TECHNICAL MEMORANDUM

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SUBJECT: **Description and usage of the Development Scale Calculator**

Background

Urban Innovators is a consulting firm co-leading research on how to adapt Alternative Intersections for use in walkable urban environments. We are partnered with the Institute for Transportation Research and Education (ITRE) at North Carolina State University (NCSU). There are three Principal Investigators for this research: ITRE's Christopher Cunningham, NCSU's Celen Pasalar of the urban design department, and myself (Mike Brown), founder of Urban Innovators.

Key Research Question – How to maximize mixed-use-compatible mobility

A major objective of our research is to find ways to increase the potential for converting auto-oriented suburban commercial corridors into "Walkable, Complete Street Boulevards." Key to walkability is to have a large amount of both residents and their daily destinations within low-speed range of each other (walking, biking, and an emerging class of low-speed vehicles). Such development cannot be catalyzed to any significant level without investments into street trees, network connectivity, and alternative modes.

Assume those things are solvable, and development of higher density and diversity can thereby be attracted. Even if a high share of the new trips are internal and/or by alternative modes, trips by car and freight delivery are still likely to increase. Can the area handle the increase? If not, resulting congestion will become a constraint, hindering the development potential. City Councils are often pressured to block new development if roads are already too congested. And even if no one blocks development, the next wave of developers may still "flee to the fringe" where it is less congested.

Overview of the Development Scale Calculator

Before community leaders and government representatives can embrace a combined land use and infrastructure vision, it is helpful to approximate how much development the infrastructure can support before it starts to strain under the load. To address this, our team has developed a "Development Scale Calculator." The calculator was designed to analyze areas up to about 1000 acres (or 1.5 square miles). In a suburban area this large, there are often several locations where two major arterials intersect. The calculator can analyze up to three such intersections together. Before describing key steps in using the calculator, it will help to first understand the key concepts the calculator relies on:

- **Vehicle Capacity**: Differences between intersection delay and system delay
- **Land Use Efficiency**: Understand how diversity and density affect vehicle trip generation.
- **Other Strategies**: Network connectivity, alternative modes… things that draw down on-corridor vehicle demand.

Vehicle Capacity: Intersection Delay vs System Delay

To estimate how much development a design can support, we need to first determine how many vehicles the design can support. For an analysis involving a single intersection, this is often just the Level of Service D-E threshold, which is about 60-seconds of delay per vehicle. However, many of the high-efficiency alternative intersection options tend to involve more than a single intersection: Quadrant Intersections involve secondary intersections along with out-of-direction travel for some movements. The U-turn family of intersections (RCIs,

Bowties, etc.) also involve out of direction travel and secondary intersections. One-way streets have lower delay per intersection (given the same volume), but they also involve at least two intersections, and maybe four (in the case of crossing one-way systems).

If your study area's potential solutions involve designs with circuitous routing and additional intersections, then an "apples to apples" comparison requires evaluating system delay. To do this, a microsimulation tool such as TransModeler or Vissim will prove helpful. Something like Synchro may also be useful to help identify the volumes where the initial intersection first hits 60-seconds of delay, but then in the microsimulator you would need to evaluate the "average time in system" for a boundary at least as large as the boundary that would encompass your other one-way, U-turn, or Quadrant proposals.

For example, say the baseline intersection reaches 60-seconds of delay in Synchro at 5000 vehicles per hour. In TransModeler, you would then input those 5000 vehicles to a system where each of the four legs run out for a quarter mile from the intersection. The average "time in system" would then include the 60-seconds of delay at the intersection (to the extent that TransModeler and Synchro create similar results), as well as the time it takes to enter and leave the system – say 70-seconds for an average of 130-seconds in the system.

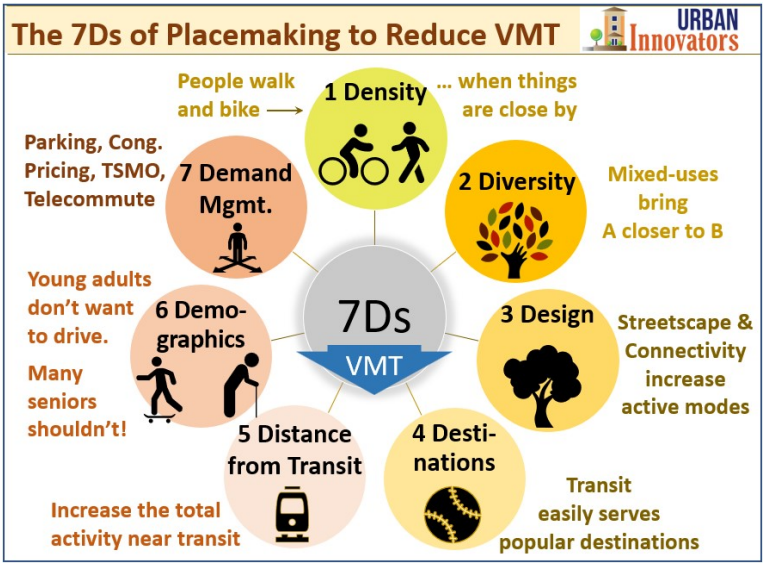
Now, when evaluating the new concepts, there is no point in determining the delay at the primary intersections in Synchro, because how can you tell when you have reached similar delay when more intersections and circuitous routing is involved? Instead, go directly to TransModeler and test the new design with the same 5000 vehicles distributed by movement in the same proportions. Suppose the 5000 now get through in just 100 seconds per vehicle. You know the design reduces overall delay, but you also know you can handle more development.

With just 100 seconds delay, suppose you now increase volumes incrementally until you reach the baseline 130 as the time-in-system, and get 6200 as the result. This means your new design can handle 1200 more vehicles than the existing design, but with the same experience as the existing design. Within this calculator, you would enter 6200 as the new intersection capacity, and the calculator will interpret this as "V/C = 1.0" (or the volume that triggers a volume/capacity ratio that you have defined as the maximum acceptable).

Land Use Efficiency: How diversity and density affect vehicle trip generation

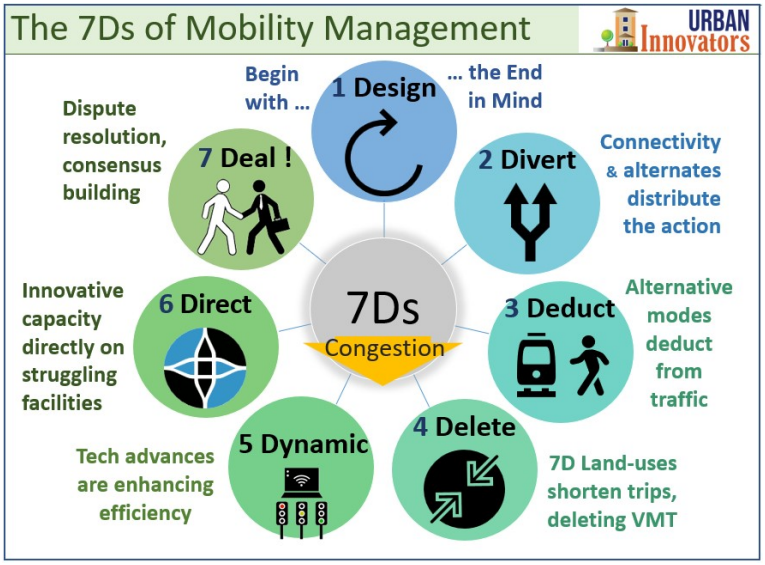
The Institute of Transportation Engineers publishes a "Trip Generation Manual" which estimates how many vehicle trips are associated with each kind of land use. When evaluating several land uses together as a single unit, the result is the sum of all the parts, less an "internal capture" which recognizes some vehicles are not new trips – they are either chaining trips together, or perhaps they park once and walk to other locations, or maybe they live in the area and don't drive, or maybe they drive through parking lots and secondary roads to multiple destinations.

Dr. Reid Ewing of the University of Utah has an extensive database of 31 regions across the nation where he has evaluated different kinds of "centers" (both mixed-use and monolithic use). He has compared how many trips are actually attracted to these areas relative to what the ITE methodology would have predicted, and created "mixed-use adjustment factors" based on observations associated with "7Ds that reduce VMT." Density and Diversity are directly considered by this calculator, and both bring origins and destinations closer together where it is practical to walk, bike, or take a shorter non-arterial drive.



Higher density areas tend to have better transit service, which also draw down vehicle demand. The overall number of vehicles will still likely be higher than in low-density, monolithic-use areas. But when evaluated as a regional system, total trips and VMT per unit will be less, and overall infrastructure will also be less (because development is densifying along existing roads rather than triggering new infrastructure in greenfield areas).

Other Strategies



Where the 7Ds of reducing VMT focus on Placemaking and land use efficiency, Urban Innovators has coined an additional 7Ds that focus more on operational efficiency and mobility management. As relevant to this calculator:

- **1 Design:** Think wholistically about the overall goal – the end-state you hope to achieve. "Think big" about what might be possible if you could wave a magic wand and get politics and funding to align with the vision.
- **2 Divert:** Are there options to get some of the traffic away from critical intersections through neighborhood connectivity, bypasses, etc.?
- **3 Deduct:** Is there opportunity for investment into alternative modes? If so, these will deduct traffic from key intersections, allowing you to increase economic development.
- **4 Delete:** Already mentioned, this is a nod to the other 7D's which delete traffic from ever showing up in the system, due to efficient land uses that naturally create a market for walking, biking, transit, etc.
- **5 Dynamic:** This factor is somewhat beyond our control, but to some extent we can have "faith" that existing and emerging technologies will make it increasingly possible to either reduce vehicle demand, or manage high demands, better than we are achieving now. Hence, to some extent we can trust that the future can handle higher levels of development even if we don't yet know how.
- **6 Direct**: This accounts for new capacity directly on the corridor itself. The calculator accounts for this when you estimate a new vehicle capacity associated with high-efficiency intersections, new lanes, etc., as described earlier.
- **7 Deal!** This isn't accounted for in the calculator but is worth mentioning because the overall vision – the ability to achieve a positive outcome for lower regional costs, improved public health, economic development, climate change – all of it depends on how well you build consensus and resolve disputes.

Pre-Calculator Steps

Steps 1-4 below all prior to opening the spreadsheet calculator. You need to know your existing constraints and how much traffic your proposed new system can handle before you can estimate how much development the area can support.

Step 1: Identify Boundaries of Analysis: Draw a boundary around a location where walkable mixed-use development is desired. Include up to three major intersections. (Usually a 5-7-lane arterial crossing another 5-7-lane arterial). It is ok if there are pockets of single-family residential within the boundary that you do not expect will see any changes.

Step 2: Determine Existing Capacity: Estimate the maximum number of vehicles per hour each key intersection can handle as presently designed. It will be something like "5000 vehicles per hour," representing the sum of all approaches within a 60-minute period, where the average delay per vehicle is about 60-seconds

per vehicle (LOS D-E threshold), along with an associated average time-in-system as noted earlier. Matching today's turning movement proportions is helpful but not necessary.

Step 3: Determine Existing Conditions: Suppose existing traffic is only 4000 vph. This means the corridor can handle more development without any changes to existing infrastructure. Whether it can attract such development without a new strategy is a question for later. Also consider the extent to which this "extra capacity" (1000 in this case) may be needed for supporting future through-trips that must use your corridor, but otherwise have nothing to do with study area land uses. Now suppose conditions are over capacity (say 6000 per hour, or 5000 + 1000 queued into the next hour). This means the area can't handle new development until something reduces the time in system back to where the current intersection has about 60-seconds of delay per vehicle.

Step 4: Identify Opportunities for Increasing On-Corridor Vehicle Capacity: Using high-efficiency Alternative Intersection design, combined with any other options you want to consider such as new left, thru, or right-turn lanes, perhaps the intersection can now support 7000 vph at a "time in system" that is comparable to the base condition.

Overview of Land Use and Trip Generation Tab

Below are the key inputs for "Subarea 1" – the first of three in the overall study area. Yellow cells are user inputs and the rest are informational or calculated. B21 shows the subarea is 111 acres. Rows 5-9 show five basic land use types. (Drop down boxes on hidden rows allow for more detailed types, but these five will work for most applications). Under "Existing" (G) you estimate how many dwelling units there are (if residential), or how many thousands of square feet (if commercial). Use GIS to help, but it is not critical to be exact. There are up to 5 "Alternatives," which can be different visions, or as described here will be a step-by-step analysis of a single vision.

For analyzing a single vision, Alt 1 (H) will be an exact copy of Existing. This is because we are evaluating the impact of our new design on the V/C ratio. Rows 21 and 22 show pre- and post-reduction V/C. Pre is what the situation would be like if there were no credits for higher internal capture associated with density and diversity, or vehicle reductions associated with various reduction strategies. Notice in Row 20 that the calculator estimates the existing situation has 11.9% internal capture based on the mix of existing uses. Row 21 shows .90 as the starting V/C ratio, meaning delay for existing traffic will be a little less than 60-seconds per vehicle. For Step 1, the V/C ratio improves to .75. This is due to our new design, which the next section will expound on.

Land Use and Trip Generation — Stepwise (1) or Alternatives Analysis (2)? 1

	Land Use		Unit	PM Peak	Number of Units					
	Description	Type	Type	Trip Rate	0 Existing	Step 1	Step 2	Step 3	Step 4	Step 5
AREA 1	Single Family Residential	Residential	DU	0.94	0	0	0	0	0	
AREA 1	Multi-Family Residential	Residential	DU	0.51	268	268	1,500	1,500	3,000	
AREA 1	Retail	Retail	KSF	6.59	100	100	300	300	700	
AREA 1	Office	Office	KSF	1.44	185	185	500	500	1,000	
AREA 1	Industrial	Industrial	KSF	0.34	100	100	0	0	0	
	TOTAL			Internal Capture:	8.9%	8.9%	10.5%	24.7%	24.2%	
				Pre-Reduction V/C Ratio:	0.90	0.75	1.12	1.12	1.81	
111	Acres			Post-Reduction V/C Ratio:	0.90	0.66	0.95	0.67	0.97	
				Floor / Area Ratio (FAR):	0.14	0.14	0.48	0.48	0.97	0.00

Trip Distribution %		
Int. 1	Int. 2	Int. 3
75%	20%	15%

In Columns N-P you tell this tool how much of the traffic generated by Area 1 development will traverse each of the three key intersections in the study area. Because Intersection 1 is inside Area 1, it will have the highest share – in this case estimated at 75%. This implies that the remaining 25% will make it to Area 1 via paths that do not include Intersection 1. O and P recognize that some portion of the traffic generated by Area 1 will also traverse Intersections 2 and 3. In this case, 20% of the trips generated by Area 1 will traverse Intersection 2. This is important because if Area 1 grows by a lot, this reduces how much Area 2 and 3 can grow without their key intersections failing. Note that these are not intended to add up to 100%.

Overview of Capacity Analysis Tab

On this tab, B5 is where you enter the existing peak hour volume, which may be above or below capacity. D6 is where you enter the existing capacity, as determined at the 60-second LOS D-E threshold. AA6 then shows .90 as the Pre-Reduction V/C ratio for existing conditions. T is where you tell the tool how much of the existing 4500 traffic is pass-through. In subsequent alternatives, you can make this higher if the corridor needs to be able to support more pass-through, or lower if a bypass or something else is expected to lower pass-through. The next section describes a stepwise process for using these two tabs iteratively to determine how much development an infrastructure package can support.

Stepwise Process for Operating the Development Scale Tool

Step 0: Enter Existing Conditions: As already mentioned, the first thing to do is describe up to three subareas on the land use tab, then describe existing volume and existing capacity on the Capacity Analysis tab.

Step 1: New On-Corridor Capacity, Same Land Use: If your new design creates new capacity, enter that new capacity as Step 1 (D7). By keeping everything else the same, this shows how the pre-reduction V/C ratio (AA7) improves.

	A	B	C	D	T	U	V	W	X	Y	Z	AA	AB	AC
1	**Capacity Analysis**													
3		Existing Volume	Scenario	Capacity (vph)	Pre-Reduction Demand						Pre-reduct V/C		Post-reduct V/C	
4					Pass-through (vph)	Area 1 VPH	Area 2 VPH	Area 3 VPH	Study Area	Thru + Study	Starting VPH	V/C	Reduced VPH	V/C,R
5		4,500												
6	Intersection 1		Existing	5,000	1,000	823	1,183	784	2,790	3,790	4,500	0.90	4,500	0.90
7			Step 1	6,000	1,000	823	1,183	784	2,790	3,790	4,500	0.75	4,000	0.67
8			Step 2	6,000	1,000	2,597	1,394	1,046	5,036	6,036	6,700	1.12	5,700	0.95
9			Step 3	6,000	1,000	2,597	1,394	1,046	5,036	6,036	6,700	1.12	4,000	0.67
10			Step 4	6,000	1,000	5,687	2,418	1,046	9,151	10,151	10,900	1.82	5,800	0.97
11			Step 5	6,000	1,000	8	2	2	12	1,012	1,700	0.28	1,700	0.28

Step 2: New Capacity + New Land Use, Iteration 1: Back on the Land Use tab (repeated below), add residential units and commercial square footage in column I to take advantage of the new capacity. Keep adding until Post-reduction V/C is at or just below 1.0 (.95 in this case). I22 shows the new V/C ratio, adjusted by a new internal capture rate associated with higher density and diversity as determined by Dr. Ewing's 31-region database. By running post-reduction V/C up to 1.0, this shows the "break point" – how much development you can add before the new design breaks down. As a variant, you can also elect to dedicate some of your new capacity to pass-through (T8 above), rather than all of it to new development.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1		**Land Use and Trip Generation**							Stepwise (1) or Alternatives Analysis (2)?		1					
3			Land Use		Unit	PM Peak	Number of Units							Trip Distribution %		
4			Description	Type	Type	Trip Rate	0 Existing	Step 1	Step 2	Step 3	Step 4	Step 5		Int. 1	Int. 2	Int. 3
5	AREA 1		Single Family Residential	Residential	DU	0.94	0	0	0	0	0			75%	20%	15%
6			Multi-Family Residential	Residential	DU	0.51	268	268	1,500	1,500	3,000					
7			Retail	Retail	KSF	6.59	100	100	300	300	700					
8			Office	Office	KSF	1.44	185	185	500	500	1,000					
9			Industrial	Industrial	KSF	0.34	100	100	0	0	0					
20			TOTAL			Internal Capture:	8.9%	8.9%	10.5%	24.7%	24.2%					
21						Pre-Reduction V/C Ratio:	0.90	0.75	1.12	1.12	1.81					
22		111	Acres			Post-Reduction V/C Ratio:	0.90	0.66	0.95	0.67	0.97					
23						Floor / Area Ratio (FAR):	0.14	0.14	0.48	0.48	0.97	0.00				

Step 3: New Capacity + Land Use Iter 1 + Reduction Infrastructure: Back on the Capacity tab, use the +/- sign above column AT to reveal hidden options for vehicle reduction infrastructure shown below. These are all options you can invest in that will reduce the total number of vehicles occurring in the three controlling intersections. Discussing each briefly: When transit is more frequent, it is more practical for more people to rely on; When transit fares are low or even free, more people will leave cars for transit; When transit type is premium, more people will ride; Biking and walking quality affect attractiveness; Parking policies influence

willingness to drive; When Street Trees are impressive, mixed-use development increases, which in turn reduces vehicle trips per capita more than a default assumption about density and diversity could account for. Network connectivity is entered as a direct reduction, meaning that if you enhance off-corridor options for vehicle circulation, then estimate how many vehicles will be diverted from key intersections as a result.

C	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ	AR	AS	AT
Scenario	Demand Reducing Infrastructure - Area 1																	See Note
	Term	Transit Freq.		Transit Fare		Transit Type		Bike		Walk / Sidewalk		NEV / LSV		Parking		Street Trees		Network
		Item	Factor	Item	Factor	Item	Factor	Item	Factor	Item	Factor	Item	Factor	Item	Factor	Item	Factor	Connect.
Existing	Long	30-min	0.75	Typical	1.00	Bus	1.00	Negligible	0.50	Good	1.00	None	1.00	Min. reqs	1.00	Negligible	0.75	0.0%
Step 1	Long	30-min	0.75	Typical	1.00	Bus	1.00	Negligible	0.50	Good	1.00	None	1.00	Min. reqs	1.00	Negligible	0.75	0.0%
Step 2	Long	30-min	0.75	Typical	1.00	Bus	1.00	Negligible	0.50	Good	1.00	None	1.00	Min. reqs	1.00	Negligible	0.75	0.0%
Step 3	Long	10-min	1.15	Free	1.48	BRT	1.31	Grade Sep.	1.48	Good	1.00	Excellent	1.48	Periphery	1.48	Excellent	1.40	10.0%
Step 4	Long	10-min	1.15	Free	1.48	BRT	1.31	Grade Sep.	1.48	Good	1.00	Excellent	1.48	Periphery	1.48	Excellent	1.40	10.0%
Step 5	Long	10-min	1.15	Free	1.48	BRT	1.31	Grade Sep.	1.48	Good	1.00	Excellent	1.48	Periphery	1.48	Excellent	1.40	0.0%

The better your factors are, the more vehicle reduction you will get – up to a point of diminishing returns. Columns BC-BL (not shown) have dampening factors to represent diminishing returns. Consider transit where you can have 10-minute service OR free fares OR premium BRT. Each of these individually will make a big difference. Combining 2 or 3 together will be even bigger, but you cannot claim a "sum of the parts" massive benefit. Why not? Because the people attracted by 10-minute frequency cannot be double-counted when also adding in free fares. After adding in all reduction infrastructure that is practical, the V/C ratio is reduced yet again, setting the stage for the next step.

Step 4: Land Use, Iteration 2: Going back to the land use tab, you can now add even more development and/or pass-through trips. By adding development until the post-reduction V/C is again close to 1.0, this now represents the maximum amount of development the overall infrastructure package can support without significant congestion. Depending on what you selected, this may be far more development than the area could support politically, or that the market could realistically create. If so, you can easily save money by reducing the scale of reduction infrastructure, or you can simply enjoy less congestion.

Understanding the Scale of Development Scenarios

In Step 2, we place 1500 residential units on 111 acres, then later placed 3000 along with a lot of jobs. The first 1500 were possible due only do direct on-corridor capacity created by an Alternative Intersection strategy. The next 1500 and associated jobs were due to multimodal investments, parking policies, street trees, and enhanced network connectivity. But what do 1500 and 3000 residential units on 111 acres look like? How practical is it? An easy first step is to compute units per acre (1500 = 13.5/acre; 3000 = 27.0/acre).

How to Prepare "Reasonably Accurate" 3D Renderings

Another good way to understand results, which will prove useful for public comprehension (next section), is to prepare 3D representations of scenarios. First create polygons in AutoCAD representing where new buildings appear to be practical (vacant land, under-utilized parking, and some redevelopment of low-value buildings). Take some care that the building footprint appears reasonable given a likely need for some parking and landscaping. Then calculate the overall square footage. Assume 100% of new buildings will be residential even on the ground floor (fix this in a later step). Then suppose the total SF of all new building polygons is 0.5-million SF spread over 111 acres. To create 1500 units, you need 1.5-million SF (1500 units x 1000 sf/unit). 1.5 million needed divided by .5 million available on the ground floor means each polygon will be 3 stories tall on average. Now fix the commercial portion by determining how much space is needed for commercial. If it needs 250,000 SF, this means the ground floor of half of the buildings would be commercial, so the average height is now 3.5 stories.

Converting 2D to 3D: Communicating Results to Stakeholders

Using the AutoCAD polygons, create a field or layer noting how tall the polygon will be (1, 2, 3, 4, etc.). Multiply the ground floor square footage by the number of floors, and iterate on the number of floors until the result is close to the average (3.5 floors per building, as noted earlier). Join buildings on each "floor layer" as "blocks" so that they can quickly be extruded in SketchUp to the correct height. Then using a rendering program such as V-Ray or Lumion, show birds-eye views of the extruded buildings to create a sense of scale.

These "cube buildings," without any trees, windows, or architectural details, will look ugly and off-putting to some extent. Counteract this by zooming in to a closeup view where you improve building details, add trees, people, etc.

In this stepwise example, the purpose is not to create an actual development vision, but instead to reveal the maximum size that such a vision could be without creating excessive vehicular congestion. If people are shocked by the amount of development – the sight of a lot of 3-6-story buildings, just tell them the system CAN support that many, and maybe it will in a hundred years. But the governance is still controlled by them, and they can craft something else. Then, with their feedback, use this spreadsheet again to assess an actual development vision that they are more comfortable with. Below is an example of 3D rendering starting from AutoCAD, moving to Sketchup, and ending with Lumion.