An Integrated Approach to Business Planning and Optimization for Wireless Broadband Networks.

Spectrum Management Consulting

Align Technology to Business Needs

An Integrated Approach to Business Planning and Optimization for Wireless Broadband Networks

By Steve Stravitz

Every deployment of a broadband-wireless access (BWA) network presents a unique combination of challenges involving hundreds of different factors, ranging from the terrain the network must cover to the regulatory framework in which it will operate. No single business plan could possibly suit all of them. It is possible, however, to identify the most important factors and assumptions that must be accommodated by any BWA network, and to suggest their ramifications.

The framework presented here, developed over seven years, is an approach to identifying, quantifying, and ultimately optimizing these factors in a comprehensive business plan. The framework breaks down into four major areas (see Figure 1): Regulatory, Marketing, Technical, and Costs and Economics. Ishikawa Diagrams (or Fishbone) are used in each major area to explain the meaningful relationship between the causes (assumptions) and their effects.

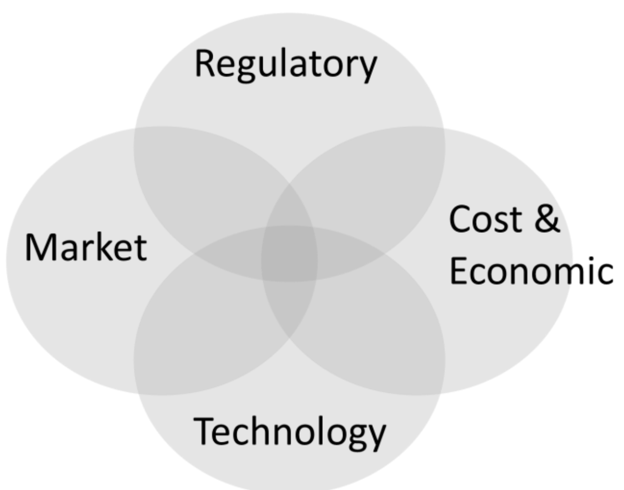

Figure 1: The framework

Regulatory Realm

In the wireless world, spectrum is the equivalent of land, and regulations are the building codes.

As shown in Figure 3, regulatory influences on a wireless business plan include four areas:

- the **spectrum** the network can use;
- Maximum **EIRP** or the power limit at which it operates;
- **interference mitigation** to ensure multiple systems can co-exist;
- and the total bandwidth available.

Spectrum. A number of licensed and unlicensed spectrum bands may be used to deliver broadband-wireless services. The International Telecommunications Union has divided the world into three regions and recommends different bands for different applications; each country then makes its own decisions about how best to serve the public good. Consequently, there are significant variations in the bands used, the availability of spectrum, and overall regulatory requirements. Figure 2 presents the most widely used and discussed bands today. Spectrum is affected by its licensing status (licensed, lightly licensed, license-exempt), which dictates whether or not the spectrum is shared and therefore influences the power that can be used.

EIRP (Effective Isotropic Radiated Power, or the strength of the signal leaving the antenna) and Interference Mitigation are primarily technical regulations promulgated as “good neighbor” measures, to ensure that wireless networks don’t interfere with one another, or with other regulated radio technologies.

Total Bandwidth is usually governed by national regulations that cap the bandwidth available to any single operator to ensure competition. These four broad areas of regulation are in turn influenced by a variety of additional technical parameters such as duplexing (FDD, or Frequency Division Duplex; versus TDD, or Time Division Duplex) and the choice of paired or non paired, with accompanying requirements for separation (closer separations might require more expensive filters to implement)..

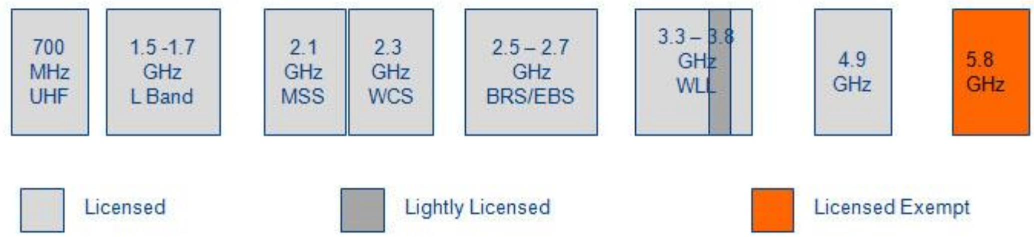

Figure 2: Broadband Wireless Spectrum

Examples of the interrelation of these factors abound. For example, in some countries the modulation and channel spacing is regulated according to the band. Similarly, the type of service—fixed, nomadic, or mobile—can also be regulated based on band. Most countries that have allocated broadband-wireless access in the 3.5-GHz band, for example, have reserved it for fixed applications only. Modifications are required for nomadic use, let alone mobile.

Finally, there are non technical issues governed by regulations that influence the economics of a system, such as spectrum license fees, build-out requirements, licensing timeframes, rights to lease and types of leases, and licensed service area.

While all of these regulatory influences play a strong role in shaping a business plan, if they are particularly burdensome, the operator does have an option to negotiate for regulatory relief and thus change regulatory limitations. Thus, while the business plan should be developed in accordance with all existing regulations, operators should keep in mind that regulatory limits are subject to change.

Making sense of marketing

The interrelationships in the marketing area are focused on understanding and establishing the balance between potential revenues, on the one hand, and the costs involved in realizing those revenues, on the other.

The single most important key to managing this category is to clearly understand the customers to be served. Simply put, one must have an understanding of how many subscribers are in which locations, require what service offering, and at what price point.
The factors in **Brand**, **Bundling** and **Distribution, Competition** and **Complementing**, and **ARPU** (Average

Revenue Per User) are so fundamental to a network they should be clearly defined at the outset, at least as far as possible (see Figure 3).

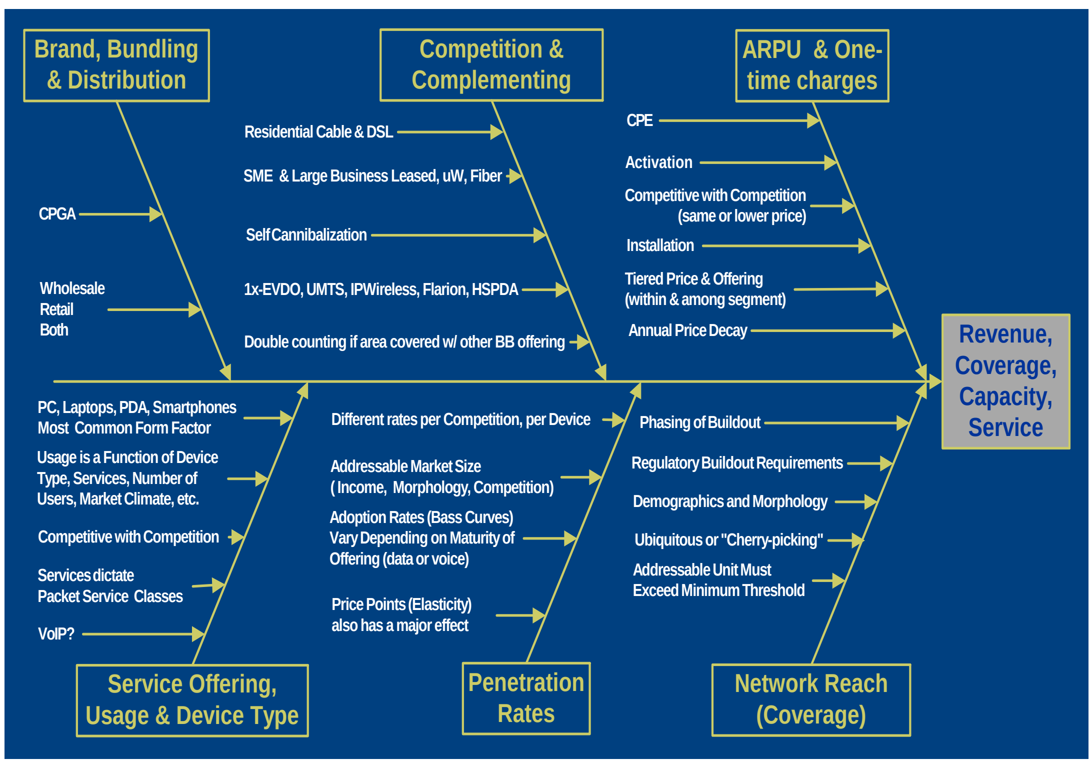

Figure 3: Making sense of marketing

The operator can define Brand, Bundling and Distribution, but in the other two areas the marketplace will at least shape operator options, if not dictate them outright.

Customer Type	Average Data Rate	% use at BH	% Time Downloading	Over Subscription	Average Data Rate per User
Consumer	384 Kbps	20%	25%	20	19.2 Kbps
Small Business	1 Mbps	20%	50%	10	100 Kbps

Figure 4: Example of User Profiles

Service Offerings, Usage and Device Type includes strongly interrelated factors. CPE (or customer premises equipment) form factors (laptops, PDA or smartphones), for example, play a critical role in dictating usage patterns and bandwidth needs—with higher demands for larger screen laptops with a full keyboard. Likewise, the kinds of applications your network will be supporting influence the capabilities it will need to offer; technical requirements for parameters such as streaming versus burst able, latency, jitter, and bandwidth all are dependent on applications. Interactive gaming, voice and video, streaming, surfing, and large file downloads place different demands on the network.

The kinds of users the network will be serving affect network configuration as well as ARPU. Businesses are generally less price sensitive than consumers and are often willing to pay for a superior user experience. On the other hand, the number of simultaneous users sharing each modem at a location is typically higher with business.

"Oversubscription" describes the sharing of the same resources among different users and is used in network capacity planning.

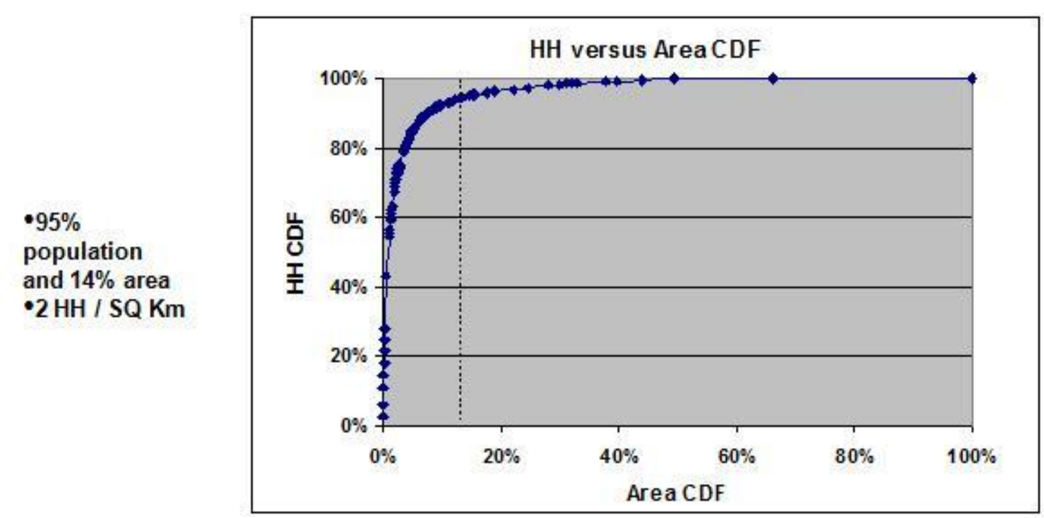

Figure 5 Examples of a Population Center that moves into a rural setting quickly

Since all users are not on the system at the same time, and all applications do not require 100 percent duty cycle of resources, the capacity of the network is shared. The higher the oversubscription rate, the greater the probability that the resource will not be available when a user requires it. If too many users are on the system at the same time, the Medium Access Control (MAC) determines priorities among users via the fairness algorithm. One potential outcome would be a reduction in average data rate for every user, falling below the user expectation.

Coverage decisions (whether to offer ubiquitous coverage, coverage by city zone, or "cherry picking" the most profitable areas) have a significant influence on network economics, and are in turn driven by the kind of network being built. A network using fixed wireless access is able to cherry pick the most desirable areas to cover (those with greatest density, or underserved areas). In fact, most fixed wireless operators using point-to-multipoint architecture have a density threshold below which they do not deploy, for the simple reason that if you do not have enough users over which to amortize the capital and operational expenses, it is not possible to be profitable. Areas below this density threshold are sometimes called "fool's gold," because no present technology can serve them cost effectively, unless subsidies are introduced.

Fortunately, in most urban areas the curve between coverage and population is quite steep. By contrast, users of a nomadic system expect that they will have network access in some defined zone of service.

And for mobile networks, there is an expectation of even wider availability, especially in areas when competing against incumbents, requiring something much closer to ubiquitous coverage. A issue related to these coverage questions is the phasing of the build-out: How much coverage do you need to provide before the network launch? How much do you need at the end of Year 1, and so on.

Taming technology

Technology is an enabler, allowing an operator to meet the requirements imposed by regulations and the marketplace while at the same time imposing requirements of its own. Moreover, many complementary technologies must be implemented to create a working system that makes economic sense, including **Network Architecture**, **Link Budget** and **Propagation Models** governing coverage, **Capacity**, and **Vendor Specification and Options** that can influence all of the above.

Overall, the radio access portion of the network usually accounts for more than 80 percent of capital costs. It can consume even more in operational expenses, because the costs associated with the core of the network can be spread over much of the overall customer base.

At the broadest level, most of the **Network Architecture** today in broadband-wireless access is point-to-multipoint, in which the operator installs all propagation sites, each of which provides service to multiple users. These point to-multipoint networks may be supplemented with a limited number of point-to-point links for special situations, such as providing a dedicated high-bandwidth link to a high-volume customer, or to extend the range from a hub.

Mesh networks, in which operator-installed propagation sites are supplemented by independently installed nodes, are gaining in practicality. Mesh networks can offer greater spectral efficiency by using higher modulations as well as multiple paths to any given user. But these advantages are only gained when enough nodes are deployed to fully implement the mesh—leaving the first successful implementation by operators leveraging the rights-of-ways of municipal or local authorities.

The density of the network is governed by the range of cell sites, which in turn is governed by the **link budget**—the technical factors associated with the uplink, transponder, and downlink that affect signal reception—and **propagation characteristics**.

Propagation (the radiation of signal energy through a physical area) is a function of the frequency and the environment. Higher frequencies (like the 5.8-GHz band) attenuate faster than lower frequencies (for example, the 2.5- GHz band). Similarly, heavily wooded and urban environments attenuate a signal faster than open suburban or rural environments. Numerous propagation models have been developed over the years that take frequencies and environmental factors into account.

Link budgets for most broadband systems are determined by the reverse link—the path from the CPE (customer premises equipment) to the base station, which generally has less capacity or range than the forward link (from the base station to the CPE). Moreover, the service offering— fixed, nomadic or mobile—has a strong influence on required cell site density as well, with different link budgets for the different CPE.

For fixed service, a further distinction must be made between networks using outdoor mounted devices versus indoor self-installable systems. Outdoor systems typically allow lower cell site density, because the outdoor directional antennas start with more gain and don't suffer from signal attenuation passing through building walls. A hybrid approach allows customers near a cell site to use indoor CPE, with households closer to the fringes of site range using outdoor equipment.

The CPE used for nomadic service requires greater site density because of the lack of power amplification (PA) in many of these portable devices, most of which have power limitations associated with battery operation. Mobile systems typically have additional fade margins added to the link budget because of their increased fading characteristics of movement.

The **capacity** of most BWA systems has been improved by adaptive rate modulation schemes. Higher order modulations allow higher throughput in better signal conditions while lower-order modulations allow longer coverage range, at the expense of lower throughput. The combination of both optimizes capacity.

Capacity and range are also affected by channel spacing; the wider the channel, the greater the capacity (more aggregate throughput is available) but the shorter the range. Channel spacing, in turn, is sometimes dictated by regulators. Thus, to obtain higher throughput from a system, the cell sites would need to be placed closer together.

To summarize, it is possible in design and implementation to trade off decreased range of a system for increased capacity.

Finally, **Vendor Specifications and Options** provide ancillary technologies like smart antennas or multiple-input-multiple-output (MIMO) devices that can improve the range and/ or the capacity of BWA networks.

Of course, with all technologies there are tradeoffs in terms of complexity of implementation and costs. Nonetheless, these tradeoffs are worth the operational and cost penalties and are becoming common parts of vendor solutions.

Costs and economics

The final component of the business plan framework is economics, with three primary elements: **capital expenses**, **operational expenses**, and **economics**.

Capital Expenses include the costs of building base stations as well as the network core. Base-station costs vary considerably, depending not only on the vendor but the station configuration, including such factors as the number of sectors and channels, the location of and type of cabinets, selection of integrated or regular antennas, required cabling and connectors, the need for tower-mounted amplifiers (TPA), the use of integrated routers, and so on.

Base-station capital expenses can also include “soft” costs such as RF design and optimization, program management, site acquisition and zoning, architectural and engineering services, site construction, and installation and commissioning expenses. Since these costs are integral to system implementation, they are usually counted as capital expenses.

Capital expense for the network core can include microwave backhaul, aggregation routers; gateway servers; billing systems; network operational center(s) (NOC); Authentication, Authorization, Accounting (AAA) servers, and other application servers.

When developing a detailed model, the depreciation schedule—an economic factor—affects the impact of all the above capital expenses.

Capital expenses can also include CPEs, which can be treated as a capitalized item only if they are leased or rented to the user (if subsidized for customer purchase, costs by must be treated as an operational expense). Likewise, the cost to purchase spectrum (one time right to use) can be treated as a capitalized cost to be amortized over the term of use, since it does not get used up. If the spectrum is leased, it is treated as an operational expense.

Operational Expenses include the wide range of costs summarized below. Of these, transport is singled out for special attention because it can provide a quick litmus test in determining whether an effective business case can be made for a proposed network. Litmus test: Take the backhaul expense and divide by the number of expected subscribers to be served, deriving your cost per sub for backhaul. If this cost per sub is higher than your revenue per sub, the business plan fails.

Reducing the costs of backhaul—by installing proprietary point-to-point microwave or, when possible, using a competitive local exchange carrier (CAP) or even a local cable company—is an important objective for all systems.

Transport is a major issue for new builds, especially where an incumbent exists, because the incumbent’s charges and service strongly influence the prospects of the new-build business plan. In many countries E1 expenses are very high. See benchmarking study: http://www.apectel29.gov.hk/download/lsg_10.pdf

Other significant categories of operational expenses include: Sales and Marketing. These expenses are a function of competition in the market, and include subscriber acquisition costs (SAC), which can include both CPE and installation subsidies; promotions; channel (retail) costs; and advertising. One useful metric is the SAC payback period, which can be compared against expected monthly churn (or its inverse, customer life—a 2 percent monthly churn = 1/.02 = 50 months).

General and Administrative. These expenses can be determined by a bottom-up staffing model or as a simple percent of revenue or assets.

Customer care and billing and bad debt: These factors are influenced by the level of service offered and the degree to which it is automated; local labor rates; and the complexity of operations. Both customer service and billing can be outsourced or provided in-house.

Prepaid service options simplify billing and greatly reduces the risk of bad debt. Maintenance costs are driven by local labor rates, cost of transportation, and tools. Both efficiency costs are tied to the ratio of cell technicians to cell sites, which in turn is tied to equipment reliability and proximity.

Site leasing can be another significant operating expense. Leasing rates vary widely depending on the location of the site and the alternatives available.

Tying it all together

Figure 6 shows the process flow of how the analysis for BWA business planning is accomplished. Once all the regulatory, marketing, technical, and economic assumptions are defined, a cell site count must be determined using a network dimensioning model. This model first determines the number of sites required to simply offer service throughout the defined service area (incorporating propagation modeling). The model then determines whether capacity sites must be added, by examining capacity demands based on number of users and service offering per user type, and compares demand to the total amount of spectrum, channel sizing, number

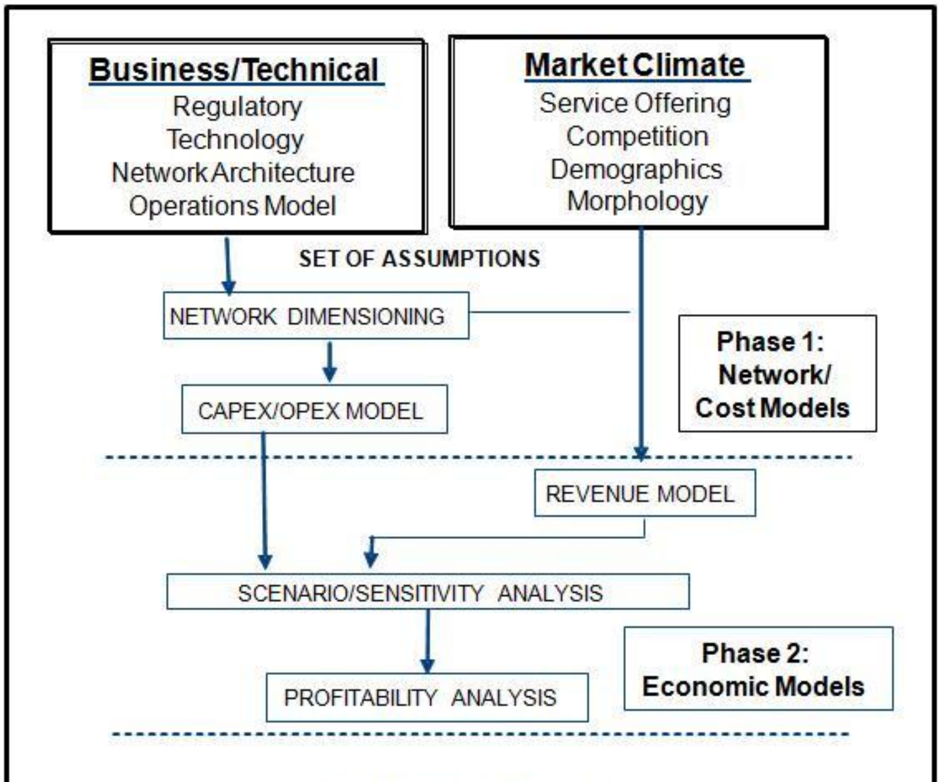

Figure 6 Trying It All Together

of channels, sectorization, and frequency reuse (traffic modeling).

With the site count known, the business model, with its associated costs and revenues, can be built. At this point, additional metrics should be established, such as major cost and revenue components on a per-subscriber or per-Mbps basis, as well as common financial measures like Negative Predictive Value (NPV), Internal Rate of Return (IRR), and overall payback.

Finally, during the seven-year evolution of this framework, I have discovered a number of truisms that can assist in optimizing the business case. Of course, there are undoubtedly exceptions to these "rules," but largely they have held up as reliable aids.

1. There is often a tradeoff between coverage and capacity, depending on the business case.

2. For coverage-limited scenarios (Nomadic/Mobile), reducing the number of cells is key to improving the business case.
   - A reduction in site counts directly impacts site maintenance, transport, depreciation, and site lease costs.
   - Implemented by considering lower frequencies, reducing channel bandwidth, considering range-improving ancillary technologies, and considering a smaller footprint in higher dense areas.
   - For capacity-limited scenarios (fixed),

   increasing site capacity is key to improving the business case.
   - Increasing capacity can directly increase ARPU.
   - Implemented through lower burst rates

   (carrier-class versus best effort, or higher oversubscription rates), more spectrum, ancillary technologies (such as diversity, MIMO or AAS), software optimization, increasing channel bandwidth, and use of more spectral-efficient technologies.

3. Overlay networks have significant advantages in cost structure over "Greenfield" networks (new deployments), with the ability to share backhaul, sites, maintenance and overhead.
   - Strategic partnerships can offset some greenfield disadvantages.

• Prospective partnerships should be considered with landowners for tower sites, broadcasters for advertising, and cable or fiber providers for backhaul. Public-private partnerships leveraging municipal assets like water towers and other sites are another form of strategic partnering (see "Local Communities Leverage Their Assets," this volume).
• Implementing microwave backhaul with cut operating expenses while increasing capital expenses.

4. Increasing revenue by offering more value-added services, including voice, can dramatically improve the business model.
• Voice does not require much additional capacity for the price that can be charged, thereby raising the price per hertz. Other services that can add significant revenue are VPN, trickle casting (download to storage for watching in the future), home gateways, and monitoring and telemetry services.

5. The degree of effect of any given factor on profitability depends on the specific situation of each network.

For capacity-loaded networks, key sensitivities include:
• Increasing spectrum availability or spectral efficiency of products
• Implementing traffic optimizing software (compression, priority, header suppression)
• Decreasing the burst rate offering

• Increasing channel bandwidth
• Decreasing CPE cost, moving to greater use of self installable units
• Decreasing backhaul costs

For coverage-limited scenarios, key sensitivities include:
• Increasing cell radius
• Improving subscriber penetration
• Decreasing BTS costs
• Decreasing CPE costs

It is hoped the above examples will provide a useful indication of how this model can help prospective operators understand, evaluate and balance the numerous factors that comprise a business plan for a WBA network, and ultimately create a unique and sustainable route map to successful, profitable operation.