Requirements Definition

A typical requirement analysis will normally include some degree of user consultation, which is not the case in this project as the "opportunity" is based on observed trends, data and recommendations from institutions such as the ITU, UN, WEF and the World Bank Group. The four barriers to broadband adoption were described in Fig. 1. The development approach is therefore centred on a product that will eliminate these four preventative factors, leading to the successful adoption of broadband services by unconnected communities.

1 New Product Development

Any new product development is ultimately motivated by fulfilling a need of some kind, typically observed as the gap between the current "status quo" and an envisioned "improved" future scenario brought forth through the introduction of the intended product. This is a complex process (often considered part art, part science) of striving to produce usability through balancing "needs & wants" against practical "realities". The "Design Thinking" school of thought describes this gap between the status quo and the envisioned better future as the "inspiration space" or "the opportunity that motivates the search for solutions" (Brown 2008). The success of any new product introduction is dependent on the ability of the target market to accept the intended change that will be effected by the product.

Kanter (2012) states that people will rather "remain mired in misery than to head toward an unknown" when describing the introduction of "excess uncertainty" as one of ten reasons that people will quite often resist change. Resistance to change is therefore one explanation for why novel products, when entering an environment where their purpose is not fully understood as a familiar concept, have a high

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C. Kotze, *A Broadband Apparatus for Underserviced Remote Communities*,
Southern Space Studies, https://doi.org/10.1007/978-3-030-15766-1_2

chance of being marginalised or completely ignored.[1] New product development by its very nature is therefore a challenging endeavour; in order to be successful it needs to introduce change. The new product therefore needs to overcome inherent resistance to change, by presenting itself in a clear light in such a way that the intended user perceives benefit of use. The designer needs to position the product in such a way as to maximise the user-centric benefit by asking the question—"How will the user benefit from using this product?" A good example being by way of the question Disney asked when planning Disneyland, namely, "How will it provide the customer with a magical experience? (Stefan Thomke 2012). The more focussed the question, the better the opportunity to define functions and constraints; in the Disneyland case, what will prevent or enable the said "magical customer experience".

Through the years a number of processes have emerged to guide the product designer, the choice of methodology normally being dictated by the intended product "arena". Each methodology though starts with producing a set of requirements to guide the process. For the requirements development of the BARC, aspects of two apparently conflicting methodologies were used, namely—classical "requirements engineering" as well as "Design Thinking".

"Design Thinking" emphasizes a human-centric approach, with the design process involving rapid, low-resolution prototype designs, where the designer is guided by viewing the problem to be solved from an empathic perspective of the intended user. This method is well suited to ill-defined real-world problems that can be expressed as conceptualised designs relatively quickly. As opposed to producing a set of specifications, this method attempts to capture the needs of the potential customer by creating "desirability" of use (Vetterli et al. 2013). In the context of this study "Design Thinking" is applied in an attempt to produce "desirability" against the minimum acceptance criteria of broadband by the target population, i.e. the 4A's.

Requirements Engineering as typically associated with software and information systems, concerns itself with the interrelationship between the "real-world" goal; functions and constraints applicable to the intended system in order to produce "precise specifications" to predict behaviour and guide future evolution (Zave 1997). An Information System is defined as the product of the synergistic action of three primary components, namely people, processes and technology (Keen 1993). The BARC can be therefore be seen as an incidence of an information system. As such, development tools rooted in the information systems world were thus considered for aspects of the requirements determination process.

Though mostly associated with the development of information systems and associated IT fields, the System Development Lifecycle, commonly referred to as the SDLC can be effectively deployed as a macro approach to overall product development. The SDLC approach for this review will be based on the one as

[1]Sørensen, J. 2013. *The simple reason products fail: Consumers don't understand what they do.* https://qz.com/132070/the-simple-reason-products-fail-consumers-dont-understand-what-they-do accessed 12 February 2018.

defined by the USA's National Institute of Standards and Technology (NIST), describing it as an overall process used from initial development to eventual retiring of a system (Radack 2009). The basic SDLC is typified by a five-phase iterative process describing the product life cycle—initiation, development, implementation, operation and disposal. The initiation phase starts with conversion of the "product story" (i.e. the reason for the product's creation) into a set of requirements, the requirements definition. The Project Management Institute (a global professional organization for project management) describes the requirements definition as the most important phase of the product lifecycle (Daniels 2000). Product requirements are normally split into two broad categories, functional and non-functional requirements.

Functional Requirements (FR) basically define "what" the product should achieve, with each "feature" or function described as single requirement in a clear, unambiguous way according to IEEE Standard 830-1998.[2]

Non-Functional Requirements (NFR) specify criteria that can be used to assess the operation of a system, rather than specific behaviours or capabilities. They define "how" the system should deliver the "what" that it is supposed to do. In other words, they specify the 'quality characteristics' of the system. Functional requirements are generally expressed as statements of the form "shall do" whereas non-functional requirements are statements of the form "shall be".

Though there are numerous models and methodologies available to guide basic requirement setting, the one chosen for this project is an adaption of the so-called "FURPS+" model, an acronym for Functionality, Usability, Reliability, Performance and Supportability. The original FURPS model was developed by Robert Grady of Hewlett Packard, as an internal product quality model, to provide a consistent way of identifying and categorising FR's & NFR's (Grady 1994). It involves five basic categories (1FR + 4NFR's) and the "+", for additional quality categories as dictated by the situation. For this project an amended version —"FURPS + CA" was used, with the "+CA" representing the "4A's" as minimum "Customer Acceptance" criteria identified by an ITU study for a remote community to accept broadband[3] (Fig. 1).

The next section develops the requirements definition using the guidelines and FURPS + CA model put forward in this section.

2 Requirements Definition

The formal requirements development starts by positioning the BARC via a "product story". In marketing a product story is a means to effectively communicate the "what, how & why" of a product to the intended audience in an informal,

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[2]IEEESTD. 1998. *IEEE Std 830-1998—Recommended Practice for Software Requirements Specifications.* 1. IEEEE.

[3]ITU. 2017. *ICT Facts and Figures 2017.* https://www.itu.int/en/ITU-D/Statistics/Documents/facts/ICTFactsFigures2017.pdf accessed 14 January 2018.

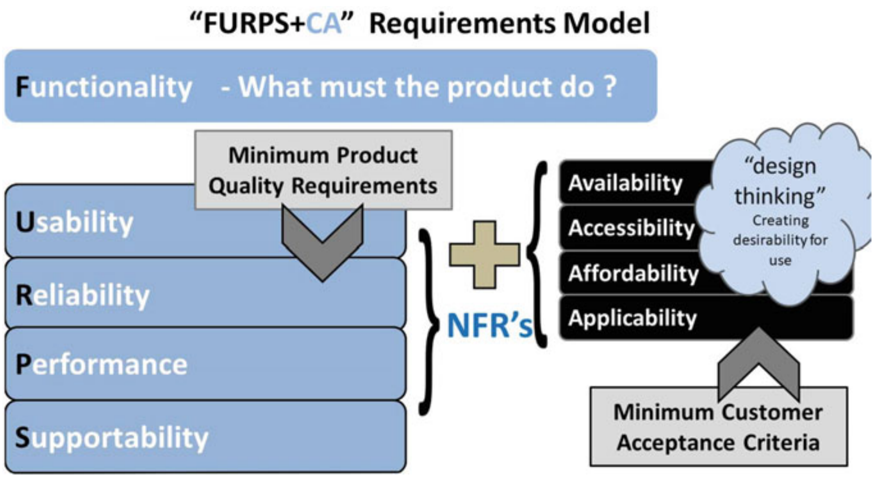

Fig. 1 Requirements determination using amended FURPS + CA

easy-to-understand way. The "product story" therefore serves as the foundation to expose the requirements. The product story is written in such a way as to cover the "customer acceptance criteria" as identified by the ITU study—earlier referred to as the 4A's—and which are highlighted in the following product story.

2.1 The Product Story

The BARC will have the ability to make broadband internet AVAILABLE to any remote community. Producing and storing its own electricity, with the means to accommodate the latest satellite communication technology, it is not dependent on any pre-existing utility infrastructure. The BARC will give communities practical ACCESS to broadband internet, by supplying all the necessary ancillary services the user will need to use the internet effectively, such as charge points and illumination at night. The system will provide infrastructure for remote environmental data collection, laying the foundation for innovative funding models to enhance AFFORDABILITY. Local culture and language will be incorporated to make the benefits of using broadband internet clear and APPLICABLE to the intended community. The BARC "product story" can be further distilled using the FAB (Features + Advantages + Benefits) framework to create a basis for an initial requirements definition (see Table 1):

To start the requirements' definition process, it is useful to imagine and list the possible actors and the expected basic interactions between them and the proposed device in achieving the intended goal, i.e. obtain the advantage of broadband access. These use-cases will also attempt to cover the possible scenarios that will prevent the successful use, i.e. not achieving the goal. The output will be a list of

Table 1 Features, advantages and Benefits Analysis

	BARC—FAB analysis
Features	Self-contained broadband internet system, using satellite communication and renewable energy technology, with the ability to collect local environmental data
Advantages	Can be deployed in most remote areas, not dependent on any existing infrastructure and providing all required supporting services for broadband internet use (e.g. power and lighting)
Benefits	Allows the community to benefit by utilising broadband internet anytime of the day or night, whilst also providing charge points for access devices to community and guest users

scenarios and actors which will later be used to link back to the identified requirements. The application of a use-case methodology for this study involves a template to describe each interaction broadly and classify the different scenarios as: [DAILY] (normal everyday use), [PERIODIC] (periodic required actions) and [EXCEPTIONAL] (rarely encountered) use cases.

Table 2 illustrates the basic use-case template which was used to construct the different use-case scenarios

There are nine basic scenarios envisioned for the successful use of the system;

1. Daily use activities, Table 3. Use-case 01.
2. Remote management activities, Table 4. Use-case 02.
3. Remote data use, Table 5. Use-case 03.
4. Activities surrounding guest users, Table 6. Use-case 04.

Table 2 The basic use-case template

Use-case number and description of the use-case and the excepted frequency of use classified as [DAILY], [PERIODIC] and [EXCEPTIONAL]	
Description	Text description of the use-case
Actor [X]	Who is the primary "actor" in the use-case identified as: [CT] = Construction Team [DC] = Data Customer [FE] = Field Engineer [FT] = Field Trainer [GU] = Guest User [OU] = On-site User [RM] = Remote Management
Flow	A stepwise description of the interactions between the actor and BARC to conclude a successful use-case
Alternative flow	An alternative stepwise description of the interactions between the actor and BARC to conclude a successful use-case
Pre-conditions	What must be in place for the use-case to be realised?
Post-conditions	What must take place if any after the use-case is concluded?
Exceptions	What will prevent the use-case to complete successfully?

Table 3 Use-case 01

Use-case #1: Broadband access [Daily]	
Actor	Onsite user [OU]
Description	This use case prescribes the way in which the [OU] will interact with the system to access broadband
Flow	1. [OU] access device attempts to link to the pre-defined Wi-Fi access point 2. On wireless authentication the system presents the [OU] with the [OU] "log-on" screen requesting authentication 3. [OU] authentication 4. On successful authentication the [OU] is granted broadband access for period of time based on policy 5. The [OU] session ends when the [OU] logs off or the time quota runs out and the access device logs the [OU] off
Alternative flow	At any time during the session the [OU] can terminate the session by using the "log-off" button and return the access device to the charge dock
Pre-conditions	Satellite broadband is available, Wi-Fi is operational, access device is available, available access device is charged, [OU] is registered on the system, [OU] is authenticated successfully
Post-conditions	Usage data is updated
Exceptions	Any system function is not available, [OU] fails to be authenticated

Table 4 Use-case 02

Use-case#2: Remote maintenance [Daily]	
Actor	[RM] Remote maintenance
Description	This use case prescribes the way in which the remote monitoring maintenance will interact with the system to monitor system functionality
Flow	1. The use-case begins when [RM] accesses the telemetry database of all linked BARC devices 2. Update telemetry management reports for devices 3. Conduct daily routine maintenance 4. Identify error trends 5. Identify improvement opportunities 6. Report errors to field support where applicable 7. Ensure data connection for external customers 8. Update asset data daily
Alternative flow	[RM] is notified automatically of any urgent error condition as defined by policy
Pre-conditions	Communication is available to remote device, telemetry database is accessible and telemetry management system is available
Post-conditions	Notify field maintenance team of any reportable conditions. Telemetry management returns to monitoring mode only
Exceptions	Communication with remote system function is not available. Telemetry management system is not available

Table 5 Use-case 03

Use-case #3: Remote data use [Daily]	
Actor	[DC] Data customer
Description	This use case prescribes the way in which data collected from a BARC is used by a [DC]
Flow	Basic flow for the use case involves the consumption of data directly or indirectly by an authorised consumer 1. The use case begins when raw-data is transmitted from BARC to a cloud repository 2. Data is classified and stored 3. Data asset value updated* 4. [DC] user is authenticated in accordance with policy guidelines 5. On authentication [DC] is allowed access to relevant data in accordance to policy and regulatory frameworks 6. Meta data on use is collected against user 7. [DC] terminates session
Alternative flow	[DC] cannot access data, reports problem as per policy
Pre-conditions	BARC in normal operation, transmitted used in accordance to relevant regulatory framework
Post-conditions	Data transfer confirmed
Exceptions	Error conditions with data transfer. Notify field maintenance of any reportable conditions with transfer

*A note on the value of the "data asset". The monetary value of data could be influenced based on the time of access. The example could be data valuable for an agricultural futures company might be more time sensitive than the same data looked at later by a climate scientist

Table 6 Use-case 04

Use-case #4: Guest users [PERIODIC]	
Actor	[GU] Guest user
Description	This use case prescribes the way in which a [GU] will interact with the system using a self-supplied access device e.g. cell phone or tablet
Flow	1. The use case begins when [GU] obtains a use token 2. [GU] powers "on" the access device 3. [GU] links to Wi-Fi access point broadcast by BARC 4. MAC address of [GU] access device is registered on BARC 5. On wireless authentication the system presents the user with the user "log-on" screen requesting acknowledgment of condition of use 6. [GU] is granted a broadband access quota based on policy in terms of access token 7. The user session ends when the time quota runs out and the access device logs the user off
Alternative flow	[GU] terminates session prior to quota running out
Pre-conditions	[GU] has access device, either using own access device or using site-supplied access device
Post-conditions	BARC updates consumption data against [GU] access device profile
Exceptions	[GU] is supplied quota over-ride by remote management

Table 7 Use-case 05

Use-case #5: Field training [PERIODIC]	
Actor	[FT] Field trainer
Description	This use case prescribes the way in which the [FT] will interact with the user base when training is required
Flow	1. The use case begins when [FT] is notified of a new installation request for a BARC 2. [FT] conducts site inspection in accordance with policy 3. [FT] conducts basic user training for use of new BARC
Alternative flow	1. [FT] is notified of a new training request on an existing BARC site 2. [FT] conducts basic user training for use of new BARC
Pre-conditions	Knowledge of local site conditions and access to site and required resources
Post-conditions	Training objectives are met
Exceptions	[FT] cannot access site

Table 8 Use-case 06

Use-case #6: Dismantlement [EXCEPTION]	
Actor	Construction team [CT]
Description	This use case prescribes the way in which the [CT] will conduct on-site operations when an installed BARC is removed from a site
Flow	1. The use-case starts when [CT] is notified of a need to dismantle a BARC 2. [CT] conducts site inspection in accordance with policy and set time scale 3. [CT] notifies [RM] and BARC is disconnected from monitoring 4. [CT] dismantles BARC 5. BARC is removed from site 6. Site is restored to pre-installation conditions
Alternative flow	Site is not accessible to [CT] within required time scale
Pre-conditions	• Community has been notified and agreed to dismantlement • Access to site • Required parts and other resources are available
Post-conditions	Site where BARC was recovered is reconditioned as per defined policy
Exceptions	BARC cannot be recovered

5. Training in the field, Table 7. Use-case 05.
6. Dismantlement, Table 8. Use-case 06.
7. Field maintenance, Table 9. Use-case 07.
8. Emergency repair, Table 10. Use-case 08.
9. Installation, Table 11. Use-case 09.

The first use-case attempts to describe the basic scenario of daily use by an on-site user i.e. the prime customer refer Table 1.

The second use-case (Table 4) attempts to describe the remote management scenario, a crucial link in the service supply chain. Apart from the daily remote

Table 9 Use-case 07

Use-case #7: Field maintenance [PERIODIC]	
Actor	[FE] Field engineer
Description	This use case prescribes the way in which the [FE] will interact with the system when a preventative maintenance is required
Flow	1. The use case begins when [FE] is notified of a fault or field maintenance request on an installed BARC 2. [FE] conducts preventative maintenance or carries out repairs in accordance to maintenance guidelines
Alternative flow	N/A
Pre-conditions	Access to site and parts are available to [FE]
Post-conditions	Return BARC to normal operation. Report on any notifiable conditions observed on-site
Exceptions	Field engineer cannot access site

Table 10 Use-case 08

Use-case #8: Emergency repair [EXCEPTION]	
Actor	[FE] Field engineer
Description	This use case prescribes the way in which the [FE] will interact with the system when an emergency repair is required
Flow	1. Basic flow for the use case begins when [FE] is notified of an emergency repair request on an installed BARC due to one of two conditions a. Remote management cannot connect to BARC b. Remote management detects an emergency condition 2. [FE] conducts emergency repair in accordance within the agreed period defined by the policy guidelines
Alternative flow	[FE] conducts emergency repair, but not within the agreed period defined by the policy guidelines
Pre-conditions	Access to site and parts are available to Field Engineer as demanded by the situation
Post-conditions	• Return BARC to normal operation • Notify management of any additional reportable conditions observed on-site
Exceptions	[FE] cannot repair problem on-site

management, this function is also responsible for pro-active maintenance, trend analysis and to ensure a reliable flow of data to customer—on-site and external.

The third use-case (Table 5) attempts to describe the remote data use scenario, an important use-case as it represents a potential revenue opportunity.

The fourth use-case (Table 6) describes the activity of any user using the system temporarily i.e. not a permanent member of the user community, for example a visiting health service provider. Such use can be short-term or for an extended period.

Table 11 Use-case 09

Use-case #9: Installation [EXCEPTION]	
Actor	[CT] Construction team
Description	This use case prescribes the way in which the [CT] will conduct on-site operations when a new BARC is installed
Flow	1. The use case begins when [CT] is notified of a need to install a BARC 2. [CT] conducts a site inspection in accordance with policy 3. [CT] confirms site suitability 4. [CT] arranges installation date with community 5. [CT] installs BARC 6. [CT] runs test sequence 7. [CT] links BARC to remote management 8. [CT] activates BARC for normal operation 9. [CT] installation is signed-off and handed over to [RM]. 10. Training team is notified
Alternative flow	1. [CT] finds site not directly suitable for installation 2. [CT] recommends remedial action to make site suitable for installation 3. Installation is relocated or rescheduled for the site
Pre-conditions	• A suitable site has been identified for installation of a BARC • Community has agreed to installation • Access to site, parts and other resources are available
Post-conditions	BARC is active for operation
Exceptions	[CT] finds site not at all suitable for installation and installation is aborted

The fifth use-case (Table 7) describes any activity of personnel dispatched to site to engage in training. Training can take two forms, i.e. primary trading and periodic reinforcement training.

The sixth use-case describes any activity of personnel dispatched to site to dismantle the equipment. Use-case 07 and 08 dals with routine maintenance and emergency repair.

The final use-case describes the installation of the system at the new site.

2.2 Functional Requirements

The Functional Requirements specify “What” must the system do. There are eight functional requirements identified:

Functional Requirements

1. F01: Provides broadband internet functionality.
2. F02: Produces electricity for system use and for use by customers.
3. F03: Stores electricity to supply power in absence of availability.
4. F04: Provides its own structure to house all functional components.
5. F05: Allows remote monitoring of the device by off-site stakeholders.

6. F06: Provides charge points to users to power access devices.
7. F07: Provides light to allow use of the facility at night.
8. F08: Collects sensor, usage and meta-data.

2.3 Non-functional Requirements

The "quality requirements", which in this case are split into two main groupings, i.e. the "Base Requirements", which are basically the non-negotiable expected quality requirements, and a set of additional "acceptance" criteria.

2.3.1 User Acceptance Requirements ("4A's")

The 4A's defines the minimum acceptance requirements for broadband acceptance as identified by the UN Broadband Commission study that needs to be satisfied before a community will accept broadband.[4] These will arguably form the most important design challenge as it will determine whether the product will be accepted or not. These requirements must be used to create a "desire" in the target user to "want to" use the product.

1. Availability

   a. U01 Everyone in the community is aware of the availability of the product
   b. U02 Product is equally available to all members of the community.

2. Accessibility

   a. U03 The product is close to the user within a short walking distance
   b. U04 All users have access to the necessary tools to engage broadband
   c. U05 All users have the necessary skills to engage broadband.

3. Affordability

   a. U06 The system is sponsored for use
   b. U07 Users can afford to use the system.

4. Applicability

   a. U08 Use of the product is relevant to local needs
   b. U09 Benefit is associated with use of the product.

[4]Biggs, P. Ed. 2018. *The State Of Broadband 2018: Broadband Catalyzing Sustainable Development*. First ed. Geneva: UN Broadband Commission.

2.3.2 Performance Requirements

The "base" non-functional requirements are the essential qualitative requirements or Performance Requirements for BARC. They are identified by the last four elements of the FURPS model, namely; Usability, Reliability, Performance and Supportability.

1. Usability
    a. P01 Ability to be optimised for multiple conditions
    b. P02 Easy to assemble—within two working days
    c. P03 Easy to use—users can be trained within a day
    d. P04 Visibility—clearly visible day and night
    e. P05 Provides wireless access from a minimum 20 m distance.
2. Reliability
    a. P06 Mean time before failure > 26 000 h
    b. P07 Robust—able to withstand normal environmental conditions
    c. P08 Power redundancy for 24 h.
3. Performance
    a. P09 Broadband uptime 95% minimum
    b. P10 Response time—average latency < 500 ms
    c. P11 Accuracy— < 2% packet loss
    d. P12 Workload—support a maximum of 80 concurrent users at 100 kbps
    e. P13 Scalable—adjusts to available bandwidth.
4. Supportability
    a. P14 Low Planned Maintenance—twice yearly on site
    b. P15 Easy to maintain—on-site component replacement must take less than 8 h
    c. P16 Compliance—must conform to all applicable local and national regulations
    d. P17 Upgradable—can accommodate future upgrades.