

Practical Implementation of Ramp Metering Using Multiple Asynchronous Algorithms



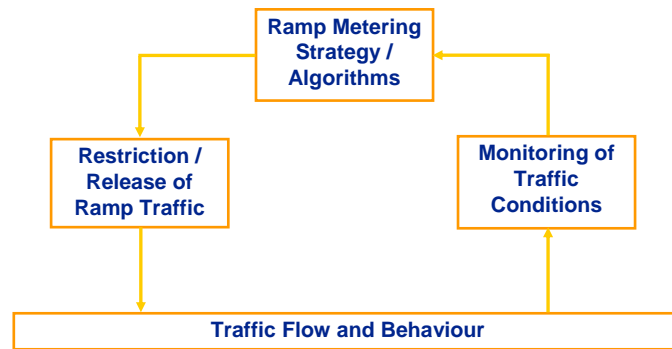
- Roger Higginson (Atkins ITS)
 - Project Manager for implementation of 30 Ramp Metering sites

History of Ramp Metering in England

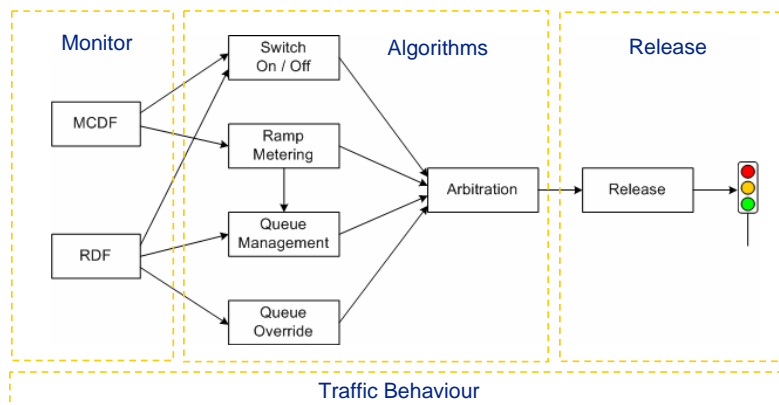
- 1986: Ramp Metering first installed on M6 near Birmingham
- 2000: Pilot schemes on M3 / M27, evaluation showed significant benefits at certain sites only
- 2004: Atkins proposed several improvements to Pilot Scheme algorithms and site selection process
- 2005: HA made top level commitment to install Ramp Metering at 30 sites by March 07
- June 2006: 10 sites were operational in North West
- March 2007: 20 further sites completed and operational

How Ramp Metering works

- RM reduces traffic congestion by regulating the flow onto the main carriageway from the entry slip roads
- There are four distinct parts to a ramp metering system



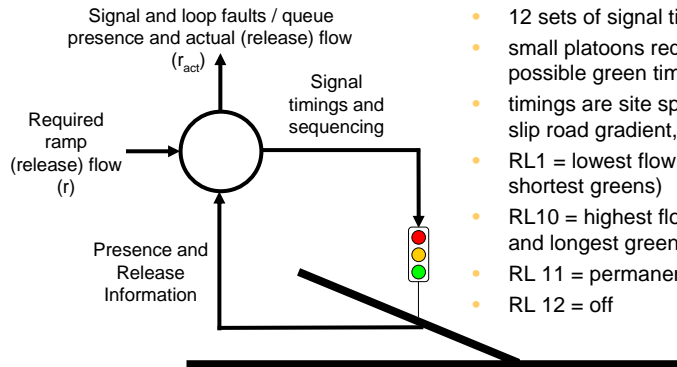
RM system architecture in current deployment



- Algorithms are *asynchronous* i.e. they all operate with different time periods

Release Algorithm

- Converts required ramp flow to actual ramp flow



- 12 sets of signal timings (10 + 2)
- small platoons required so shortest possible green time
- timings are site specific - depend on slip road gradient, %HGVs, etc.
- RL1 = lowest flow (longest reds and shortest greens)
- RL10 = highest flow (shortest reds and longest greens)
- RL 11 = permanent green
- RL 12 = off

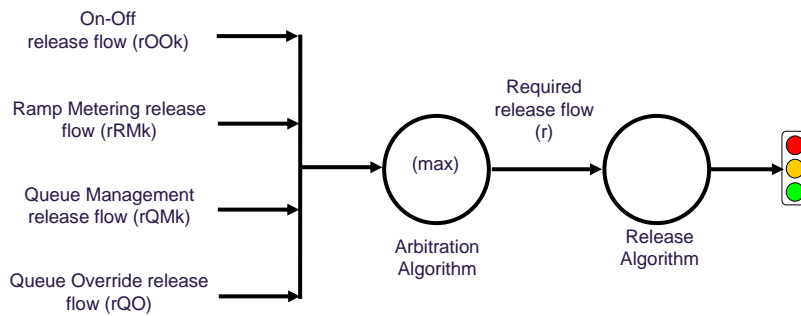
Example release rates

- Actual flows achieved after review during calibration

Release Level	Starting amber	Green	Stopping amber	Red	Total cycle time	Actual veh / cyc (2 lanes)	Cycles / hour	Veh / hour	Ideal release Level	Error
(r_{min}) 1	1.5	1.5	3	41	47	6.5	76.6	497.9	500	-2.1
2	1.5	1.5	3	23	29	5.25	124.1	651.7	650	1.7
3	1.5	1.5	3	17.75	23.75	5.25	151.6	795.8	800	-4.2
4	1.5	1.5	3	13.75	19.75	5.25	182.3	957.0	950	7.0
5	1.5	1.5	3	11.5	17.5	5.25	205.7	1080.0	1100	-20.0
6	1.5	1.5	3	9	15	5.25	240.0	1260.0	1250	10.0
7	1.5	1.5	3	7.5	13.5	5.25	266.7	1400.0	1400	0.0
8	1.5	1.5	3	6.25	12.25	5.25	293.9	1542.9	1550	-7.1
9	2	4.5	3	6.5	16	7.75	225.0	1743.8	1700	43.8
(r_{max}) 10	2	6	3	8.5	19.5	10	184.6	1846.2	1850	-3.8
(perm gr) 11	0	12.5	0	0	12.5	8	288	2304	-	-
(off) 12	0	0	0	0	-	-	-	-	-	-

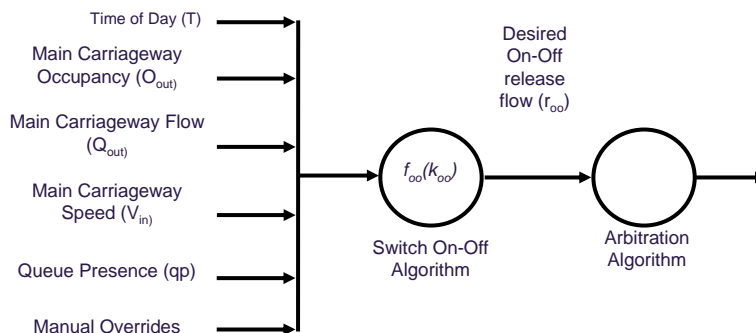
Arbitration algorithm

- Chooses the maximum value from the four algorithms
- $rQM_k > rRM_k$ if queue is too long
- $rQOk$ can be higher than rRM_k or rQM_k (RL10 or RL11)
- $rOOk$ is highest of all (RL12 forces switch off)



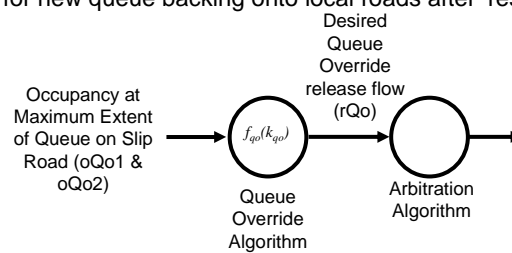
Switch on / off algorithm

- Four states; standby, switching on, operational, switching off
- Decision made using several different conditions – site dependant



Queue Override

- QO prevents queue backing onto local roads
 - Detect occupancy @ QO loop above threshold {oQo1 > oQo1t OR oQo2 > oQo2t} for trigger time (tQot)
 - Increase flow to pre-defined release rate usually Release Level 10 or 11 for pre-defined 'clear time' (tQoc)
 - Wait for back of queue to move / clear {oQo1 < oQo1t AND oQo2 < oQo2t}
 - Look for new queue backing onto local roads after 'reset time' (tQor)



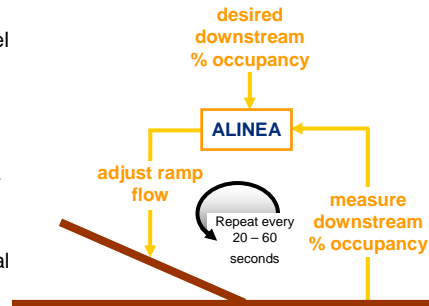
Queue Management

- Proportional Occupancy Queue Management (POQM)
 - Works based on the on assumption that the average occupancy (oCq) of all Queue Loops reflects the actual queue
 - Adjusts the ramp metering flow (rRMk) up or down depending on whether the queue (oCq) is too big or too small
 - New algorithm designed for the system – not previously been used
 - Prevents excessive QOs, much easier to set up that QM used in pilot scheme
 - Because it uses the ALINEA output, the two algorithms can cancel each other out during transition from Ramp Metering to Queue Management
 - We are currently investigating a solution to this

$$r_{poqm}(k) = r_{RM}(k) + K_{poqm} [o_{cq}(k-1) - o_{descq}]$$

RM algorithms for main carriageway: ALINEA

- ALINEA
- Controls occupancy to desired level to minimise potential of flow breakdown
- Adjusts ramp flow to alter downstream occupancy
- Feedback equation - constantly re-adjusts for errors
- Limited to between minimum and maximum values to prevent integral wind-up
- Very simple to use and calibrate (contrary to popular belief!)



$$r(k) = r(k-1) + K_R[o_{des} - o_{out}(k-1)]$$

$r(k)$ limited to within the range $[r_{min}, r_{max}]$

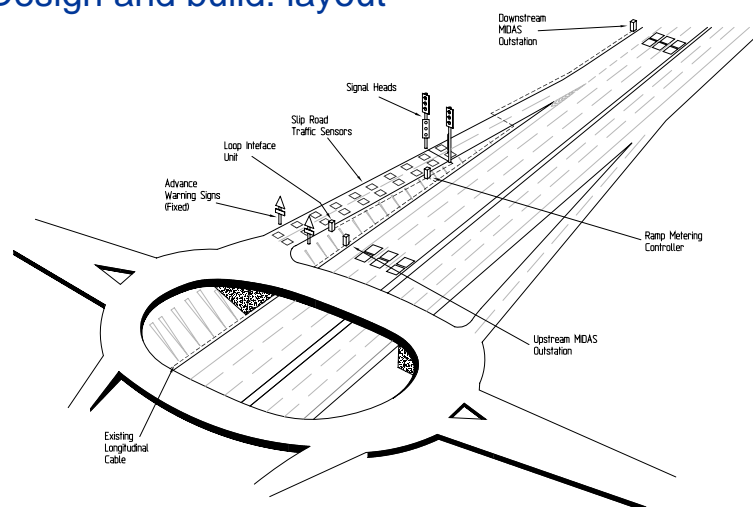
Data filtering algorithms

- Main Carriageway Data Filtering (MCDF) calculates from MIDAS raw vehicle data:
 - smoothed flow
 - smoothed speed
 - smoothed occupancy
 - per lane and per MIDAS loops site
- Ramp Data Filtering (RDF) calculates for various loops on the slip road:
 - smoothed flow
 - smoothed occupancy
 - vehicle count
 - presence

Site selection

- Site must have sufficient congestion / flow breakdown
- Flow breakdown must be generated by over utilisation at the merge
- The slip road flow must be 'in proportion' to main line flow in order to make a significant effect, e.g. 10 – 40% of downstream flow out of junction
- The slip road flow must be 'manageable', i.e. <900 vehicles / hour / lane
- It must be possible to achieve safe merge speeds, which depends on:
 - main carriageway speeds during flow breakdown
 - sufficient acceleration and merge distances
 - gradient and %HGV etc.
- There must be sufficient storage on the slip road (note that the position of the stop line is a compromise between achievable merge speed and available queue storage length)
- Process detailed in Interim Advice Note 66 (05) to be refined and updated in light of findings of implementation of 30 sites

Design and build: layout



Design and build: practicalities

- Passive Poles
- Yellow signs incorporating light signals
 - (LED signal heads plus backing boards)
- Up to 20 slip road loops (Queue, Presence, Release)
- 600 cabinet for Ramp Metering Control Outstation
- Quad cable links to existing MIDAS outstations
- IP communications / internet access to outstations
- Anti-skid and advanced warning signs



Design & build: web-based user interface

The screenshot shows a web browser window displaying the RMC interface. The browser title is "M60 J2 Clockwise (Ref 10.77) - SI Site Monitor - Microsoft Internet Explorer provided by Atkins". The address bar shows the URL: "http://213.123.38.46/F132004/monitor.php?ref=si".

The main content area is titled "RMC Name: M60 J2 Clockwise (Ref 10.77)" and includes a "Site Monitor" section showing a graphical representation of the highway with various control points. A "Site Monitor" dropdown menu is open, displaying a list of parameters and their current status:

Parameter	Status
DefProject	OFF
DefAgent	OFF
DefV	ON
Q1	OFF
Q2	OFF
Q3	OFF
Q4	OFF
Q5	OFF
Q6	OFF
Q7	OFF
Q8	OFF
Q9	OFF
Q10	OFF
Q11	OFF
Q12	OFF
Q13	OFF
Q14	OFF
Q15	OFF
Q16	OFF
Q17	OFF
Q18	OFF
Q19	OFF
Q20	OFF
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Q93	OFF
Q94	OFF
Q95	OFF
Q96	OFF
Q97	OFF
Q98	OFF
Q99	OFF
Q100	OFF

The interface also includes a sidebar with navigation options: System Management, User Management, Fault Management, Logging Management, Algorithms, and Component Configuration. The bottom status bar shows the system is running on a Windows XP desktop with a taskbar containing various application icons and a system clock showing 10:10 on Monday, 21st October 2008.

Calibration and switch-on

- The calibration process:
 - Collection and Analysis of pre-data (week before switch on)
 - determine desired release flows, switch on parameters and critical occupancy safe merge speed
 - Switch On (day 1)
 - when flow is broken down to allow safe merge speed to be confirmed through observation
 - Signal Timings (days 1 - 4)
 - most time consuming part, observe flows achieved for each release level, needs frequent review and adjustment due to changing driver behaviour
 - rT1-10, staT1-10, gT1-10, spaT1-10, RL1-10
 - Queue Override (days 2 - 3)
 - trigger occupancy, (oQo1t, oQo2t)
 - trigger time (tQOt), clear time (tQOc), reset time (tQOr)

Calibration and switch-on

- The calibration process continued:
 - Queue Management (days 2 – 4)
 - desired queue length and gain
 - frequent review and adjustment required due to changing driver behaviour, (learn to queue in both lanes equally and learn to crawl down slip at constant speed with larger gaps between vehicles)

$$r_{poqm}(k) = r_{RM}(k) + K_{poqm}[o_{cq}(k-1) - o_{descq}]$$

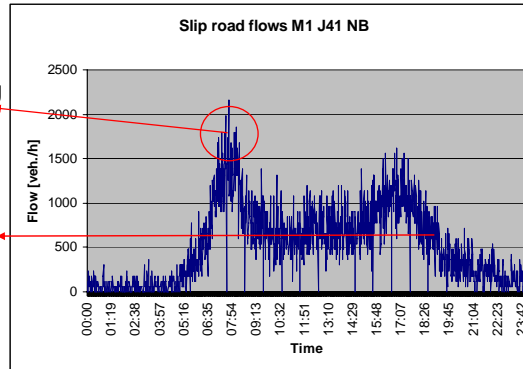
- ALINEA (last day)
 - desired occupancy, time period and gain
 - (by far the easiest aspect of entire calibration process)

$$r(k) = r(k-1) + K_R[o_{des} - o_{out}(k-1)]$$

$r(k)$ limited to within the range $[r_{min}, r_{max}]$

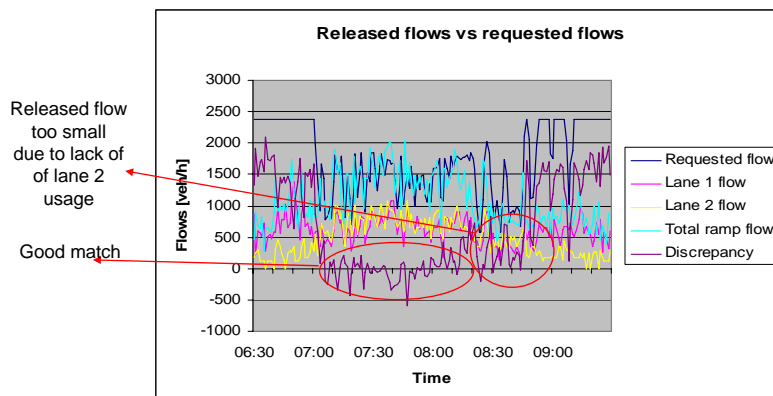
Slip road flow profiles

- The range of metered slip road flows needs to be matched to the existing slip road flows.
- Upper limit: Max occurring smoothed flow disregarding short term peaks.
- Lower limit: Derived from experience minimum achievable metered levels are 500-600 vehs./h for a two lane slip.



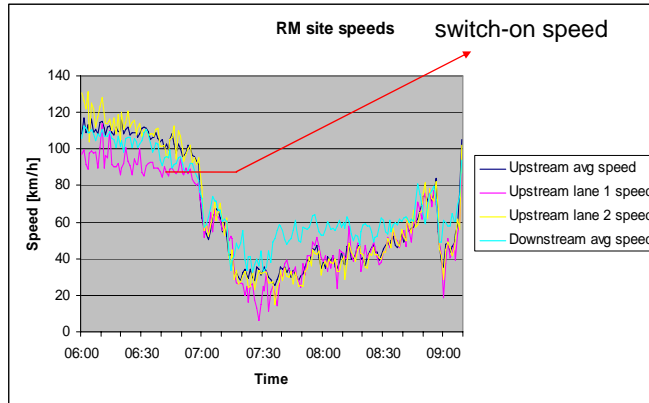
Signal timings and actual flow

- Signal timings control the actually released flow
- Released flow can vary and may not always match the requested flows due to several reasons mentioned earlier



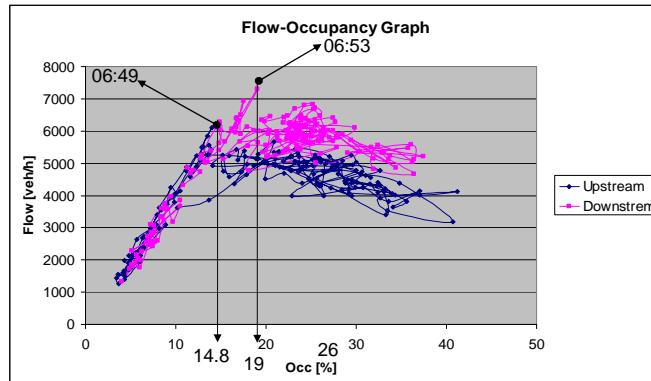
Switch-on parameters

- Criterion 1: Upstream speed low enough for safe merging from the stop line.
 - Determined by modelling and observations on site.



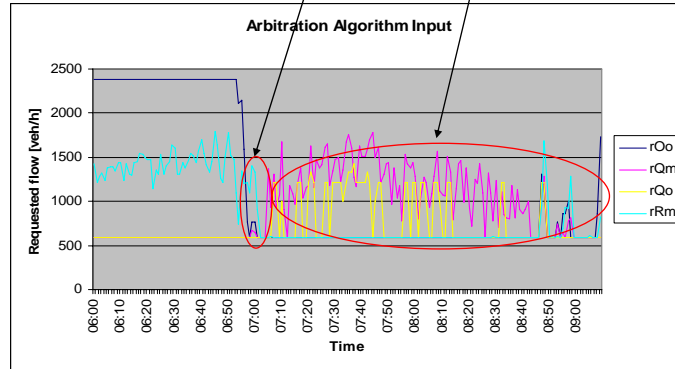
Switch-on parameters

- Criterion 2: Downstream occupancy high enough to prepare for ramp flow reduction
 - Determined by observing transition times between switch-on occupancy o_{on} and critical occupancy o_{cr}



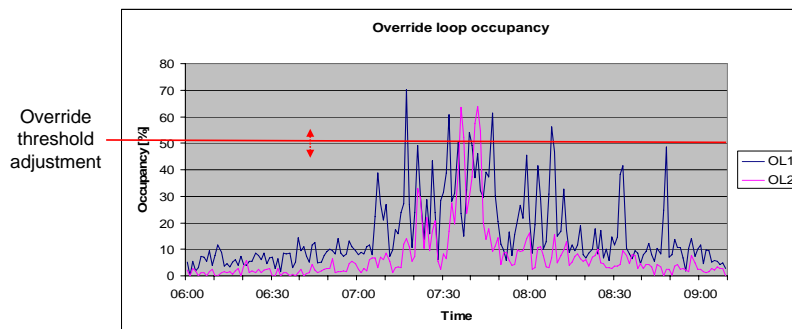
RM operation

- Typically two operational regimes are run:
 - Support for flow recovery (Queue Management)
 - Congestion prevention (Ramp Metering)



Queue override

- Queue override requirements are assessed on site by observing queuing patterns.
- Override thresholds are set to match frequency and timing of required queue override operation.

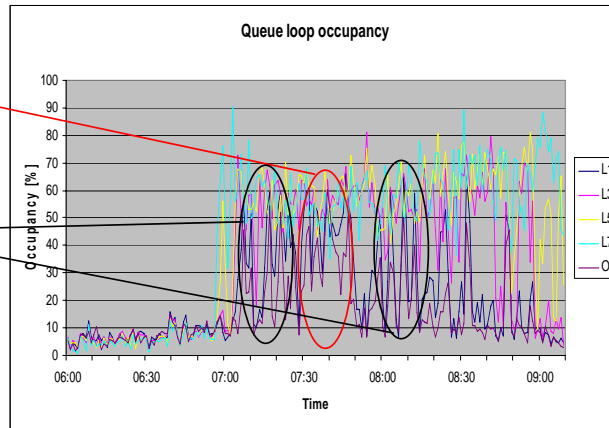


Slip road queue

- Slip road queues can be analysed on the basis of queue loop occupancies

Long queues between 07:29 and 07:48

Long queues can be reduced very quickly

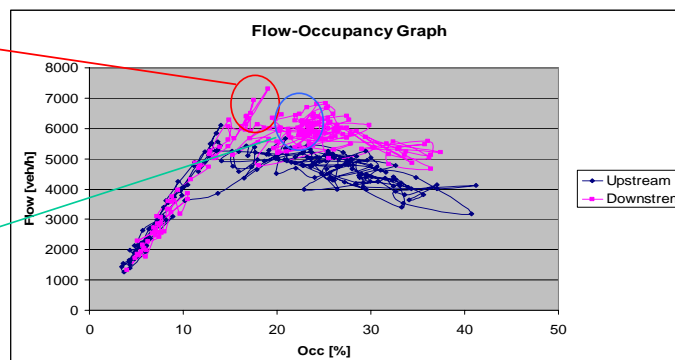


RM parameters for ALINEA

- Critical occupancy is read from flow occupancy graphs as shown earlier
- At some junctions maintaining occupancies at or below o_{cr} is not realistic and the target zone for ALINEA may need to be moved.

ALINEA ideally aims to keep the system in this operating area

If critical occupancy can not be achieved this operational area may be targeted



Evaluation

- Evaluation required to quantify benefits to road users
- Mainly reduced congestion, improved journey time
- Compare journey times before and after
- Also compare flows before and after to show improved journey times are not obtained due to lower traffic levels
- Method:
 - 20 days MIDAS before and after limited to 2km upstream and downstream
 - comparable times of year – minimise impact of seasonal variations
 - collect accident and weather data to discard non-comparable data
- Initial results
 - significant reductions in journey times on main carriageway
 - evaluation of slip road journey times on-going
 - difficulties in measuring the delay imposed on vehicles queuing on slip

Lessons learned

- Site selection – many of the most congested sites must be ruled out, e.g. unsuitable road layout or congestion not caused by merging traffic at that junction
- Design – position of the stop line requires careful consideration – if too far forward the safe merge speed is too low, if too far back there is insufficient queuing capacity
- Calibration – it has been identified that there are ‘rules of thumb’ which could be coded into the system to reduce future calibration effort
- Evaluation – changes need to be made to the data log to make it more comprehensive, also the measurement of delay on the slip road is an important element in determining overall system performance
- System needs simplification, especially build issues, evaluation and algorithms

Future developments

- Automatic calibration
 - Adaptive traffic signal timings
 - Adaptive ALINEA algorithm
 - Adaptive QM algorithm
- Automation in the design stage
 - better link between site selection and design
 - calculation of switch on parameters and critical occupancy
 - calculation of optimum stop line position
- Automatic evaluation
 - automatically collect required data from multiple sources
 - present in suitable format to simplify the evaluation process

Questions

