

ESD 71 Final Project: Second-Mile Internet Data Backhaul in Kenya

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The Case

- An internet backhaul provider needs to service an isolated remote area with a 10km backhaul link
 - Common situation in developing or rural markets
- At current demand levels, the link bandwidth required is very small, but demand growth is very large
 - Initially, low-cost solutions are viable
 - Within 20 years the operator will need to deploy a fiber network to service demand
- The provider must decide how to design the best deployment for the local conditions
- 20-Year Excel simulation used to analyze design alternatives



Analysis Goals

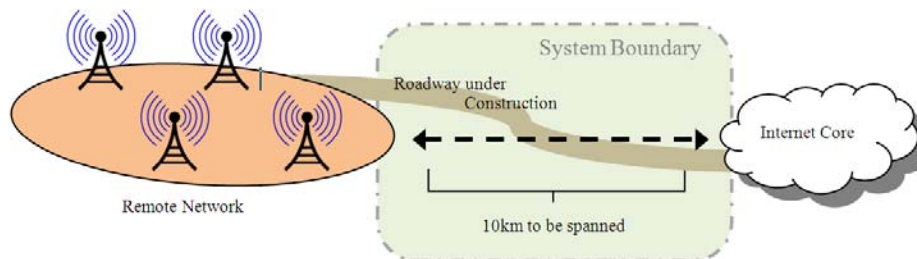
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- Identify the highest value deployment strategy for the network operator's preferences
 - Risk averse, sensitive to efficiency of CAPEX
 - Determine
 - Technology Mix
 - Decision Thresholds
 - Work with other concurrent projects? (road work)
- Apply flexibility-in-design methods to create a realistic simulation and avoid the scenario-based design trap



System Definition

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- Operator must span 10km to remote site with buried fiber optics or microwave radio
 - Cost/Performance trade off
- Serendipitous road construction provides an opportunity to control the cost of fiber installation



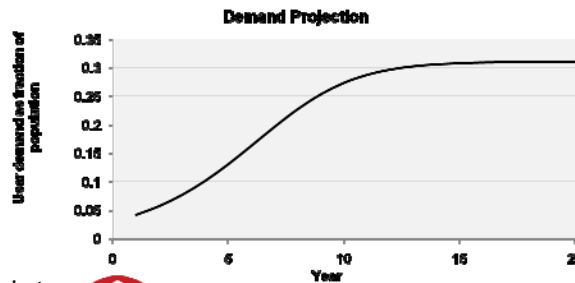
Uncertainties: User Demand Projection

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- Initial demand
- Demand growth

$$D_t = D_{t-1} \left(1 + R(1 - HD_{t-1}) \left(\frac{1}{1 - HD_0} \right) \right)$$

- Conflicting estimates increase uncertainty
- Projection must capture saturation effect



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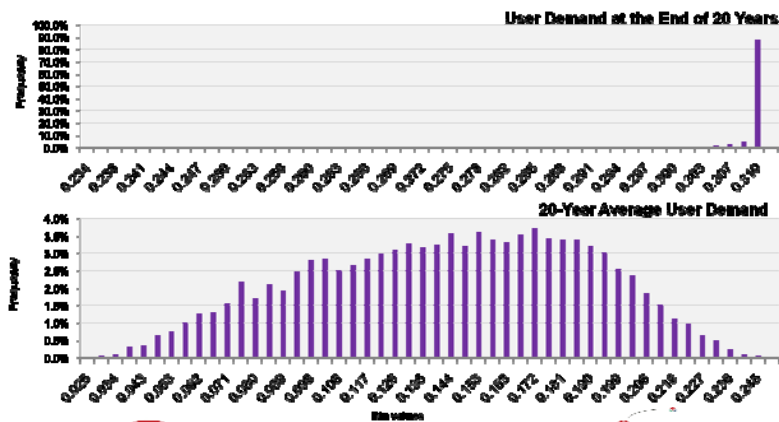


Uncertainties: User Demand Model

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$$D_t = D_{t-1} \left(1 + (R - V_p + 2V_p * RAND())(1 - HD_{t-1}) \left(\frac{1}{1 - HD_0} \right) \right)$$

- Result: "Certain" endstate but uncertain average demand



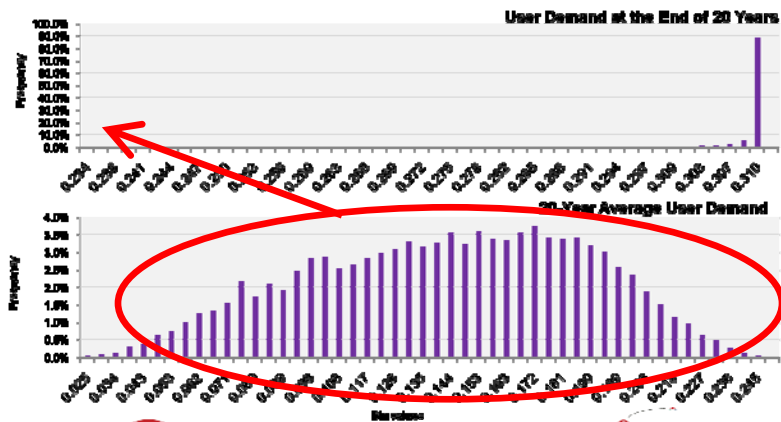
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Uncertainties: Cost to Deploy Fiber

- Cost range between \$15-95K/km
- Depends mainly on labor and logistics for trenching
- Cost and uncertainty can be minimized by pre-planning route and sharing costs with road construction
 - Co-construction: \$25K/km
 - Pre-planned, deploy on demand: \$30K/km
 - No plan, deploy on demand: \$15-55K/km (random)

$$C = 40,000 * RAND() + 15,000$$

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Technology and Design Alternatives

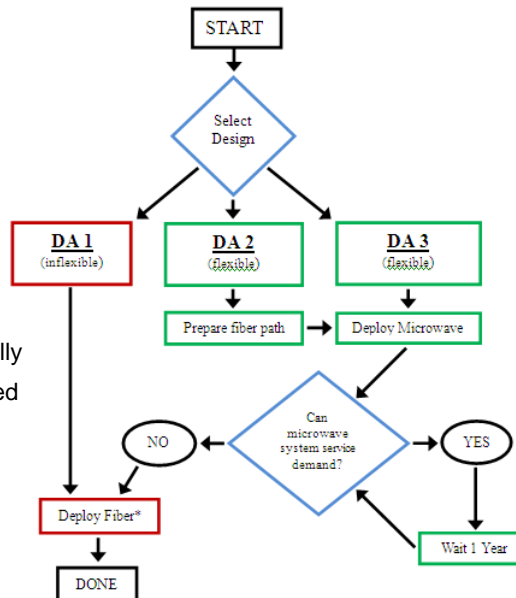
- Three design alternatives analyzed:

DA1: Fiber Full-Deploy	
Cost in year 1	\$250k
Recurring cost	\$1000/yr
DA2: Fiber Partial-Deploy (flexible)	
Cost in year 1	\$10k + Microwave (DA3)
Recurring cost	\$0/yr + Microwave (DA3)
Expansion cost when needed	\$300k
Recurring cost after expansion	\$1000/yr
DA3: No Fiber Prep (flexible)	
Cost in year 1	\$50k
Recurring cost	\$300/yr + \$8201/yr (x .125, .25, .5, or 1 based on use)
Expansion cost when needed	Uncertain, mean \$35K
Recurring cost after expansion	\$1000/yr



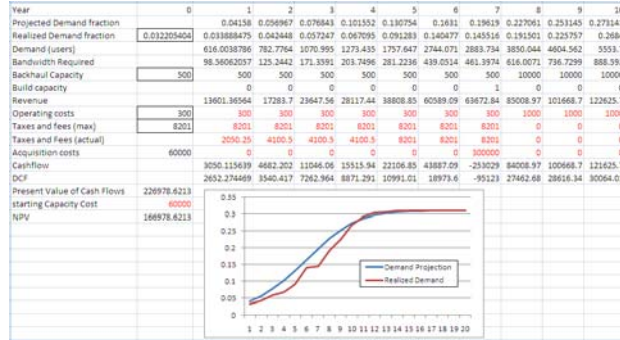
Decision Rules

- Fixed system
 - Deploy fiber at outset
 - Fixed cost
- Flexible systems
 - Start with microwave
 - Evaluate demand annually
 - Deploy fiber when needed
 - Cost fixed or variable based on pre-planning
 - Operator must assess demand a full year in advance



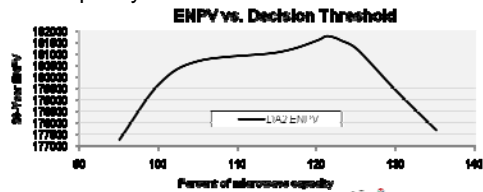
Model Design

- Excel model simulates 20 year project lifespan with randomized initial demand and random growth variability
- Expansion decision triggered based on demand projection

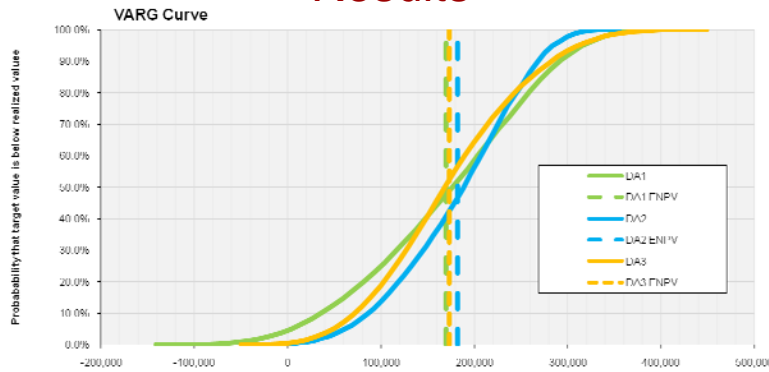


Model Tuning

- Precision checking to 1% error
- | Number of Model Runs | Maximum error fraction for any design alternative |
|----------------------|---|
| 2000 | .0237 |
| 5000 | .0158 |
| 10000 | .0139 |
| 25000 | .0058 |
- Decision rule threshold tuned to find highest ENPV of all three designs at all reasonable thresholds
 - Expansion triggers when extrapolation of t-1 data predicts demand in year t+1 = 122% of current capacity



Results



Design alternative #	-95%	ENPV	+95%	Standard Deviation
Design alternative 1	169,627	170,823	172,020	96,545
Design alternative 2 (flex)	180,177	181,023	181,869	68,228
Design alternative 3 (flex)	171,135	172,102	173,069	78,032

Pre-planned, staged deployment provides highest value

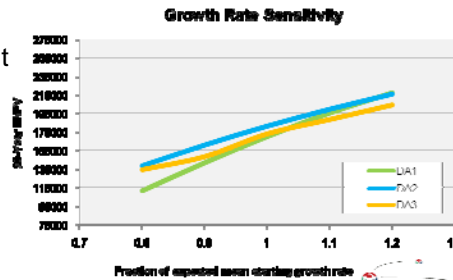


Results

- Flexible designs have lower capital costs and give more efficient ROI
- Operator pays a capital efficiency premium to achieve best ENPV and lowest variability
- Flexible designs exhibit greater robustness to deviations in input assumptions

Design alternative #	B/C ratio
Design alternative 1	1.664
Design alternative 2 (flex)	1.755
Design alternative 3 (flex)	1.752

Design alternative #	ENPV/CAPEX ₀	ENPV/CAPEX _p
Design alternative 1	0.678	0.678
Design alternative 2 (flex)	3.017	1.006
Design alternative 3 (flex)	3.442	1.033



Results

- All designs are profitable in expectation
- Results suggest that the operator would benefit most from pre-planning a fiber path, but delaying full fiber deployment until demand requires it (design alternative 2, benefit ~\$10,000)
 - Design is more profitable in expectation, less volatile, more robust, and has a better downside
 - Lower capital efficiency vs DA3 is worth considering
- With current assumptions, value of flexibility before costs is > \$120,000
 - Value decreases as input conditions become more favorable

