THE IMPLICATIONS OF FIXED LOAD CAPACITY AND RENTING COST OF TOWER SPACE IN GHANA'S SINGLE TELECOM INFRASTRUCTURE MARKET

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ABSTRACT

This paper aimed at "assessing the implications of fixed load capacity and renting cost of tower space in Ghana's single telecom infrastructure market". In particular, the research sought to determine the impact of the fixed load capacity and renting cost on; investment decisions of mobile operators; network coverage; and revenues of a tower company (TC) in a single market. The research applied a deterministic linear regression model and market share of the mobile operators was used as the predictor variables.

The research concluded on the following; revenues of a TC, typically is at break-even or at a loss at population of PL ≤150,000 within an infrastructure location; mobile network operators are presented with three major decisions on investing under the current fixed load and renting cost strategy, one: the "pause "decision-when the market share cannot produce a minimum volume of traffic that can assure an operator some profits, two: "pull" decision-when existing operator would have to leave a market when there is a sudden change in market share (decrease in market share) due to stiff competition, and as a result is unable to produce a minimum volume of traffic that can assure profits, three: "push" decision-when new entrants or existing operator may want to invest irrespective of its market share or current regulation mandate them to. Areas with low population, especially at (PL ≤150, 000) are likely not to be reached, especially under a free market and the current access renting conditions. The research recommended that Ghana's telecom infrastructure market should adopt a more flexible approach to granting of tower space, especially on the issue of equipment's load capacity. A more "fit-in" tower spaces for individual operators based on their market share or subscriber base at different locations on differentiated cost will encourage investment.

***Key words**: tower space, load capacity, telecom tower, mobile network operator (MNO), infrastructure sharing (IS), infrastructure access, fixed pricing, renting cost, operational expenditure (OPEX), capital expenditure (CAPEX), the tower company (TC).*

INTRODUCTION

The rising demand of mobile phone and its associated services is likely to put massive infrastructure cost on Mobile Network Operators in Ghana. The announcement of Infrastructure sharing (IS) came as welcoming news not only for the cash trapped operators but also for the growing industry as subscribers may enjoy services anywhere, anytime with improved quality.

Over a decade now since the enactment of Infrastructure sharing policy by the National Communication Authority yet over 5 million of the Ghanaian population (representing 20% of the population) are without access to mobile network infrastructure. (Report from Ministry of Communication, (2004) and (2011)) and the problem persists till now. This raises questions over whether IS has lived up its expectations as a way of reducing cost of infrastructure investment and encouraging the spread of mobile network infrastructure. The ineffectiveness of the IS strategy may be because the owners of Telecom infrastructure in Ghana typically employs "fixed" pricing model in the implementation of the IS, (Osei-Owusu and Armah (2014)). (OECD, (2010)), in their draft report on the pricing policy instrument for scarce resources showed that, developing countries face the challenge of designing a pricing policy instrument to support scarce resource. They showed that Policy makers have traditionally tended to rely mostly on decisions of the monopoly firms. But this historical approach needs to be reassessed once a competition is introduced in a sector.

An added complication of the fixed pricing strategy is the fixed load capacity, tower owners imposed on Mobile operator's radio equipment and this is likely to skew mobile network competition towards high populated or urban areas, especially if the capacity of load is too large for less populated market to make profit from system underutilization, as a result competition in less populated or rural areas of the country may probably not materialize and large portion of the society shall be left untreated.

In less populated areas, only government subsidies will make private investment viable, unless a more innovative pricing approach is considered. But even in areas covered without the need for public subsidies, especially the high populated or urban areas, the number of operators rolling out their network may change once a mobile operator starts losing out market share and can no longer make a profit under the fixed price conditions offered by the infrastructure market. Large swathes of the country will most likely be left with only one network provider, while urban areas might be covered by two or more.

Unlike countries where the telecom industry is solely owned by government, single infrastructure Areas does not represent a market failure, however, in most developing countries like India, Indonesia and Ghana where the telecom industry is purely private owned, it only takes government subsidies to even have a single telecom company investing in such areas. Private owned telecom companies like any private organizations invest for profit and do not follow the logic of 'public good'.

While assessment of current pricing strategies and recommending more efficient strategies for markets is plausible from the point of view of competition law now popular in telecommunications regulation, there is a lack of theoretical research on the fixed load capacity tower owners will grant at a fixed cost for a tower space and how it may impact on firms' investment decisions, revenues and network coverage and Ghana presents a unique case. The aim of this paper is to fill this gap.

BRIEF OVERVIEW OF PRICING STRUCTURE OF TOWER OWNERS OR COMPANIES IN GHANA

Figure 1: ***The structure of the Telecom Tower***

Source: http://www.pathlosstraining.com/

Pricing Regime of the Tower Companies in Ghana

We consider a 40meters (m) network tower in a low lying geographical area in Ghana,

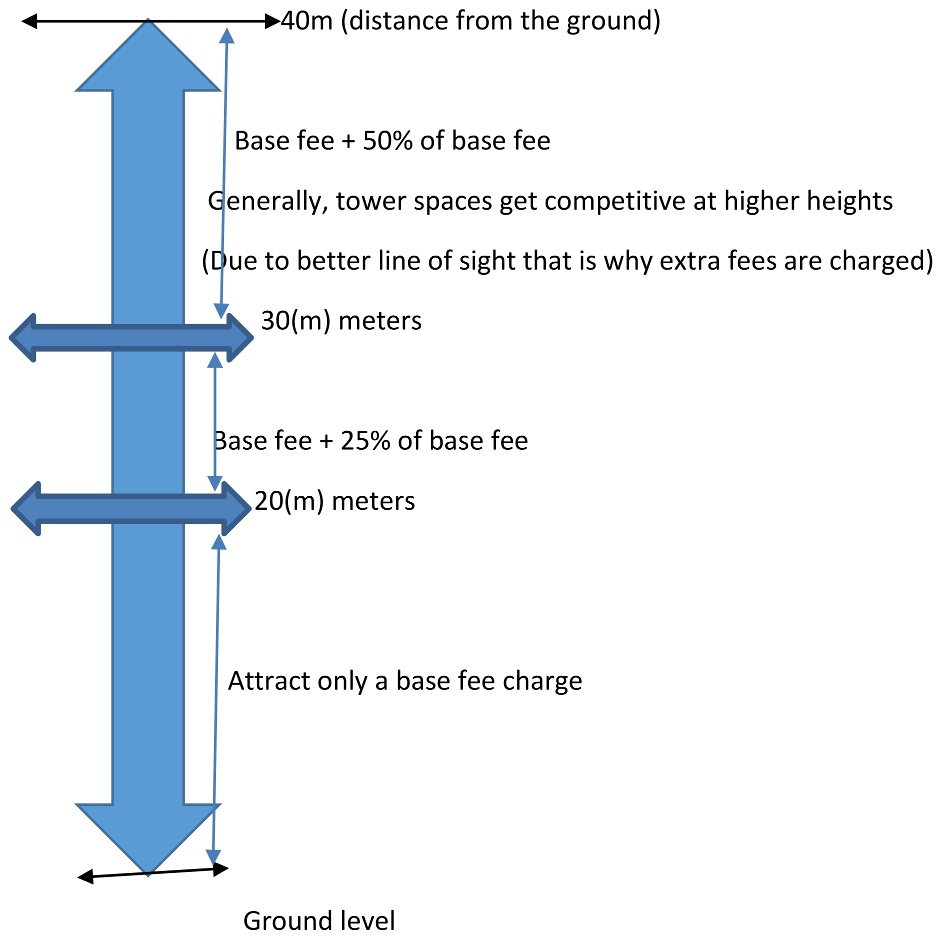

Figure 2: A structure and the demarcation of renting space for a 40meter tower

Source: researcher's field data (2015)

The telecom tower companies in Ghana operate under a pricing regime called the fixed price approach or the Uniform pricing approach.

Requesting Operator pays a fee over an agreed period of rent to the Infrastructure Owner.

The composition of the fee includes a fraction of Capital Expenditure (CAPEX) of building a complete tower and a fraction on ongoing Operational Expenditure (OPEX) over the period of rent.

Mathematically, we can express the fee for renting access space of a tower as

T=a. CAPEX + b. OPEX

*Fee component **a** for a tower space is a fraction of the capital expenditure (CAPEX) of building a complete tower of Q number of spaces.*

In Ghana apart from the base or fixed fee for a tower space, different heights on the tower, especially upward level attract extra fees. See table 1.0 below

Apparatus mounted on the tower at 20 meters or below	*+0%*
Apparatus mounted on the tower between heights of 20-30 meters to be subject to a fee increase of:	*+25% of Base fee*
Apparatus mounted on the tower above 30 meters to be subject to a fee increase of:	*+50% of Base fee*

Table 1.0: Rate card

High height assures a good line of sight, which is capable of providing good quality of service to subscribers or downstream clients.

Prior to installation radio equipment's or apparatus by the requesting party or the mobile operator, tower companies or owners of infrastructure, conduct structural analysis to determine whether or not the installation of the radio equipment or apparatus of the requesting operator or the MNO shall exceed the load capacity or structural integrity of the Tower. This is to say that requesting operator is faced with a fixed load capacity agreement for any space of tower requested.

The load capacity measures the power (volts) required for efficient transmission data, in a more precise term, it translates into the capacity rate of the radio equipment to be installed by the requesting mobile network operator. The capacity rate of a radio transmission equipment is directly related to the permissible load capacity of the communication system. Requesting operator is forced under the access agreement to install equipment that can "fit in" to the load capacity requirement, this is to say the choice of radio equipment, in this case is dictated. Each tower's space load capacity is derived from the load capacity of the entire tower setup. For example, if a complete 30meter tower has a maximum load capacity of L, then a tower of 10 spaces is most likely to get a fixed load capacity of L/10unit. The resultant capacity rate (thus, from a system's load capacity) can be measured over a period and obtain the dimensionless load factor known as Erlang.

*Fee component **b** is the operational cost charges over an agreed period, **b** for a requested tower space is a fraction of the operational expenditure (OPEX) of operating the entire tower of Q number of spaces after a period of rent. There are so many items that go into the **b** fee and the popular among them includes, fuel for site generators, security and other equipment needed at the tower sites.*

Countries like Ghana where inflation is not predictable, mobile operators pay for the extra on-going cost if there is change in fuel price for generators and other site equipment. There is an agreed annual escalating fees, new fees is effective 1 January each year, the new fees being calculated on the basis of a weighted average percentage representing an effective increase in the cost of operating the Infrastructure.

Composition of typical tower space provisions by tower companies in Ghana

The infrastructure owner provides requesting party with Tower Space for a single cellular installation of maximum 3m2 wind loading on tower as follows:

- *3 sectorised panel antennae of maximum height of 2.6m per antenna, all mounted around the tower at the same height above ground level; and*
- *6 feeder cables (7/8th feeder cable) for the above antennae; and*
- *2 parabolic RRUs (microwave antennae) of up to 0.6m diameter each, or equivalent wind loading; and*
- *2 feeder cables (20mm) for the above microwave dishes.*

RELATED LITERATURE

Academic research has started to look into issues of access pricing and investment, according to Valletti (2002). Valletti asserted that problems in access pricing and regulation have not been studied sufficiently.

In Infrastructure access obligations, most papers focus on the role of uniform pricing constraints and their impact on network coverage and market competition. Valletti, Hoernig, and Barros (2002) showed that the introduction of uniform pricing and coverage constraints in Infrastructure access is not competitively neutral: Under uniform pricing, the equilibrium coverage may be lower than without any regulatory intervention. Similar results from the strategic links created through pricing restrictions on infrastructure access have been found by Anton et al. (2002), Choné et al. (2000, 2002) and (Foros and Kind (2003)). Hoernig (2006) concentrated his analysis on the imposition of uniform pricing constraints and shows that the opening of the market to competition in the presence of uniform pricing constraints on all operators gives rise to a series of neighboring monopolies rather than competition for customers within the Infrastructure market.

Bourreau and Dogan (2006) considered a model of infrastructure investment in a telecommunications market with access regulation. One of the firms already owns an *infrastructure, and thus only the other firm must decide if it wants to enter as a service-based or facility-based competitor. Therefore, the regulator simply has the problem of setting an access price such that the entrant duplicates at the socially optimal investment date.*

Varada and Hoernig (2010) showed how mandatory access influences the investment dates of two firms that want to build new infrastructures in the telecommunication industry and concluded that in the context of access pricing, lower access charges may lead to waiting, while high access charges lead to preemption. While higher access charges make the follower invest earlier, and also the leader in a waiting equilibrium, its effects are ambiguous under preemption. If the stand-alone incentives for investment are strong enough, then also under preemption the leader's investment will occur earlier. If on the other hand the reduction in payoffs caused by the anticipation of the follower's investment is the determinant factor, then the leader's investment will be delayed by a higher access charge.

Osei-Owusu and Armah (2014) posited that the uniform or fixed pricing approach currently being used in infrastructure access pricing in Ghana faces several challenges including deterring of new entrant, not helping to achieve expected revenues, however, showed that dynamic pricing may be an efficient method of pricing shared infrastructure in the market. This research goes to confirm assertion by Cambini and Valletti (2004) that firms might use, interconnection or infrastructure access terms in weakening the intensity of competition in the market. For that reason Armstrong (1998) and Laffont et al. (1998) advocated for stronger policies or regulation must be put on pricing strategies that firms follow. Centrally to the fixed pricing approach Cambini and Hoernig (2013) sought to analyze access pricing based on different location (more of a differentiated pricing approach) in their research on geographic access rules and investment.

Some studies analyze the incumbent's investment incentives (Foros, 2004; Katakorpi, 2006; Brito et al., 2010; Nitsche and Wiethaus, 2011; Mizuno and Yoshino, 2012) or the alternative operators' (Bourreau, and Do˘gan, 2006) as a function of the access pricing regime or policy. Several other papers (Gans, 2001 and 2007; Hori and Mizuno, 2006; Vareda and Hoernig, 2010) study the impact of access charges in a dynamic investment race between the incumbent and the entrants. Finally, additional papers have recently focused on the interplay between access regulation and the migration from the old legacy network to an NGAN infrastructure (Bourreau, Cambini and Do˘gan, 2012; Brito, Pereira and Vareda, 2012; Inderst and Peitz, 2012).

Though several studies have focused on uniform or fixed price; differentiated pricing and its impacts, none has focused on the conditions under access, especially the offered load capacity for requesting operator's radio equipment and how it may impact investment decisions, revenues and network coverage. Ghana presents a unique case where such phenomenon is practiced. Network Infrastructure market in Ghana appears to follow some sort of traditional path dependency access pricing approach, requesting mobile operators will have to 'take it or leave'; a fixed load capacity at a fixed price for a requested network tower space. The researcher is of the view that once competition is introduced such approaches must be reassessed.

THE MODEL SETUP

Consider the following situation. Tower Company (TC) has two types of firms to grant network access, Current Operators (COs) and New Entrant (NE) that its need to provide infrastructure access. This infrastructure has all the feature of a public utility, that is, the public pursues social objectives such as 'Equal Access' of all firms to the Infrastructure. Typically, this situation reflects liberalization of a Telecommunication infrastructure market, where the current operators firm (COs) and a new entrant (NE) faces investment decisions in entering new areas.

This model considers two geographical areas: Urban and Rural Area(s)), where the definition of Urban and Rural Area is purely based on the human population density and not built features such as houses.
We assume a single infrastructure market for both locations, where infrastructure access or renting is based on a fixed pricing approach and an added condition of the fixed load capacity of radio equipment.

***Cost Structure**: In this model the researcher wants to capture the typical cost structure of next-generation access network infrastructure. Whereas the marginal cost of running the network is independent of the location. (Bourreau, Cambini and Hoernig (2013)).*
A firm request Access and is given a tower space Q (at a fixed load capacity), who is charged a fixed fee of T for the expected rent period. If operational cost remains the same over the entire period of rent, then a charge T for a space Q (at a fixed load capacity) will also remain the same or else an escalation fee may apply at agreed period. ***Such pricing practice is a fixed price approach***

Revenue Structure: *we assume the revenue under the fixed price approach as follows;*
A firm TC receives a revenue over time period; $(R_t) = T(Q)$ *for number of tower n spaces requested and a corresponding profit (P) received (P) =* $(R_t)-TCO_{NT}$ *, where* TCO_{NT} *is the Total Cost Ownership to build a Network Tower of n spaces (*TCO_{NT} *= CAPEX + OPEX)*

The revenue structure satisfies a deterministic linear regression $Y= BX$

Access Competition: *In a competitive infrastructure market like Ghana, we expect the emergence of Duplicate Infrastructure Areas (DIAs), where two tower companies (TCs) have rolled out and single infrastructure areas (SIAs), where only one tower company (TC) has rolled out a network. Similar to Bourreau, Cambini, Do˘gan, P. (2012), classification of incumbent investment choice of network infrastructure, however, this research will only consider (SIAs)*

Access Demand Constraint: *The infrastructure demand by a particular firm (COs or NEs) is dependent on its population of the particular location in relation to the fixed load capacity* *constraint imposed by the owners of the tower infrastructure under a fixed pricing strategy terms. Osei-Owusu and Armah (2014) showed how pricing strategy affects demand.*

MAJOR OBJECTIVES

To determine the impact of fixed load capacity and rent cost on the investment decisions of the requesting MNOs

To determine the ***effect of*** *fixed load capacity and rent cost on revenues of Telecom Tower Company in UA (S) and RA(s) in a single Infrastructure Market.*

To determine the impact of fixed load capacity and rent cost on Network Infrastructure coverage

CASE 1: Outlook of Revenue of a TC in RAs and UAs under fixed load capacity and rent cost

Hypothesis: $(\mathbf{R_t}, Q)_{RA} < (\mathbf{R_t}, Q)_{UA}$, *we assume the single infrastructure company (TC) exist in both areas.*

We are interested in the relation between the capacity rate of the radio equipment as a result of the offered fixed load capacity of a tower space Q as a function of the market share of MNO in an infrastructure location.

We are aware of the concept of 'demand and supply' and the environmental factors which affect demand. This research in particular is not interested in high commercial activities effect on demand, but rather high population, and assume that at high population, the more network tower spaces take up a request or access and the higher the frequency of such request.

We assume that for a certain number of spaces demanded over a period, the mean revenue will be linearly related to the profit (P)

Further, for some reason, if demand remains steady per the estimation of population over time within the two areas, we believe that revenue will normally distribute with unknown standard deviation ∂ (that is, ∂ measures how variable demand other than population size)

Thus, we fit a deterministic model relating
Profit P to the revenue over a period (charge T multiplies by the number of space Q requested)

$$\textbf{Profit (P)} = -TCO_{NT} + T(Q) + U$$

So that $P|Q \sim N(-TCO_{NT} + T(Q), U)$

One limitation of linear regression in this research is that it restrict our interpretation of the model to the range of values of the predictor variables that we observe in our data. We cannot assume this linear relation continues outside the range of our sample data.

Market share of MNO in Ghana

The range of data of predictor variables for this research was obtained from the market share of the MNO at each location and this will enable the researcher predict which operator is likely to request access in selected areas within single infrastructure UA and RA

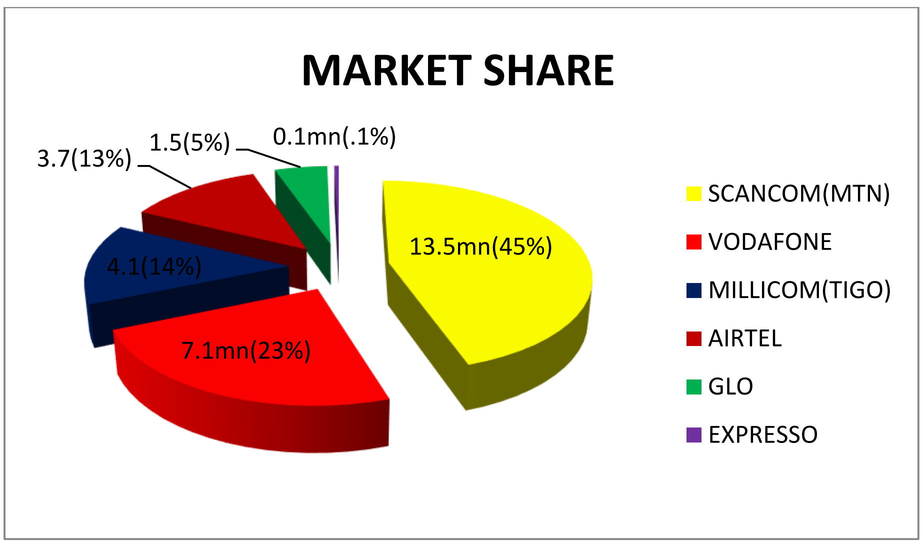

Figure 3: market share of Telcos in Ghana
Source: National Communication Authority's (NCA) website (2014)

We assume that MNO decision of requesting an access in an area will depend largely on its market share of a particular location of access in relation to the fixed load capacity obliged by tower owners. Fixed load capacity determines the capacity rate of the radio equipment.

Telecom radio access engineers will have to calculate the system (radio equipment's) capacity rate over a time period to obtain a dimensionless load factor called Erlang. Requesting operators are able to compare their expected Erlang from their market share to the fixed capacity been offered at a fixed cost before finalizing a request. For large MNOs like MTN or Vodafone, they may even have to request for extra space due to their large expected transmission or erlangs.

*According to Parviala and Erikoistyo (1998), a mobile phone user produces an average volume of traffic or Erlang(erl) of 0.03 and thus we can calculate expected Erlang from a market share within a location ($MS_{L)}$ by multiplying MS_L * 0.03.*

We produce a general formula relating revenues over a period (R_t) of a TC in relating the fixed cost of rent, expected Erlang from MNO's market share in a location and the capacity of the radio equipment in Erlangs

We assume for UAs all the six MNO in Ghana may produce some reasonable expected Erlangs to make some minimum profit against the fixed cost rent and other capital investments. If such condition is true, then we expected at least one space each request and Revenue (R_t) of a TC given us;

$$(R_t) = T\ \Big[(MS_{Lmtn*}0.03) \div R(erl)) + (MS_{Lvodafone*}0.03)\div R(erl)) \ (MS_{Ltigo*}0.03)\div R(erl)) + (MS_{Lairtel*}0.03)\div R(erl)) + (MS_{Lglo*}0.03)\div R(erl)) + (MS_{Lexpresso*}0.03)\div R(erl))\Big] \ldots\ldots (1)$$

*(If (MS_L *0. 03÷Rerl) >1, then the request will be more than one tower space), where R (erl) is the Erlang supported by the fixed load capacity offered to MNO by tower owners.*

*For RAs, we expect conditions where MS_L *0. 03÷Rerl << 1, and at such some MNO may drop request to take up a tower space and its implication will reflect in the Revenue (R_t) in (1)*

Remarks1:

An MNO will be well motivated to ask for access in a new area if its market share can provide an Erlang equivalent to R (erl) or at some level of erl, deem as the profit level of mobile operator. This is because any market share that will not guarantee such Erlang will have the whole infrastructure system underutilized and likely to produce less revenues to the investor.

We also observe that in an event that some of the MNO fallout from investing as a result that their market share cannot guarantee them profit in relation to the fixed cost investment, such scenario may likely reduce expected revenues of the TC. Such scenario is quite typical with RAs infrastructure markets.

CASE II: Impact of fixed load capacity on investment decisions of the MNOs

We assume a market share of a MNO produces Erlangs equivalent to R (erl) and thus it is motivated to invest because of the possibility of making some profits, if this operator's share is *such that it receives a volume of traffic* ***(Verl)*** *every hour; we can calculate an expected revenues over a monthly period.*

$V_m = 1hr*24*30days$

We assume K as the charge per traffic per minute, then revenue over a month

$(R_m) = K* V_m$........ (2)

From equation (2), R_m *is directly proportional to* V_m, *and such relation forms the basis of investment decisions of a MNO in a location.*

We identify three main investment decisions face by MNO; ***"Pause", "Pull" and "Push"***

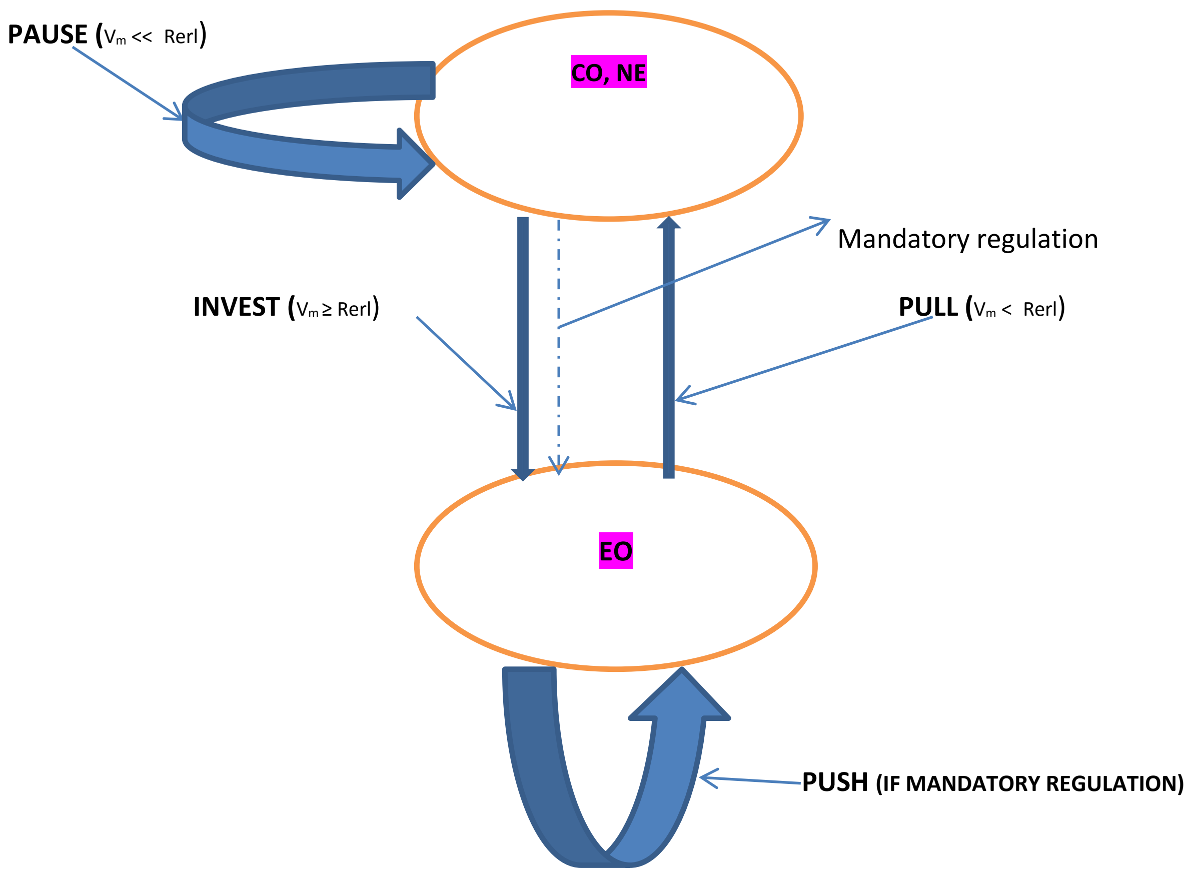

Figure 4: Investment decision model
Source: researcher's model (2015)

A "pause" decision of such will arise typically for a new entrant (NE) or a Current Operator (CO) who is deciding to enter a different market or location. Analyzing the conditions of Access or rent of infrastructure, where a fixed price and fixed load capacity constraint applies in relation to his expected market share and its expected volume of traffic ***(V_m << R (erl))****, might pause the decision to enter such market to latter date where conditions may be favorable. Such decision to wait is what the researcher described as "pause" decision.*

A "pull" decision is one made by an existing operator (EO) who is not making a profit due to a sudden decrease in market share and faces a fixed price and fixed load capacity. Such operator losses proportion of its market share to a competitor to a level that it volume of traffic per month ***(V_m)*** *is far below profit making level****. A decision to quit the market based on this constraint is what the researcher described as a "pull" decision.***

A "push" decision is usually made when an operated is mandated by a regulation to enter a market as a form of Universal Service Obligation. It can also be a case that the operator interns to use a cross subsidy (that is if there is abundant profit in other market) or increase it charges on subscribers (which might not be a wise choice) or enter the market, knowing well, it's not going to make profit but hope to make profit with time, if only it can increase its market share. Any of such decision that will keep or force an operator into a market is what the researcher describes as "push".

CASE III: Impact of fixed load capacity and fixed price strategy on network infrastructure coverage

Table 1.1 Cost structure of building a standard 40meter Telecom Tower

Capital Expenditure (CAPEX) for building a complete tower	*7500Ghana cedis ($2500 @ 3 Ghana cedis per a dollar)*
Monthly Operational Expenditure (OPEX)	*8300 Ghana cedis ($2766. 7@ 3 Ghana cedis per a dollar)*
No. of Spaces of Tower (Tower spaces)	10
Cost of renting one Tower space (Q) per month (T_m)	*4000 Ghana cedis (@ 3cedis per dollar, $1266. 7*
Allowable load capacity or capacity rate of a tower space over a period in (Erlang or Rerl)	*2000 erl*

Source: *M-P Infrastructure Ltd, Accra-Ghana Office (2015)*

With the above information we calculate for the expected revenues and the network coverage of locations

We recall from the equation (1)

$$(R_t) = T \left[(MS_{Lmtn}*0.03) \div R(erl)) + (MS_{Lvodafone}*0.03) \div R(erl)) \; (MS_{Ltigo}*0.03) \div R(erl)) + (MS_{Lairtel}*0.03) \div R(erl)) + (MS_{Lglo}*0.03) \div R(erl)) + (MS_{Lexpresso}*0.03) \div R(erl))\right]$$

Where $(MS_L *0.03 \div Rerl) > 1$*, then the request will be more than one tower space*

$$(R_m) = T_m \left[(MS_{Lmtn}*0.03) \div 2000erl) + (MS_{Lvodafone}*0.03) \div 2000erl) \; (MS_{Ltigo}*0.03) \div 2000erl) + (MS_{Lairtel}*0.03) \div 2000erl) + (MS_{Lglo}*0.03) \div 2000erl) + (MS_{Lexpresso}*0.03) \div 2000erl)\right] \ldots\ldots \; (3)$$

We put in market share values for each operator,

$$(R_m) = T_m \left[(0.45*P_L*0.03) \div 2000erl) + (0.23*P_L*0.03) \div 2000erl) \; (0.14*P_L*0.03) \div 2000erl) + (0.13*P_L*0.03) \div 2000erl) + (0.05*P_L*0.03) \div 2000erl) + (.001*P_L*0.03) \div 2000erl)\right] \ldots. \; (4)$$

$$(R_m) = T_m \left[(0.0135*P_L) \div 2000)_{mtn} + (0.0069*P_L) \div 2000)_{vodafone} + (0.0042*P_L) \div 2000)_{tigo} + (0.0039*P_L) \div 2000)_{airtel} + (0.0015*P_L) \div 2000)_{glo} + (0.00003*P_L) \div 2000)_{expresso}\right] \ldots\ldots(5)$$

By using any of the equations (4) and (5) and knowing the population of the infrastructure areas (P_L) *we can predict the tower space each MNO is likely to request from a tower company (TC), leading as to calculating the expected monthly revenue* (R_m) *of the TC.*

We express individual revenues in a deterministic liner regression form Y=BX

$$(R_{m1})_{Mtn} = T_m (6.75\mu*P_L)$$

$$(R_{m2})_{Vodafone} = T_m (3.45\mu*P_L)$$

$$(R_{m3})_{tigo} = T_m (2.1\mu*P_L)$$

$$(R_{m4})_{Airtel} = T_m (1.95\mu*P_L)$$

$$(R_{m5})_{Glo} = T_m (0.75\mu*P_L)$$

$(R_{m6})_{expresso} = T_m (0.015\mu * P_L)$

Where $\mu = 10^{-6}$

We write a Matlab code and obtain a graphical representation of expected revenues and network coverage over population density of a location, as shown in figure 3 below.

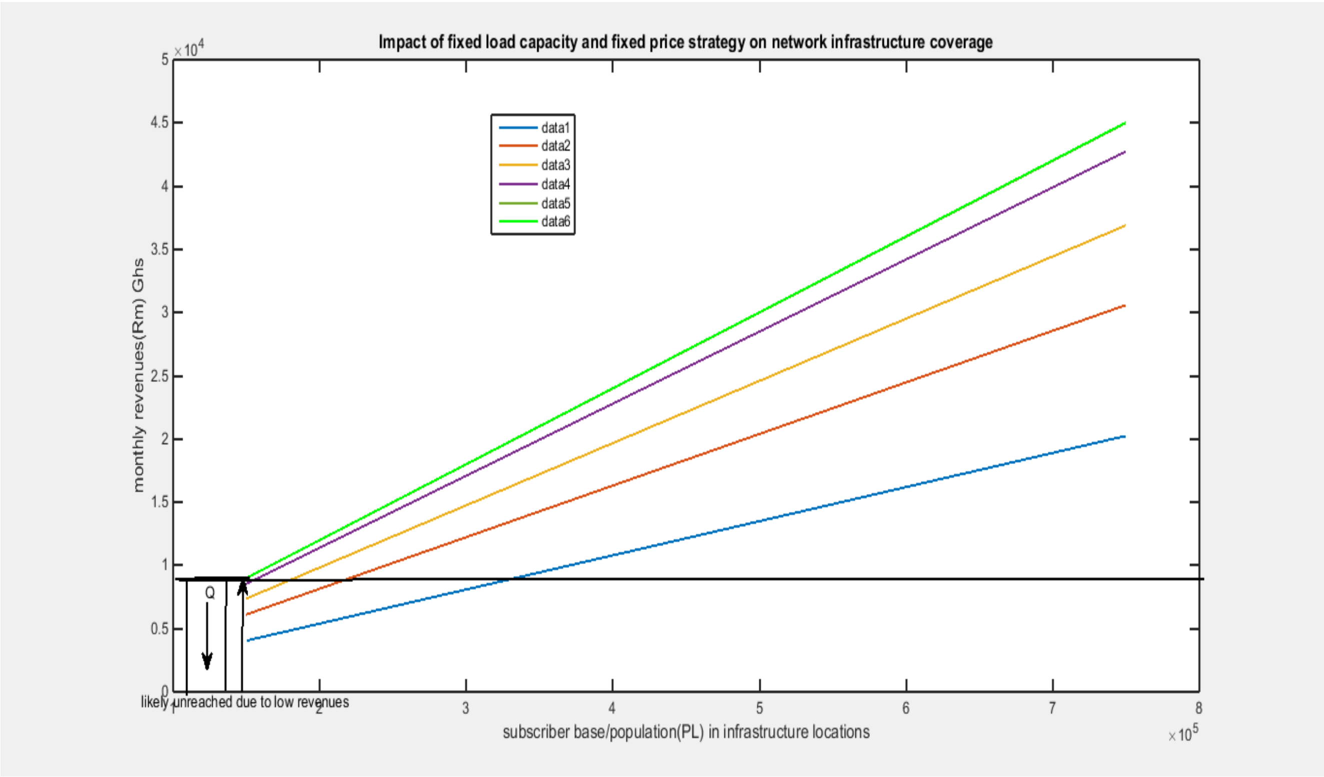

Figure 5: outlook of revenue and Network coverage
Source: researchers' field data (2015)

From the figure 5 above the line labeled data1 shows the revenue outlook when only MTN is able to request access in the market or such infrastructure location and thus Rm for a TC is $(R_m) = (R_{m1})_{mtn} + (0)_{Vodafone} + (0)_{tigo} + (0)_{airtel} + (0)_{glo} + (0)_{expresso}$.

The line labeled data 2 shows Rm for a TC where two MNOs requested access
Thus , $(R_m) = (R_{m1})_{mtn} + (R_{m2})_{Vodafone} + (0)_{tigo} + (0)_{airtel} + (0)_{glo} + (0)_{expresso}$

Labeled data3 shows,

$(R_m) = (R_{m1})_{mtn} + (R_{m2})_{Vodafone} + (R_{m3})_{tigo} + (0)_{airtel} + (0)_{glo} + (0)_{expresso}$

Labeled data4;

$(R_m) = (R_{m1})_{mtn} + (R_{m2})_{Vodafone} + (R_{m3})_{tigo} + (R_{m4})_{airtel} + (0)_{glo} + (0)_{expresso}$

Labeled data 5;

$(R_m) = (R_{m1})_{mtn} + (R_{m2})_{Vodafone} + (R_{m3})_{tigo} + (R_{m4})_{airtel} + (R_{m5})_{glo} + (0)_{expresso}$

Finally labeled data 6

$(R_m) = (R_{m1})_{mtn} + (R_{m2})_{Vodafone} + (R_{m3})_{tigo} + (R_{m4})_{airtel} + (R_{m5})_{glo} + (R_{m6})_{expresso}$

Remarks 2: *At PL <150,000, the TC records it lowest revenues, this is as a result of the shortfall of population density, it's effect on market share and its subsequent effect on the decision to invest by MNO, since it may be impossible to make a profit from a fixed cost renting of a bigger but fixed capacity system. The situation is expected to worsen as PL <<<150,000, where the market share of even the largest MNO, Mtn cannot even guarantee a volume of traffic half of the capacity of the radio equipment paid for at fixed cost. Low turnout of request of tower space may deter further investment and likely to also cause a pullout by already existing tower company.*

Remarks 3: *The shaded region Q in figure 3 shows the areas or locations likely to be unreached, unless TC and MNOs are forced through regulation.*

OBJECTIVE NON-QUALITATIVE EVEIDENCE

Table 1.2: Single Infrastructure UAs and RAs

	SITE NAME/CITY	REGION	POPULATION	TOWER OWNER	REVENUE TYPE
1	Assin Fosu	Central	161,341	AIRTEL	SILVER
2	Boo (Jirapa)	Upper West	88,402	AIRTEL	SILVER
3	Puisga	Upper East	131,550	HELIOS	SILVER
4	New edubiase	Ashanti	115,378	AIRTEL	SILVER
5	Nsuta	Ashanti	71, 232	HELIOS	SILVER
6	Mampong	Ashanti	88,051	AIRTEL	SILVER
7	Sunyani Odumase	Brong Ahafo	85,272	EATON	SILVER
8	Abetifi Kwahu (abetifi)	Eastern	77,125	MTN	SILVER
9	Kwahu Tafo (abetifi)	Eastern	77, 125	MTN	SILVER
10	Jasikan	Volta	59, 181	HELIOS	SILVER

11	Nkonya	Volta	65,901	AIRTEL	SILVER
12	Ashaiman	Greater Accra	190,972	ATC	PLATINUM
13	Amasaman	Greater Accra	262,742	EATON	PLATINUM
14	Tarkwa	Western	90,477	AIRTEL	SILVER
15	Tamale	Northern	371,351	AIRTEL	GOLD

Silver=fair, gold= good, platinum=very good. Source:
Source: M-P Infrastructure Ltd, Accra-Ghana Office

CONCLUSION

The revenue analysis above showed that under fixed pricing strategy, revenues of Tower Companies (TCs) suffer against change in population in infrastructure locations.
MNOs have to make a decision to request access based on their market share, how much traffic they can receive at K charges and compare against the fixed load capacity at a fixed cost.

No investor would want to pay for a bus that has a fixed capacity of let say H and end up using for transporting people less that H, putting the cost of running the bus and the cost of buying the bus, this will definitely be a bad investment. By relating it to the MNOs, if one's market share is said that it cannot produce the volume of traffic that can make some expected profit, then there is a reason to invest in such areas or locations. This leaves TC with just one or few MNOs with significant market share investing in low populated areas.

Mobile Network Operators are presented with three major decisions on investing. One; the "pause" decision when the market share cannot produce a minimum volume of traffic that can assure an operator some profits. Two, "pull" decision when existing operator would have to leave a market when there is a sudden change in market share (decrease in market share) due to stiff competition, etc. and as a result are unable to produce a minimum volume of traffic that can assure profits. Three, "push" decision when New Entrants still want to invest irrespective of its market share or current regulations mandate them to, or existing operator is unable to pull out if current regulations mandate does not permit, the operator may also want to continue to compete till it gets its customers back, then a "push" condition applies.
These hard decisions are likely as a result of fixed load capacity and renting cost conditions of a tower space pursued by TC's in Ghana.

Areas with low population (common with rural areas) are likely not to be reached, especially under a free market. This may likely be the possible reason why 20% of rural areas are still unreached by network infrastructure in Ghana.

RECOMMENDATIONS

Ghana's Telecom infrastructure market should adopt a more flexible approach to granting of tower space, especially on the issue of equipment's load capacity, different load capacity can be granted to an individual requesting operator though not exceeding levels that can cause unnecessary interferences to neighboring towers. A more "fit-in" tower spaces for individual operators based on their market share or subscriber base at different locations on differentiated cost will encourage investment.

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