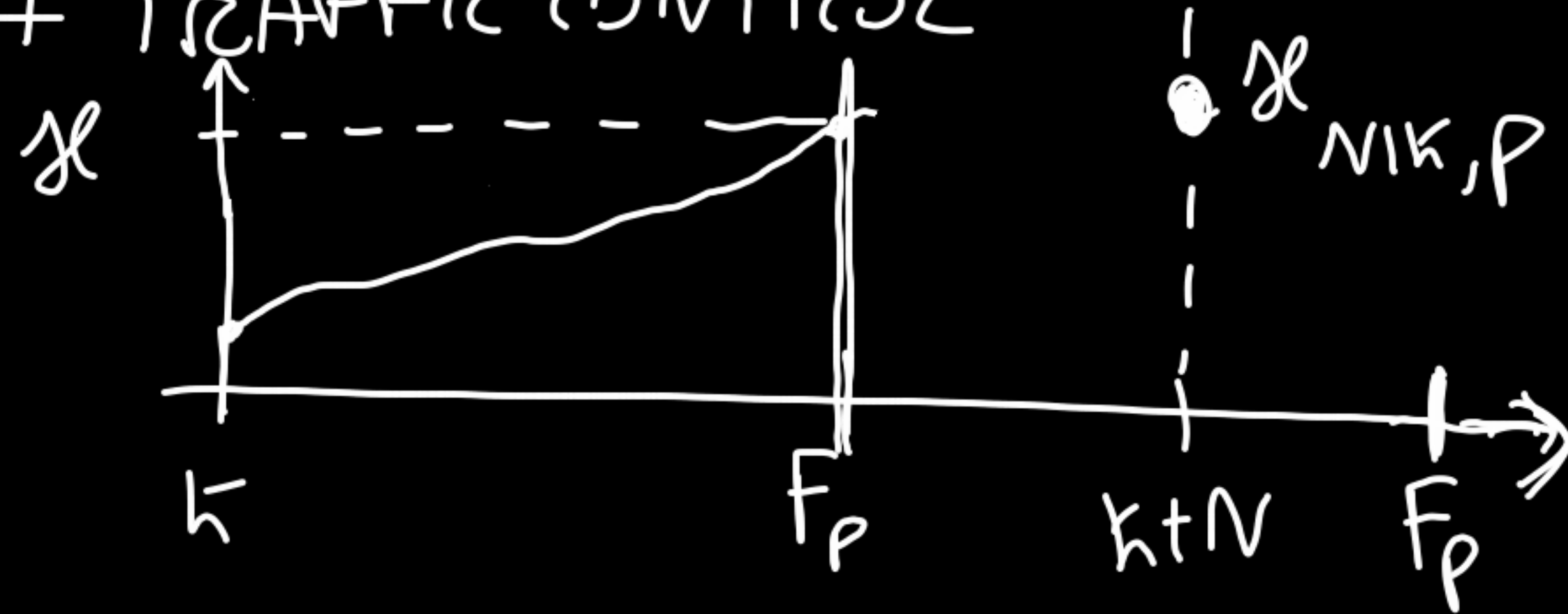


22/10/26 - PEV AGGREGATOR + TRAFFIC CONTROL

USER PREFERENCES:

- F_p FINAL CHARGING TIME
- x_p^{ret} DESIRED FINAL SOC



$$\bullet \boxed{x_{F_p|k,p} \geq x_p^{ret}}; \quad \forall p: F_p \leq k+N$$

$$\bullet \forall p: F_p > k+N \longrightarrow J^{reg} = \sum_{p: F_p > k+N} (x_{N|k,p} - x_p^{ret})^2$$

OBJECTIVE FUNCTION:

① TOTAL POWER P_{ik} TRACKS REFERENCE P_{ik}^{ret}

② TERM ON FINAL SOC (PREVIOUS SLIDE)

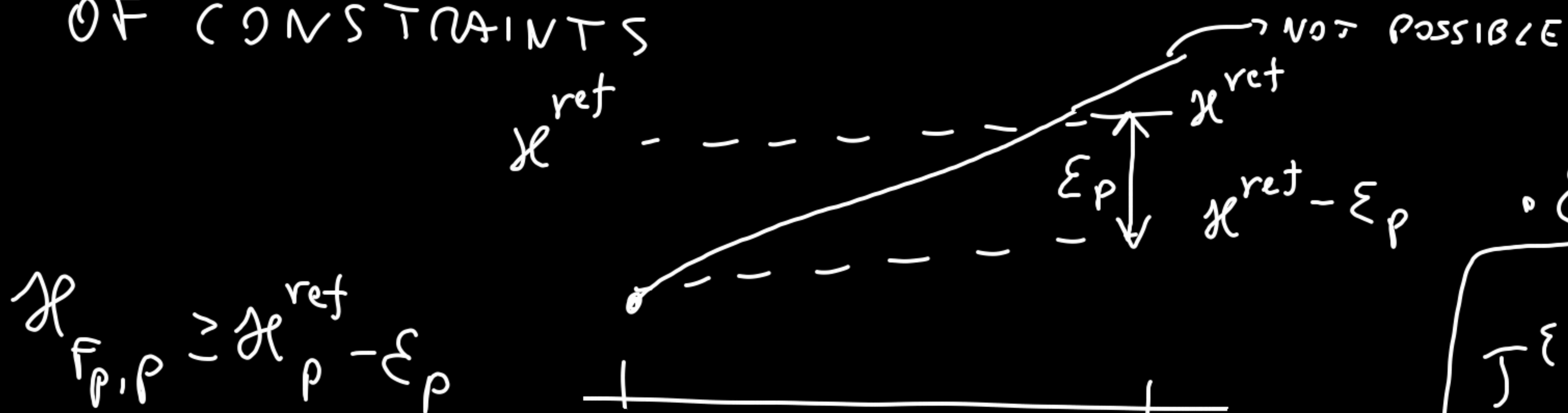
$$J = \sum_{i=0}^{N-1} (P_{ik} - P_{ik}^{ret})^2 + \sum_{\boxed{p: F_p > k+N}} (\alpha_{F_p, p} - \alpha_p^{ret})^2$$

↑

RELAXATION OF CONSTRAINTS FOR REC. FEASIBILITY

$$x_{F_p, p} \geq x_p^{\text{ref}}, \quad \underbrace{\forall p: F_p \leq K+N}_{\bar{p}}$$

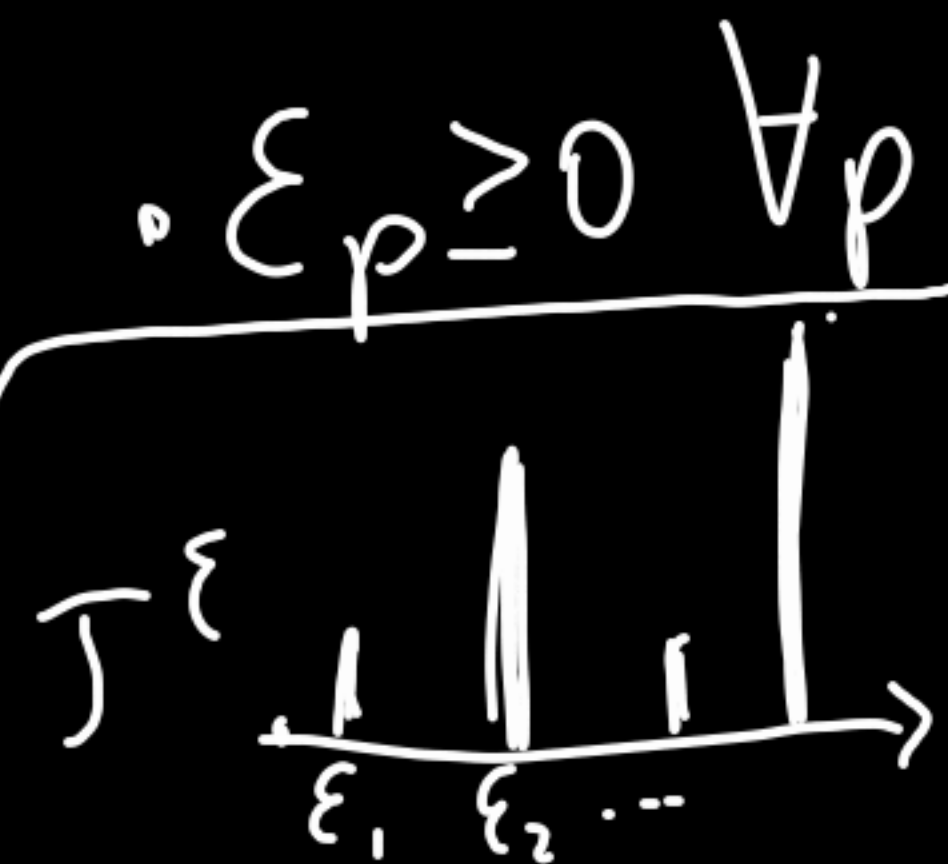
WE INTRODUCE POSITIVE VARIABLES TO MODEL VIOLATION OF CONSTRAINTS



$$J^\epsilon = \sum_{p \in \bar{p}} \epsilon_p$$

$$J^{\epsilon'} = \sum_{p \in \bar{p}} (\epsilon_p)^2$$

BETTER FOR FAIRNESS



$$J = \underline{d_1 J^{\text{reg}, P}} + d_2 J^{\text{reg}, \mathcal{R}} + d_3 J^{\varepsilon}$$

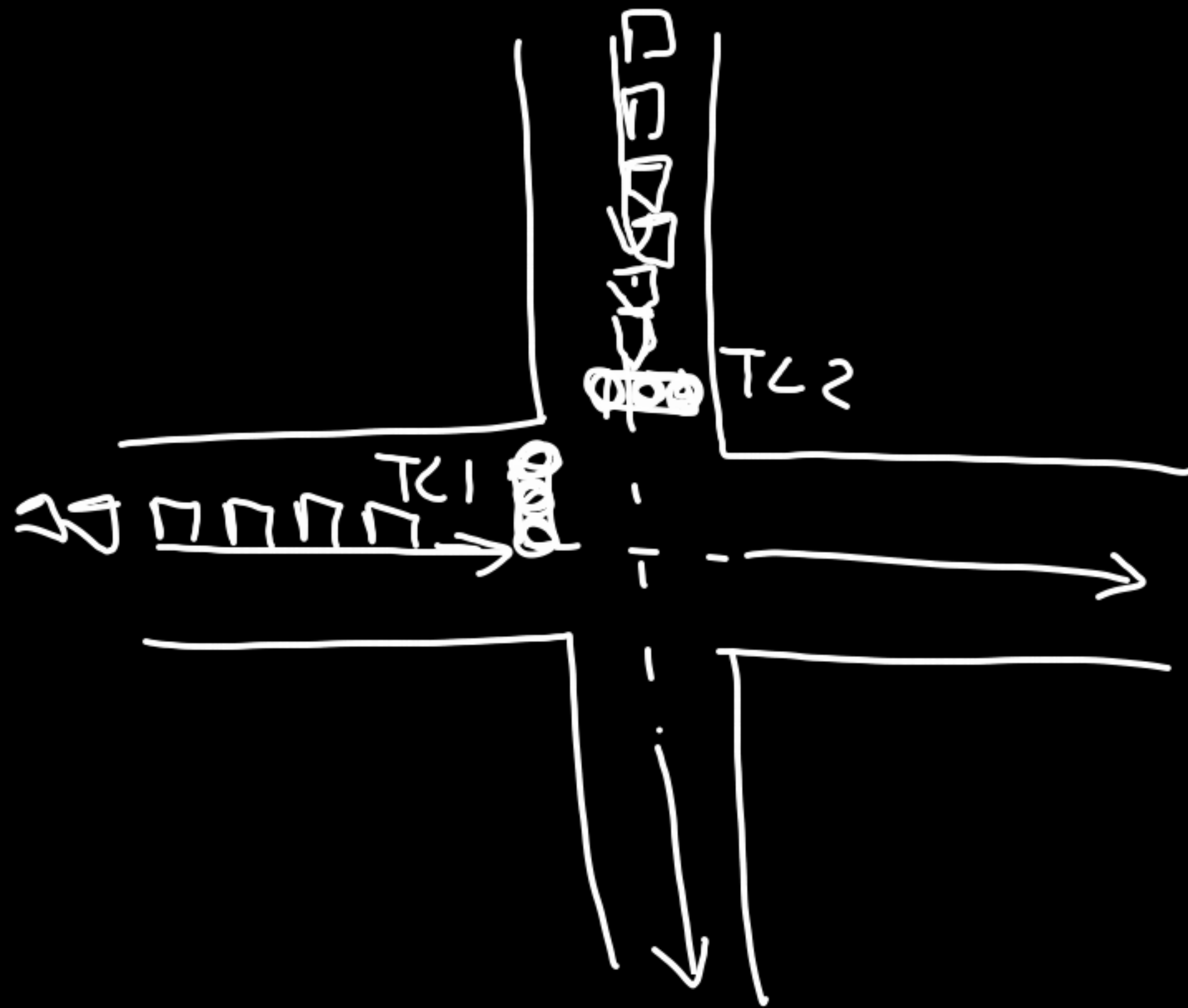
$$\underline{d_1}, \underline{d_2}, \textcircled{d_3}$$

d_3 :

- SMALL $\rightarrow$ ALLOW VIOLATIONS TO IMPROVE $J^{\text{reg}, P}$

- LARGE $\rightarrow$ VIOLATIONS ONLY IF REALLY NECESSARY (CONSTRAINTS CANNOT BE SATISFIED).

MPC FOR TRAFFIC CONTROL - SINGLE INTERSECTION



J INDEX FOR GENERIC TL (TRAFFIC LIGHT), AND CORRESPONDING QUEUE OF VEHICLES.

GOALS:

- ① MINIMIZE QUEUES (TRAFFIC MANAGER)
- ② MINIMIZE WAITING TIMES (DRIVER-RELATED)

CONTROL VARIABLES

CONTROL ACTION: AT EVERY k , MPC DECIDES COLORS OF TCS.

$\mathcal{J}$ SET OF TCS AT THE INTERSECTION

$j \in \mathcal{J}$ IS THE GENERIC TCS IN $\mathcal{J}$.

$\forall j \in \mathcal{J}$ WE DEFINE THE FOLLOWING CONTROLS:

$g_{ik,j}, y_{ik,j}, r_{ik,j} \in \{0, 1\}$ WHEN EQUAL TO ONE, THE

RESPECTIVE COLOR SHOULD BE DISPLAYED.

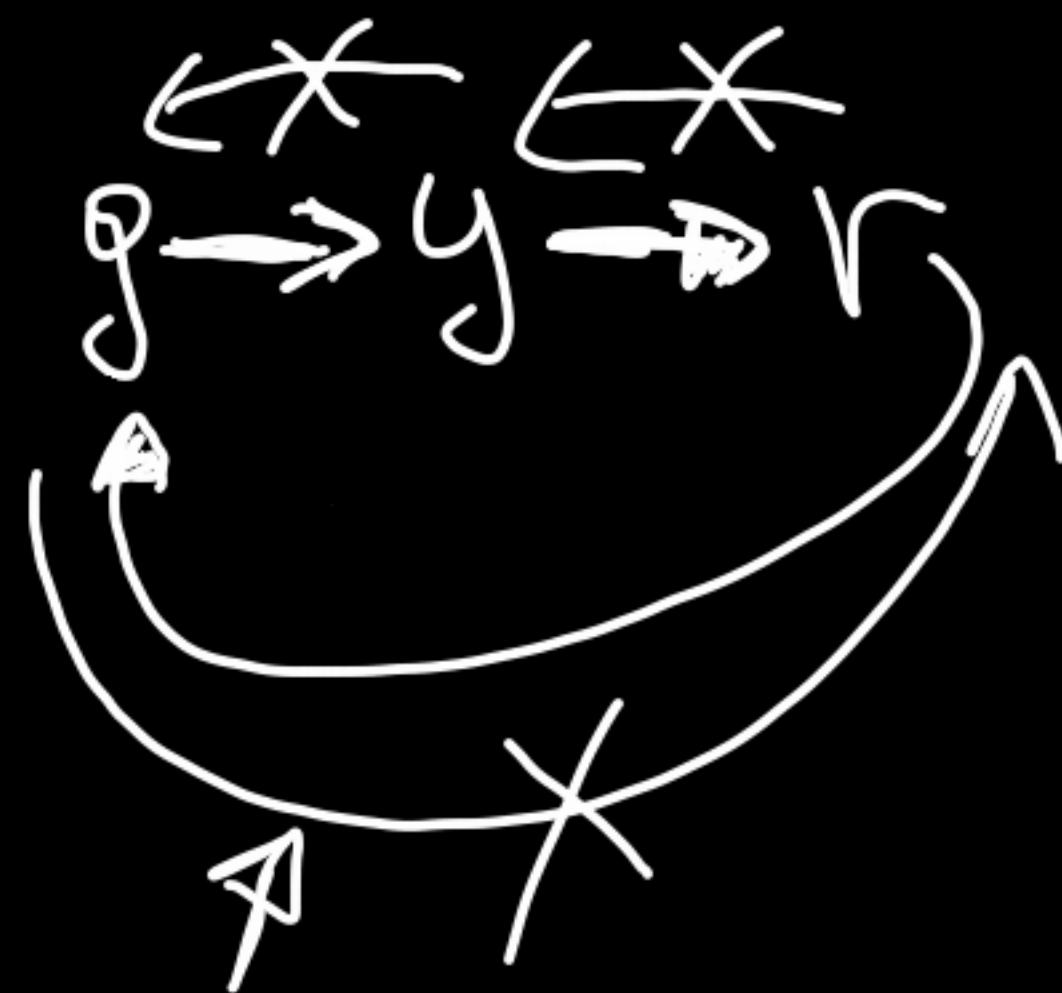
LOCAL (TL) CONSTRAINTS

- ONLY ONE COLOR AT EVERY TIME $\forall TL$

$$g_{ik,j} + y_{ik,j} + r_{ik,j} = 1, \quad i=0,1,\dots,N-1, \quad \forall j \in J$$

- CORRECT TRANSITION OF COLORS

$$\equiv \equiv \equiv g_{ik,j} = 1 \longrightarrow r_{i+1|k,j} = 0$$



$$\bullet \quad p \not\rightarrow r \equiv (p_{i+k,j} = 1) \rightarrow (r_{i+k,j} = 0)$$

|||

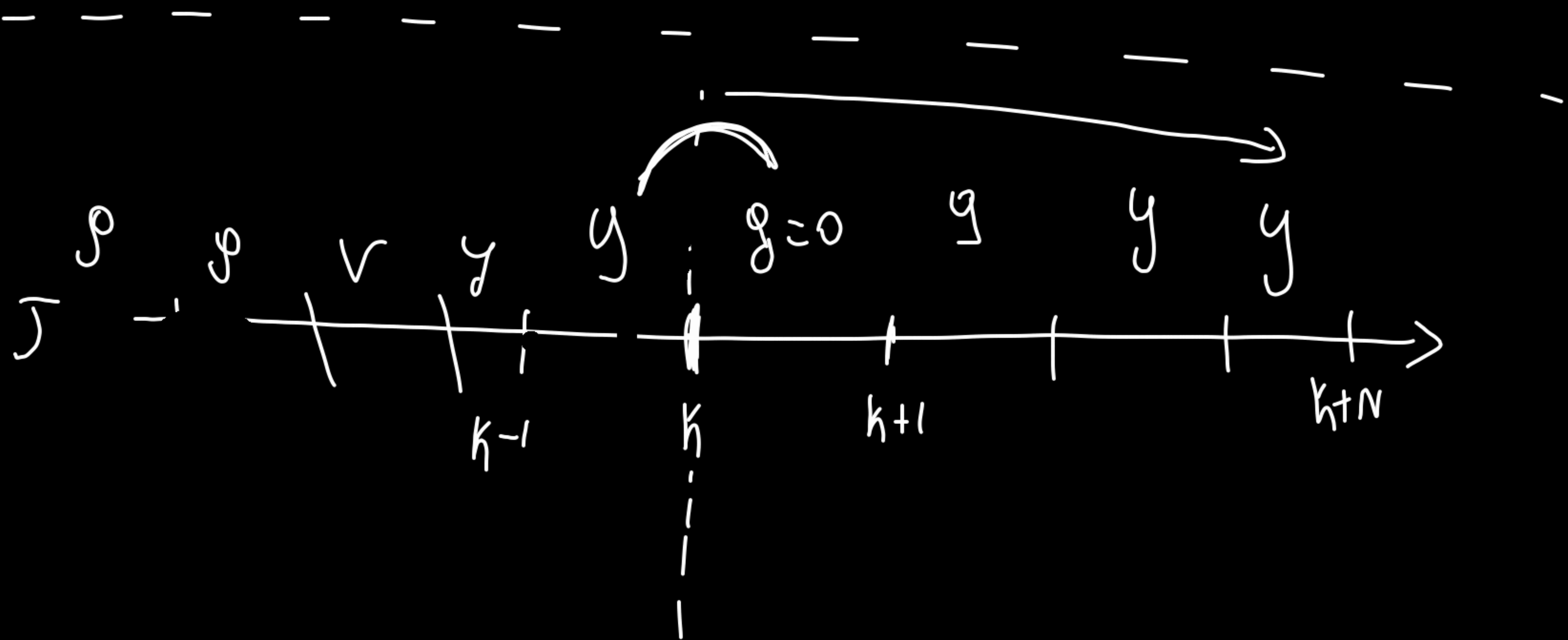
$$r_{i+k,j} \leq (1 - p_{i+k,j}), \quad \forall i, j$$

IF $p_{i+k,j} = 1 \rightarrow r_{i+k,j} = 0$ GOOD

$$\text{IF } p_{i+k,j} = 0 \rightarrow r_{i+k,j} \leq 1$$

$$r \not\rightarrow y \quad : \quad y_{i+1:k, J} \leq 1 - r_{i:k, J} \quad , \quad i=0, 1, \dots, N-1, \forall J$$

$$y \not\rightarrow g \quad : \quad g_{i+1:k, J} \leq 1 - y_{i:k, J} \quad , \quad i=0, 1, \dots, N-1, \forall J$$

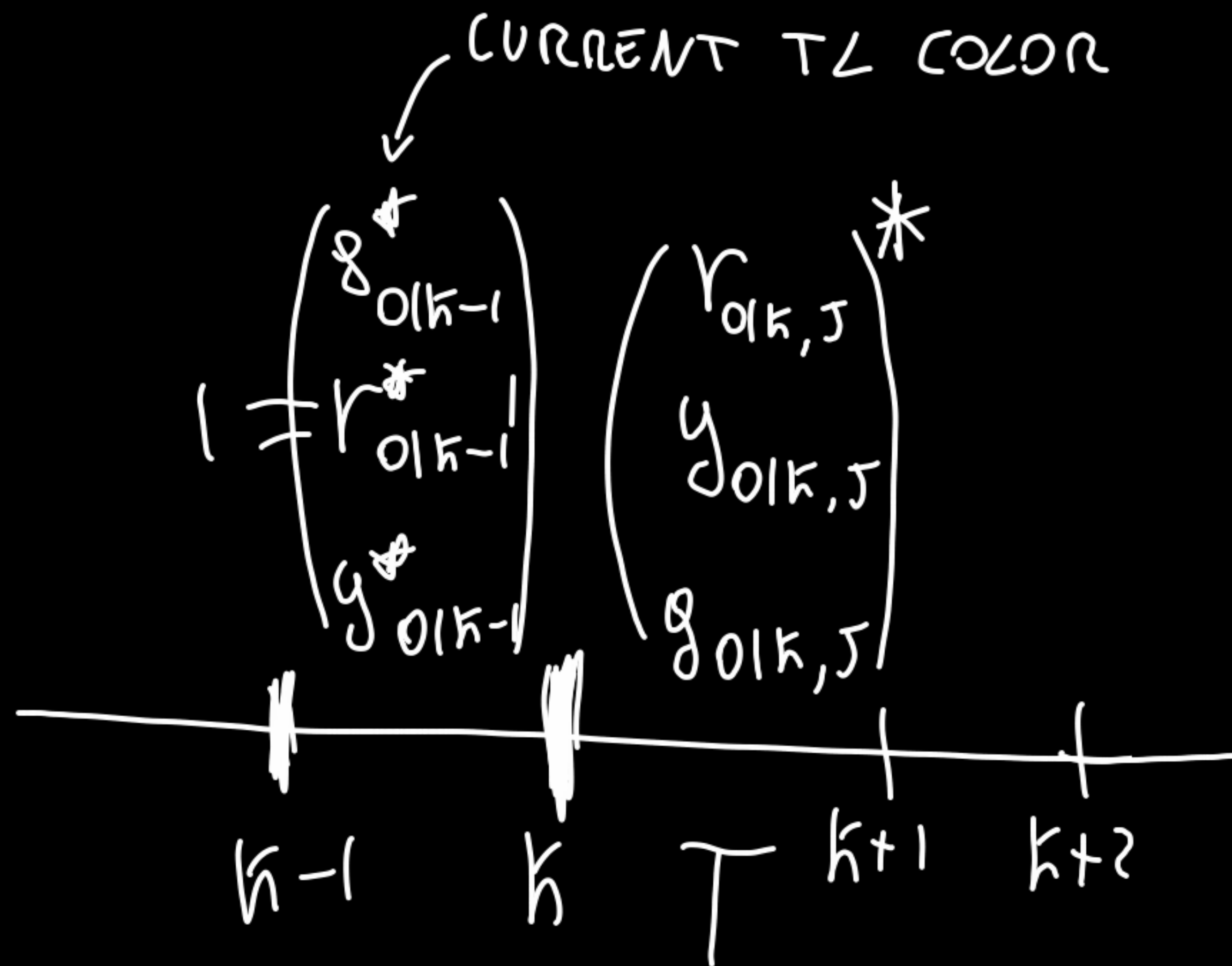


$$g \times \rightarrow r$$

$$r_{0|k,J} \leq (1 - g_{0|k-1}^*)$$

$$y_{0|k,J} \leq (1 - r_{0|k-1}^*)$$

$$g_{0|k,J} \leq (1 - y_{0|k-1}^*)$$



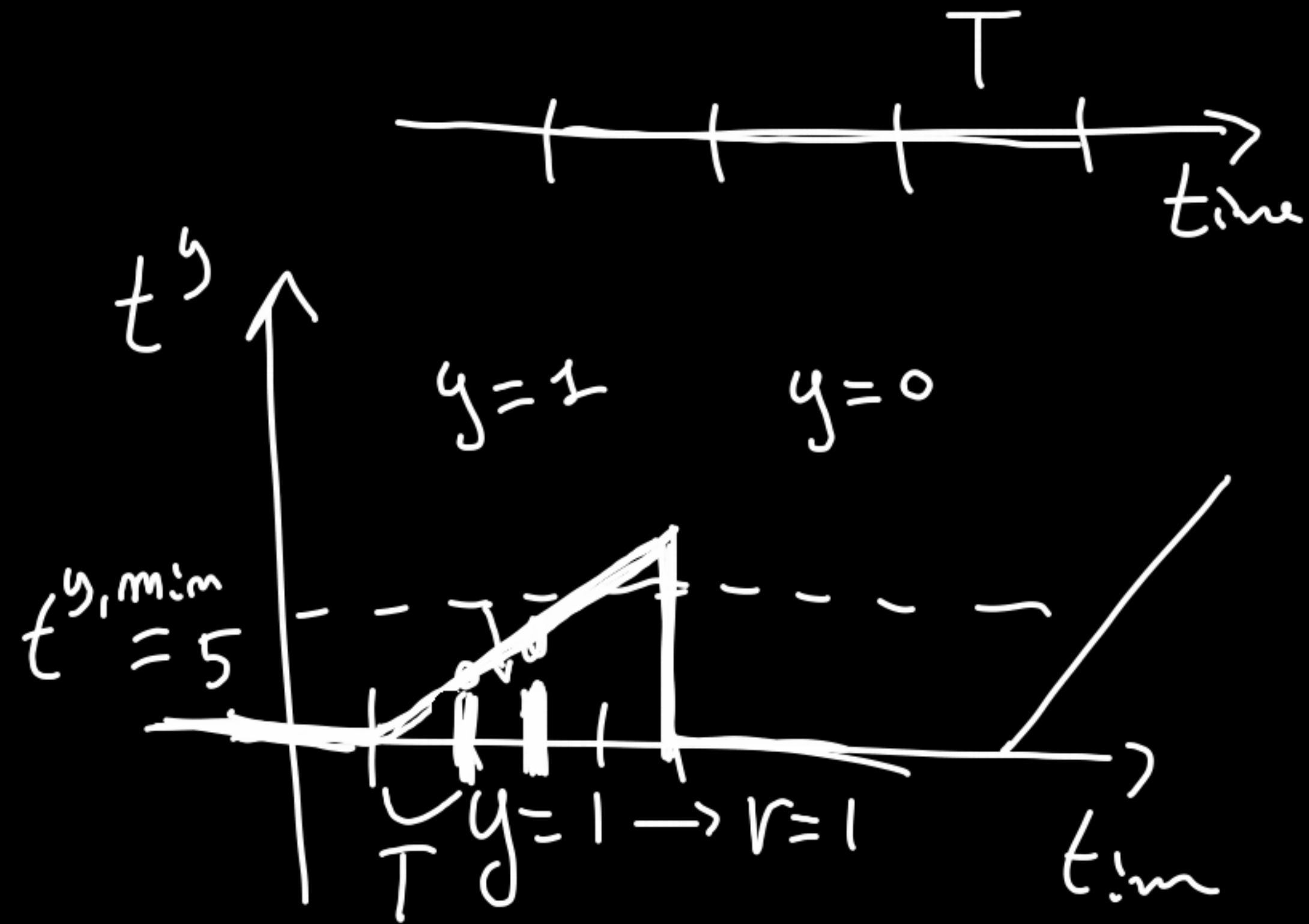
CONSTRAINTS ON CONTROLS

AT k AND $k-1$

(ROC CONSTRAINTS)

SAFETY CONSTRAINT ON MINIMUM DURATION OF YELLOW COLOR.

$$t_{ik,j}^y \geq 0, \quad \forall i, j$$



$$t_{i+1k,j} = (t_{ik} + T) \cdot y_{ik,j} = \underbrace{t_{ik} \cdot y_{ik,j}}_{\substack{* \\ \text{TO BE} \\ \text{LINEARIZED}}} + T y_{ik,j}$$

$\forall i, \forall j$

$t_{ik,j}^y$

CONSTRAINT ON MINIMUM DURATION OF ^{SIGN} YELLOW

 $t^{y,min}$

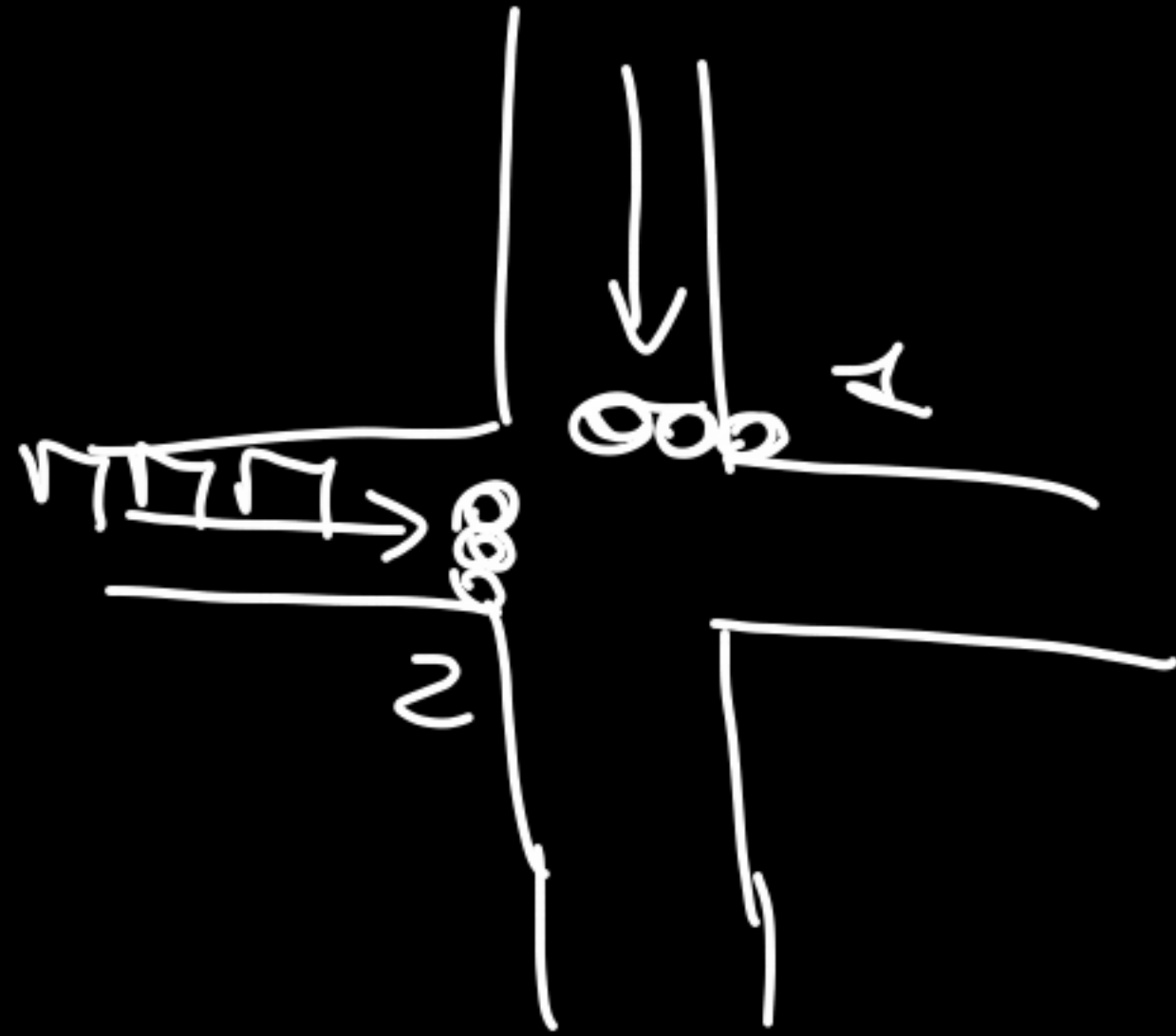
$y_{ik,j} \not\rightarrow r_{i+1k,j}$ IF $t_{ik,j} < t^{y,min}$

$$r_{i+1k,j} \leq \frac{t_{ik,j}}{t^{y,min}} ; \forall i,j$$

CHECK: IF
IT WORKS

GLOBAL (INTERSECTION-LEVEL CONSTRAINTS).

$$J = \{1, 2\}$$



THEY CANNOT BE BOTH
GREEN (AND YELLOW) AT THE
 SAME TIME

$$\sum_{j=1}^2 (g_{ik,j} + y_{ik,j}) \leq 1, \quad i = 0, 1, \dots, N-1$$

MODEL LENGTH OF QUEUES (NUMBER OF VEHICLES) AND WAITING TIMES. TWO APPROACHES:

- AGGREGATE MODEL;
- DETAILED MODEL.

AGGREGATE

- QUEUES' LENGTH.

$n_{ik,j}$ NUMBER OF VEHICLES WAITING AT TLT AT ik .

↘ STATE VARIABLE

QUEUE DYNAMICS:

$i=0,1,\dots,N-1, \forall j$

$$\begin{cases} m_{i+1|k,j} = m_{i|k,j} + \underbrace{v_{i|k}^{IN} \cdot T}_{\text{VEHICLES ARRIVING}} - \underbrace{v_{i|k}^{OUT} \cdot T \cdot \rho_{i|k,j}}_{\text{VEHICLES DEPARTING}}, \\ m_{0|k,j} = m_{k,j}, \forall j \end{cases}$$

CURRENT VEHICLES IN QUEUE (OBSERVED WITH CAMERA).

$$m_{i|k,j} \geq 0, \forall i, j$$

APPROXIMATION

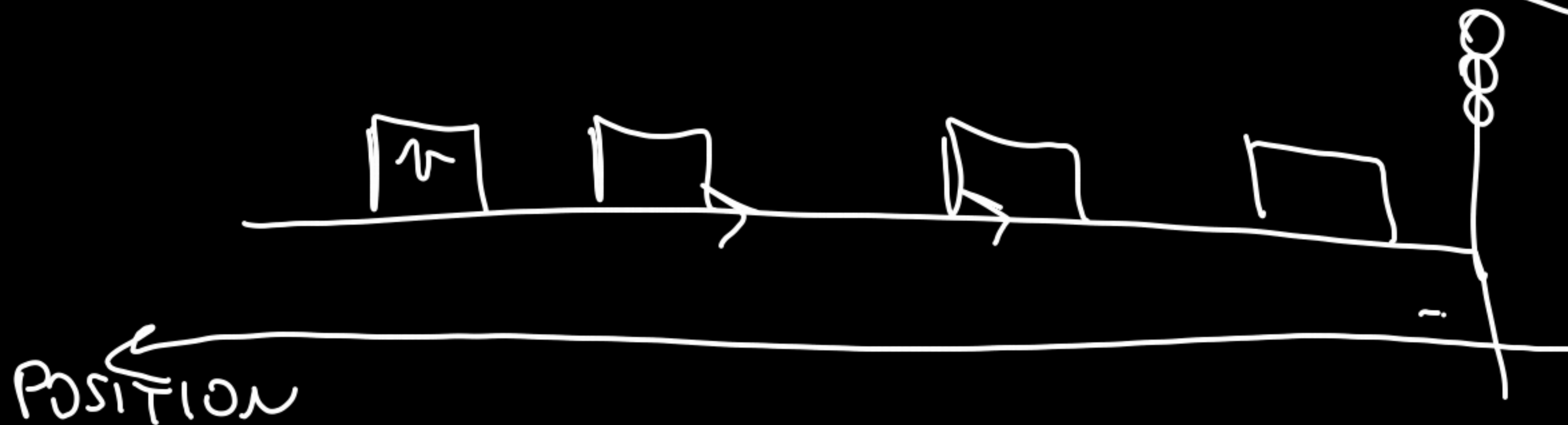
- LITTLE LAW FOR AVERAGE WAITING TIME.

• DETAILED MODEL

$\forall J, \forall v \in V_J$ (FOR EVERY VEHICLE IN EVERY
 TL):

$\underbrace{p_{ik,v}, v_{ik,v}}_{\text{STATE VARIABLES}}, \underbrace{a_{ik,v}}_{\text{CONTROL}} \in \mathcal{M}$

HUMAN, SELF-DRIVING



DYNAMICS OF P, v

- $v_{i+1k,v} = v_{ik,v} + a_{ik,v} \cdot T, \quad \forall i, \forall v$

(CONSTANT ACCELERATION ON T SECONDS)

- $p_{i+1k,v} = p_{ik,v} - v_{ik,v} \cdot T - \frac{1}{2} a_{ik,v} T^2, \quad \forall i, \forall v$

MODEZ HUMAN DRIVING
COMMAND IN SELF-DRIVING

WAITING TIMES

$$W_{ik,v} \geq 0 \quad \forall i, v$$

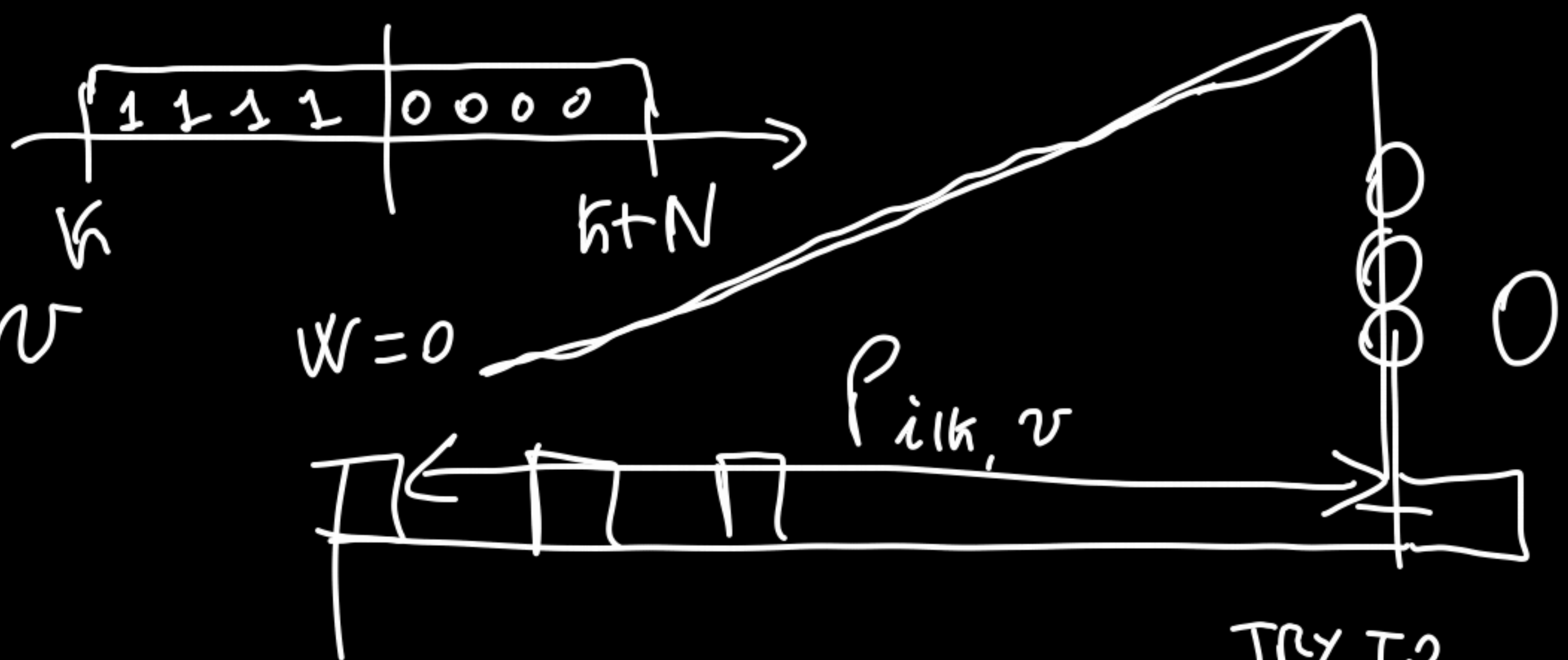
(STATE VARIABLES)

DYNAMICS OF WAITING TIMES

$$W_{i+1,k,v} = (W_{ik,v} + T) \cdot \delta_{ik,v}, \quad \forall i, v$$

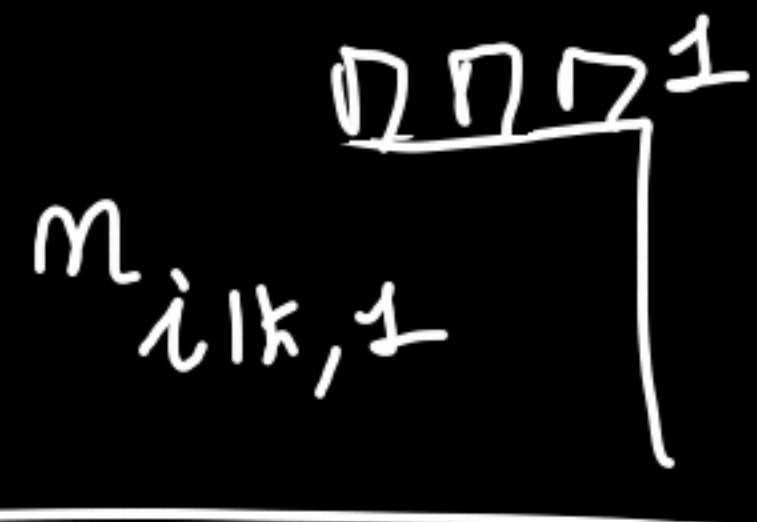
$\delta_{ik,v} \in \{0, 1\}$

- 1 VEHICLE IN QUEUE ($P_{ik,v} > 0$)
- 0 VEHICLE LEFT QUEUE ($P_{ik,v} < 0$)



$$n_{ik,j} = \sum_{v \in V_j} \delta_{ik,v}, \quad \forall i, j$$

$w_{ik,v}$



TARGET FUNCTION

$$\textcircled{1} J^m = \sum_{i=0}^{N-1} \sum_{j=1}^2 (n_{ik,j})^2$$

MINIMIZE LENGTH OF
QUEUES $n_{ik,j}$

$\textcircled{2}$ WAITING
TIMES

MINIMIZE THE MAXIMUM WAITING TIME
OF THE ENTIRE INTERSECTION

