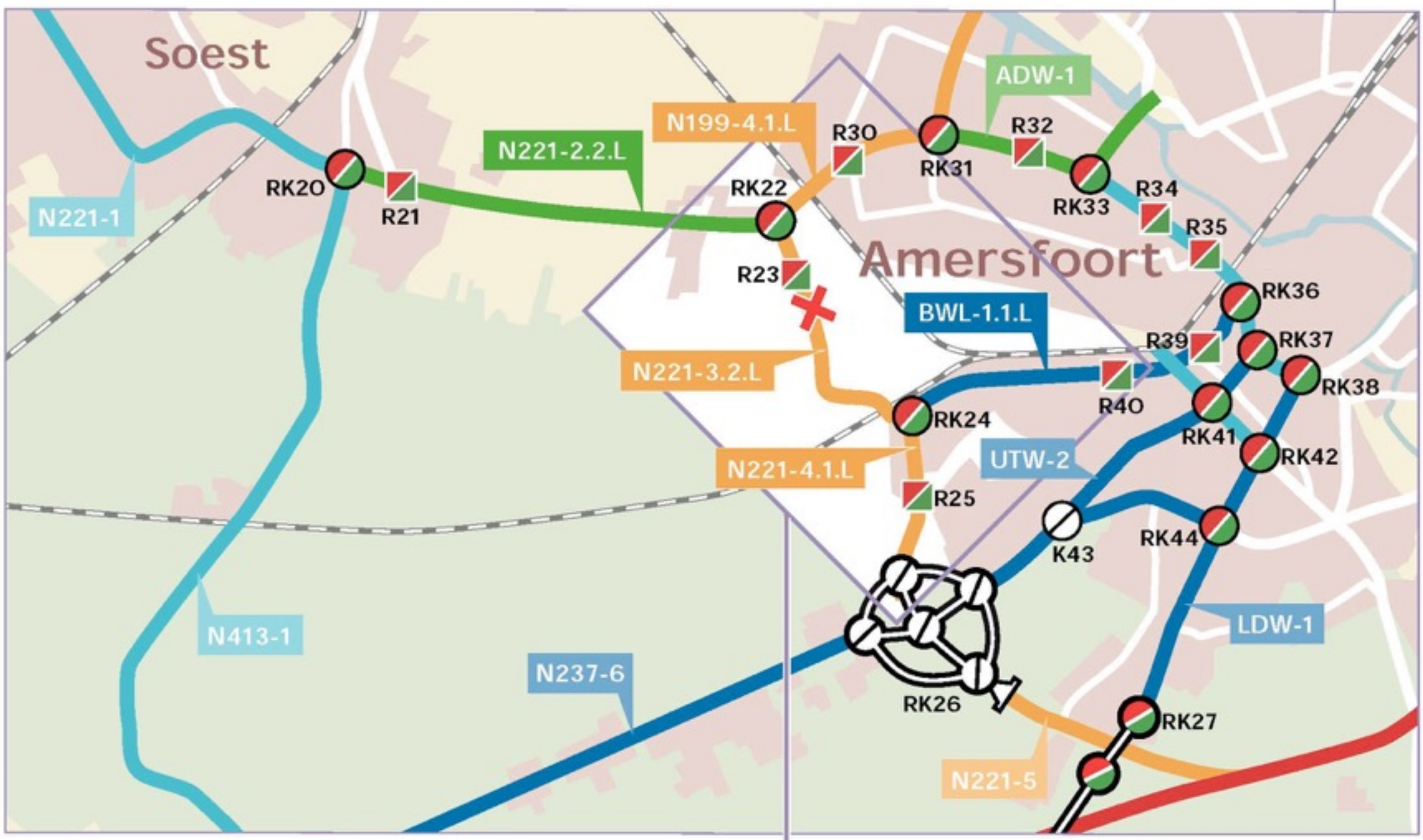
N221-3.2.L

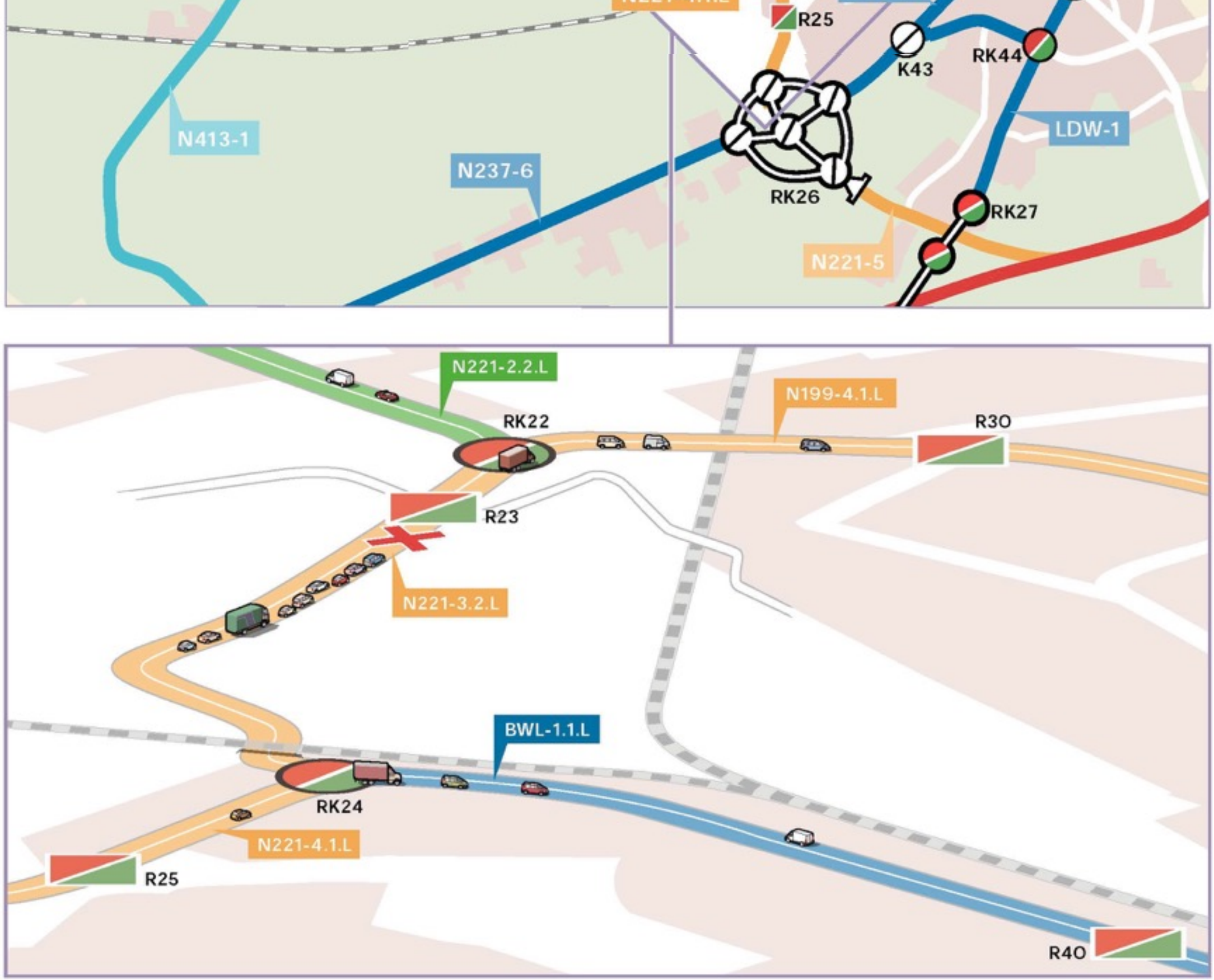
- wegnummer
- nummer routedeel
- nummer link
- richting link

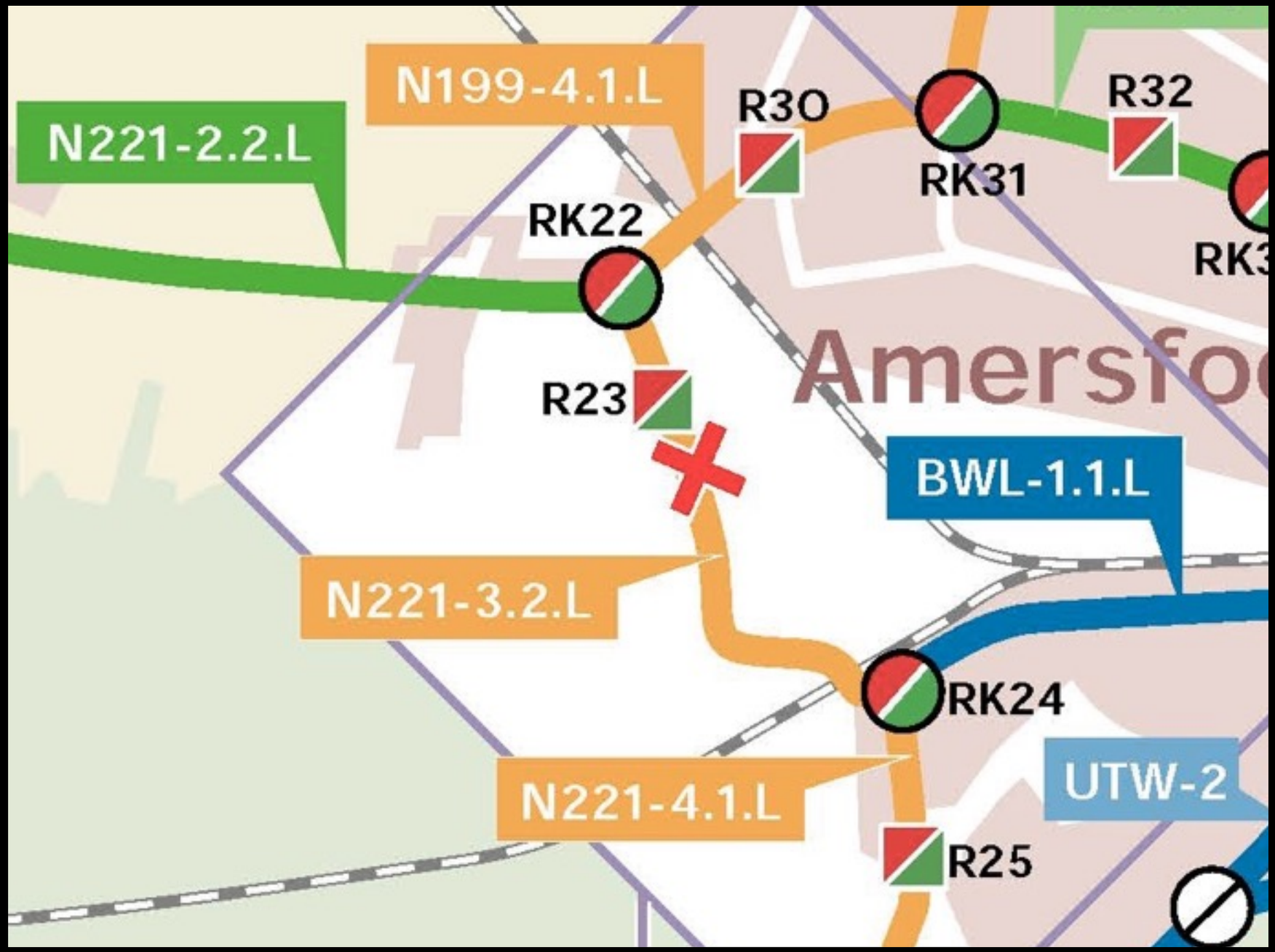
RK — Samengesteld regel- en keuzepunt

wegnummer
nummer routedeel
nummer link
richting link

# overview on a map




09:18 PM SATURATION ON N221-3.2.L

09:19 AVAILABLE SERVICES:

---

R 23: PROMOTE OUTBOUND TRAFFIC

RK22: PROMOTE OUTBOUND TRAFFIC

RK24: DECREASE INBOUND TRAFFIC

R26: REROUTE TRAFFIC

---

09:20 SERVICE EXECUTION:

---

R 23: PROMOTE OUTBOUND TRAFFIC

# educational game for traffic operator

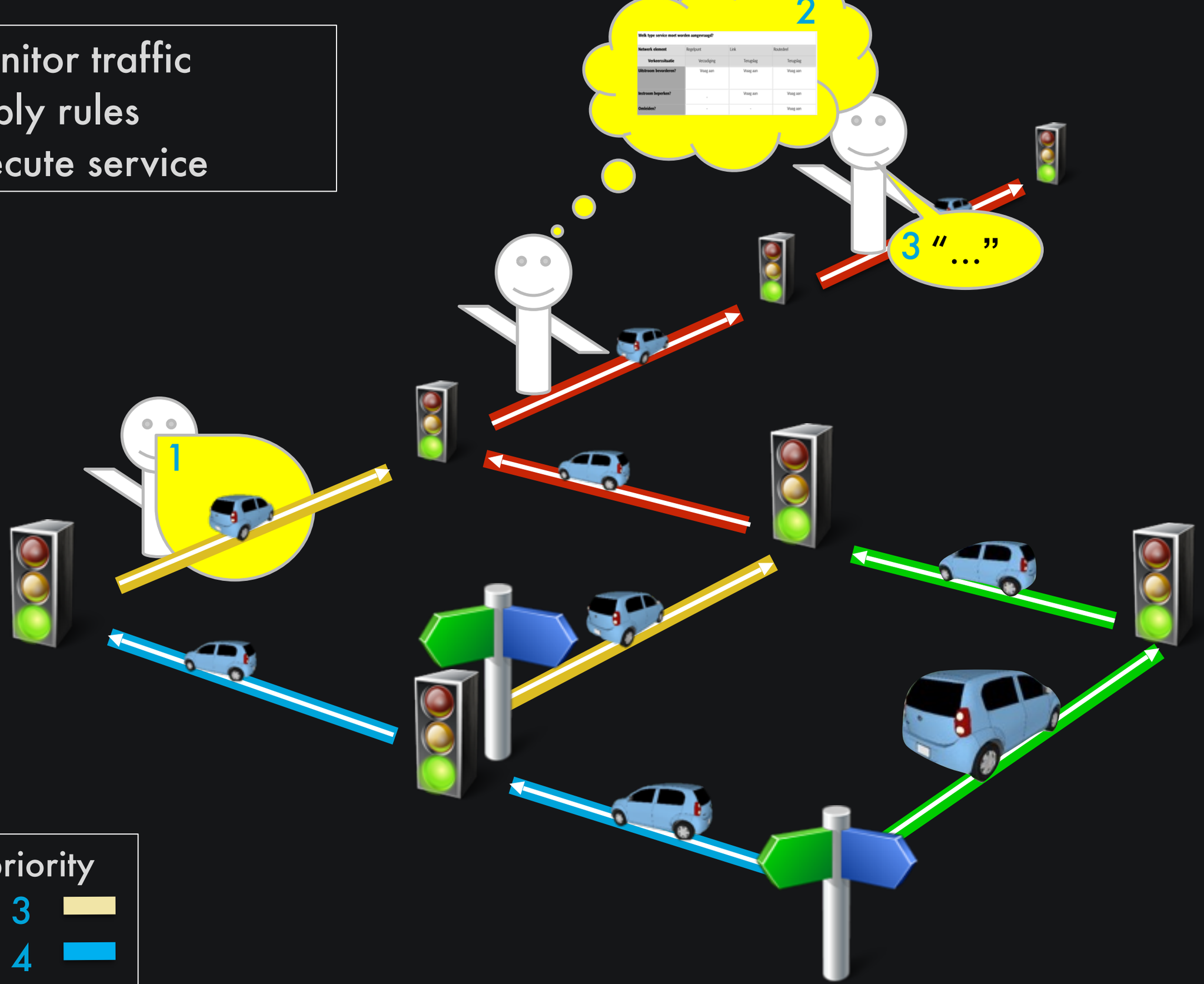
players

Road priority

1 3

2 4

1. Monitor traffic
2. Apply rules
3. Execute service




Road priority

1 3

2 4

Saturation on 1

1

2

3

4

5

6

7

8

Road priority

1 3

2 4

Saturation on 1

PROMOTE OUTBOUND TRAFFIC

available? yes | conflicts? no

1

2

3

4

5

6

7

8

Road priority

1 3

2 4

Congestion on 1

REDUCE INBOUND TRAFFIC

available? yes | conflicts? no

1

2

3

4

5

6

7

8

Road priority

1 3

2 4

Saturation on 2

PROMOTE OUTBOUND TRAFFIC

available? no | conflicts? no

1

2

3

4

5

6

7

8

Road priority

1 3

2 4

Congestion on 2

REDUCE INBOUND TRAFFIC

available? yes| conflicts? no

1

2

3

4

5

6

7

8

Road priority

1 3

2 4

Saturation on 3

PROMOTE OUTBOUND TRAFFIC

available? no | conflicts? yes, with higher priority link

1

2

3

4

5

6

7

8

Road priority

1 3

2 4

Saturation on 1

STOP REDUCE INBOUND TRAFFIC
START PROMOTE OUTBOUND TRAFFIC

1

2

3

4

5

6

7

8

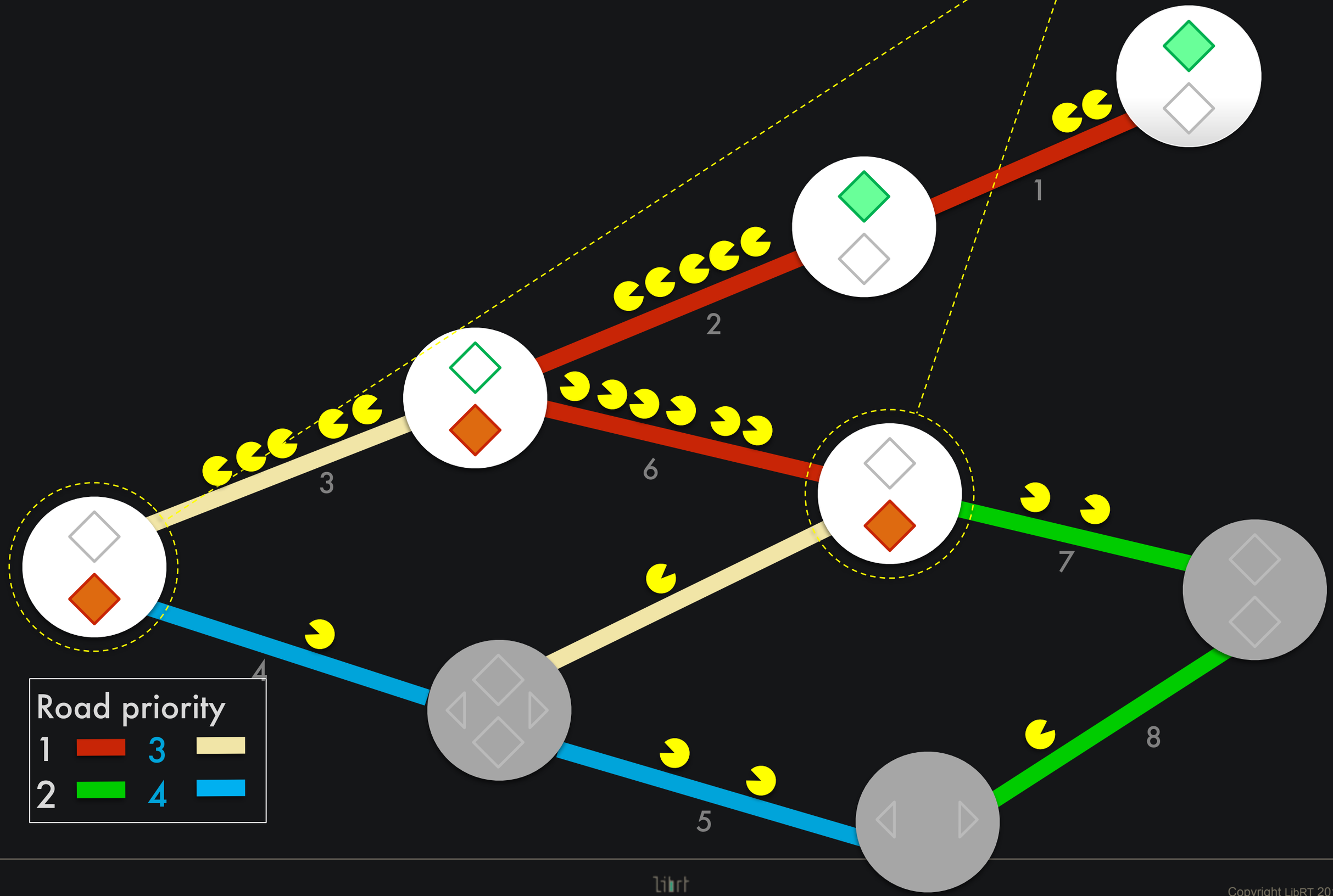
Road priority

1 3

2 4

# Gridlock on 3 en 6

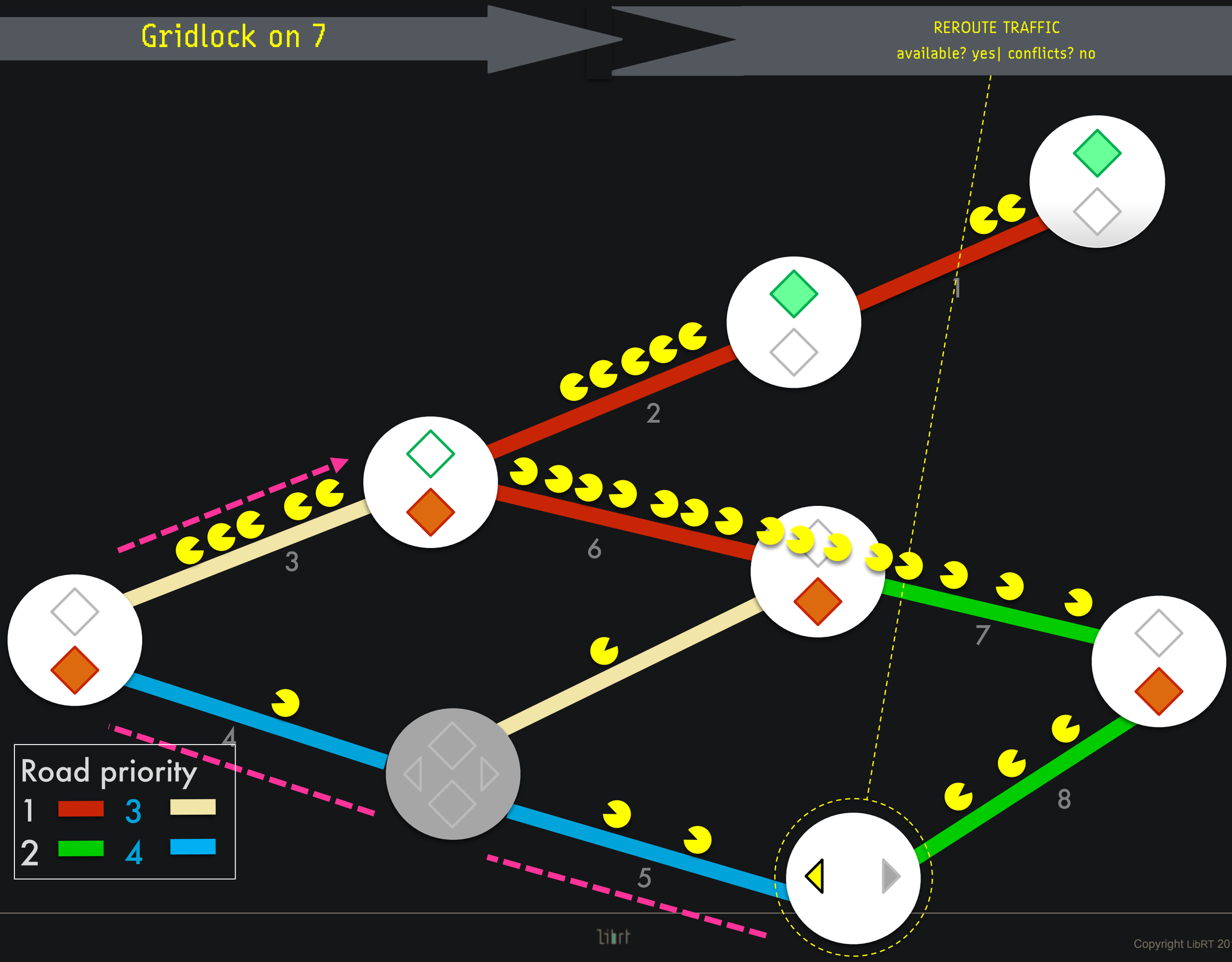
STOP REDUCE INBOUND TRAFFIC
START PROMOTE OUTBOUND TRAFFIC



# Gridlock on 7

REROUTE TRAFFIC

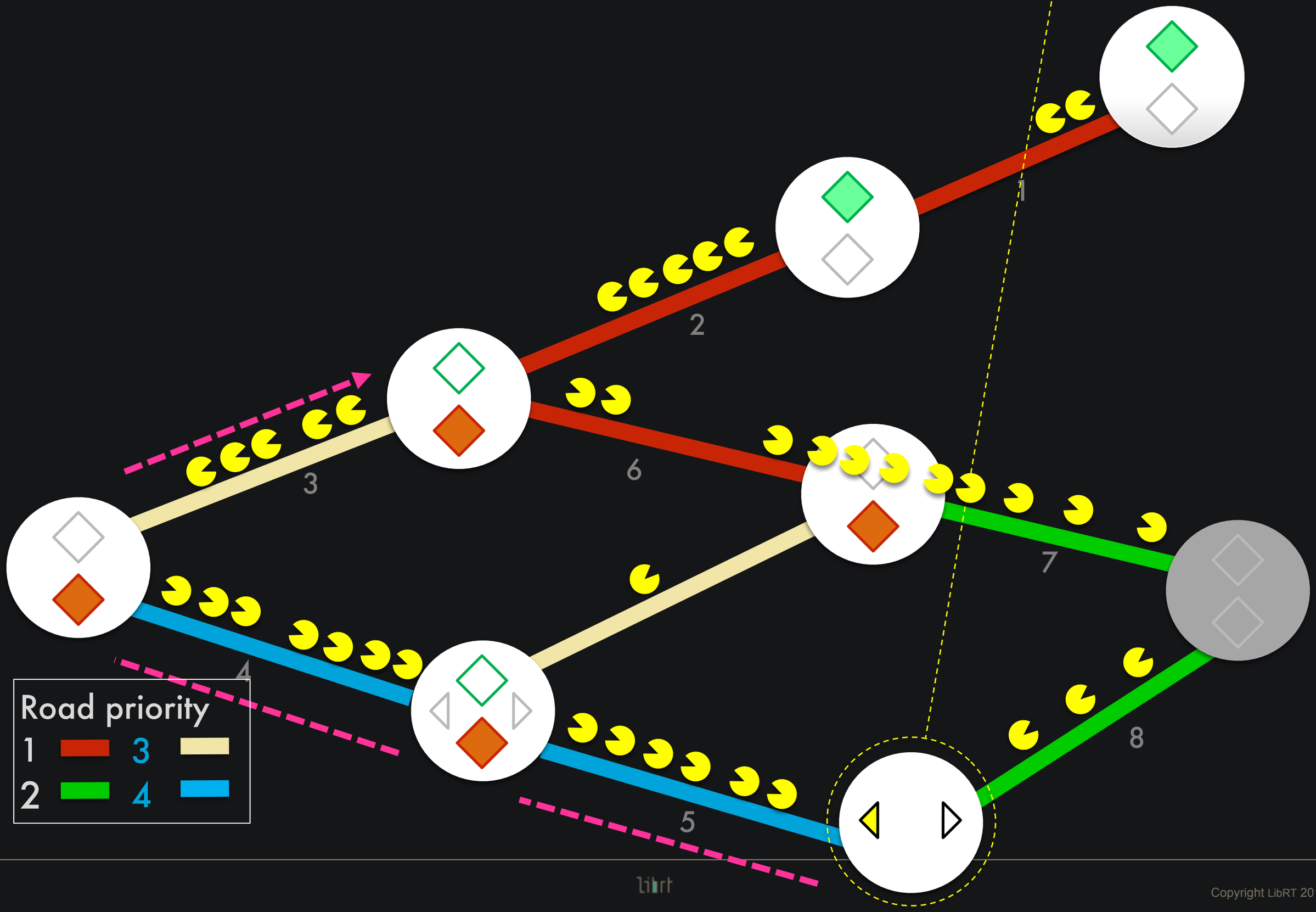
available? yes| conflicts? no



# Gridlock on 5

REROUTE TRAFFIC

available? no| conflicts? Yes,  with higher priority link



Saturation on 2

STOP REDUCE INBOUND TRAFFIC

START PROMOTE OUTBOUND TRAFFIC | conflict? Yes | on link 6

1

2

3

4

5

6

7

8

Road priority

1 3

2 4

# development of the approach

- First steps (2008 - 2011)

3 major cities independently experiment with the idea of a rule based approach but each use different terminology and says to do something special and different.

- Getting together(2011 - 2012)

9 workshops with 21 representatives of different road authorities get together to agree on systems requirements for a Advanced Traffic Management System.

- Development (2014 - 2016)

Development handbook of rule based traffic management version 1 with 6 road authorities in 5 workshops.  Official publication

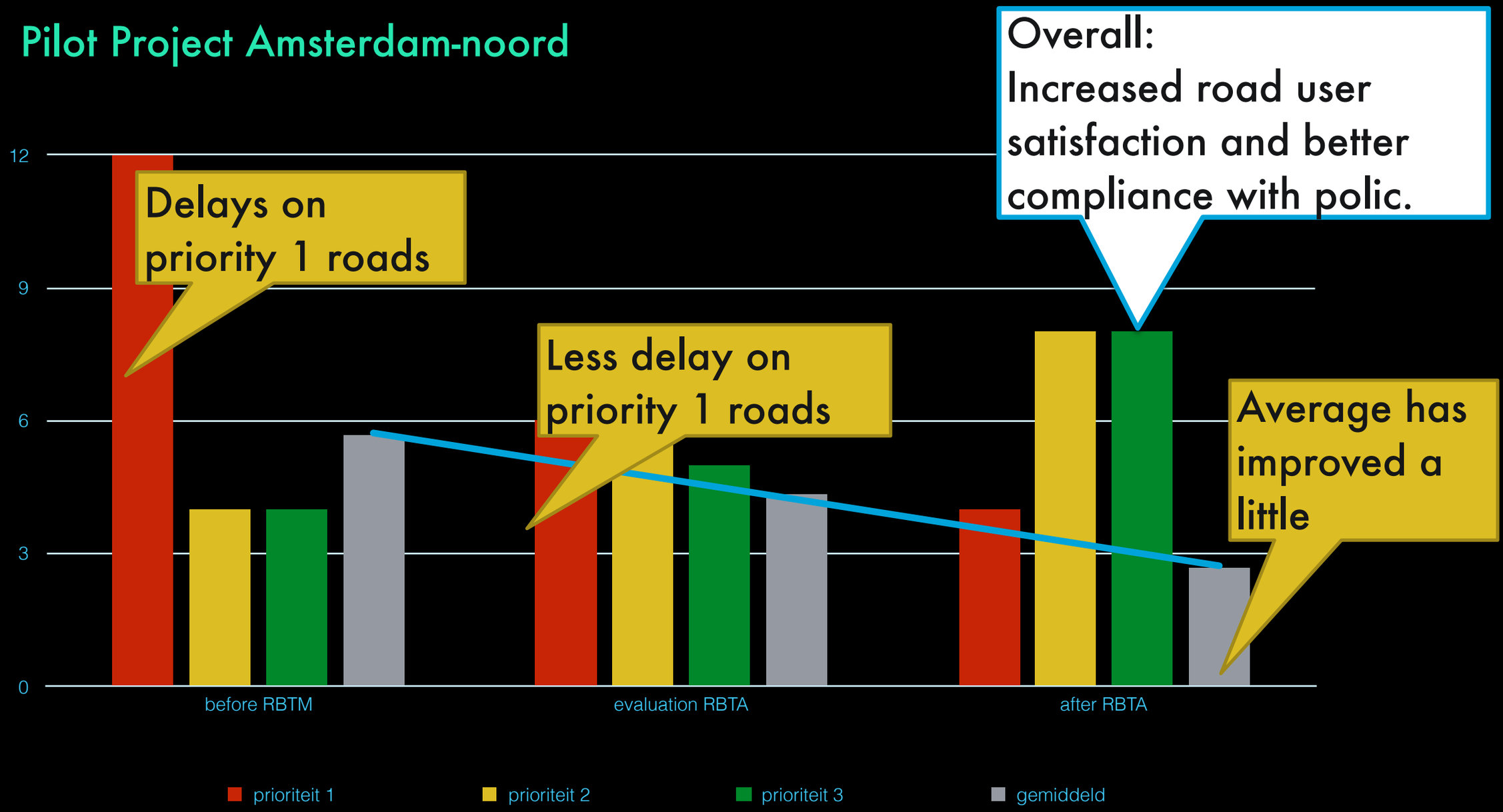
Reference:
www.crow.nl/regelaanpak

- Dissemination and adoption (2017 - 2018)

Evaluation, training material, maturity model, implementation guidelines, animation etc.

Reference:
youtu.be/8twSS0mJD9M

# evaluation – traffic perspective




Reference:
www.praktijkproefamsterdam.nl

# evaluation – AI perspective

## Practical application of AI technologie

- The solution is a **multi-agent system** (MAS).
  Every link is an intelligent agent of type **"model based reflex agent".**

- Other AI technology that failed in this domain:
  Forward chaining production rules: complex and difficult to control
  Neural networks: difficult to understand & not hybride

- Weakness :
  Solution is data hungry
  Reliable data is a must-have
  Processor capacity of road side equipment may nod to be upgraded

Reference:
Ferber, 1999
Russell & Norvig, 2003

# evaluation – business rules perspective

## few rules generate complex behavior

- Operational and policy level are tightly connected

  Policy changes (like traffic norm or road priority) is now just a parameter update in the system.

- Technology independent

  We request services, we do not change a setting on a traffic signal device.

  Easy to accommodate new technology like in-car systems (IoT), self driving cars and navigation systems

- Less rules, simplification and decision tables

  The business users find them intuitive to read.

- Define and standardize terminology.

  Most important for collaboration.

Reference:
Business Rules Manifesto
www.businessrulesgroup.org

# next steps

- Create a simulation program

  Check if the LPS language would work for this purpose

- Apply to other domains

  Crowd management, air-port control

- Generalize the reasoning with different kinds of rules

  Obligation, permission and possibility rules for case management

- User experience

  User needs good interface and explanation facility.

**download proceedings paper at: ceur-ws.org/Vol-1875/paper8.pdf**