Sustainability in a Hospital-Based Biobank and University-Based DNA Biorepository: Strategic Roadmaps

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Sustainability in the biobanking community has recently become an important and oft-discussed issue as biorepositories struggle to balance limited external funding and complex cost recovery models with high operating costs and the desire to provide the highest quality materials and services to the research community. A multi-faceted view of biobanking sustainability requires consideration of operational and social sustainability in addition to the historical focus exclusively on financial sustainability. Planning and implementing this three pillar model creates a well-rounded biorepository that meets the needs of all the major stakeholders: the funders, the patients/depositors, and the researcher recipients. Often the creation of a detailed business plan is the first step to develop goals and objectives that lead down a path towards sustainability. The definition of sustainability and the complexity of a sustainable business plan may differ for each biorepository. The DNASU Plasmid Repository at Arizona State University stores and distributes DNA plasmids to researchers worldwide, and the Biobank Core Facility at St. Joseph's Hospital and Barrow Neurological Institute consents patients and collects, stores, and distributes human tissue and blood samples. We will discuss these two biorepositories, their similar and different approaches to sustainability and business planning, their challenges in creating and implementing their sustainability plan, and their responses to some of these challenges. From these experiences, the biobanks share lessons learned about planning for sustainability that are applicable to all biorepositories.

Introduction

BROADLY DEFINED AS THE “CAPACITY TO ENDURE,” the term sustainability has been applied as a descriptor to support the continuing existence of various ecosystems and activities. A modern interpretation of sustainability in the context of sustainable environmental development comes from the 1987 Brundtland Commission Report.¹ In *Our Common Future*, the Commission outlines a blueprint for sustainability that requires sustainable development to “meet the needs of the present without compromising the ability of future generations to meet their own needs.” Within this, they acknowledge that the solution is multifaceted and rests on three pillars: economic growth, environmental protection, and social equality, each of which is connected to the others and relies on all three for achieving successful environmental sustainability.

In 1994, this sustainable development concept was extended into economics and corporate America by John Elkington in the accounting framework the *Triple Bottom*

Line.² In his report, Elkington suggests that three bottom lines should be considered in the sustainability of a company: the financial bottom line of revenue and losses, the social bottom line measuring how socially responsible the company is, and the environmental bottom line focusing on the company's environmental responsibility. This concept has been applied in corporate, non-profit, government, healthcare settings, and most recently, in the biobanking community.^{3,4}

Current publications focusing on biobank sustainability have embodied the spirit of the Brundtland Report and Triple Bottom Line with a multi-faceted vision of sustainability outlining the three pillars of biobank sustainability as financial (economic growth/financial bottom line), operational (environmental protection/environmental bottom line), and social (social equality/social bottom line).^{5,6} This Biobanking 3.0 model further defines three sustainability aims: 1) operational sustainability, which aims to develop policies and procedures to improve the quality of biospecimens and increase the efficiency of biorepository operations; 2) social

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sustainability, which aims to cultivate a positive perception of the biorepository with the public and the researchers it serves; 3) financial sustainability, which aims to optimize the ability of the repository to be financially sustainable.^{5,6}

As with the environmental and economic models, the biobanking sustainability model takes an integrated approach and focuses on the interconnected dependence of all three of these pillars and the needs of all stakeholders for sustainable success.^{5,6} Although striving for financial sustainability is important, the Biobanking 3.0 model acknowledges that this needs to be weighed with the overall importance of the existence of biobanks, the research they support in the scientific community, and the public that benefits from the research outcomes.

However, within these sustainability frameworks, biobanks run into the reality of implementation. As with all sustainable development concepts, the challenge is not in defining the pillars of sustainability or the relevant stakeholders, but in effectively prioritizing these concepts at individual biobanks within the context of broader organization goals and effectively measuring success when sustainability relies on more than just dollars and cents. In essence, the entire ecosystem must be considered, which includes the biobank and its immediate research community, often extending into the greater research community and the public.

As highlighted in the Brundtland Report “no single blueprint of [environmental] sustainability will be found,” and the same is true for biobanks. Here we will describe, compare, and contrast the strategy for sustainability for two different biobanks: The DNASU Plasmid Repository at Arizona State University, a university-based DNA plasmid biorepository, and The Biobank Core Facility (the SJHMC/BNI Biobank) at St. Joseph’s Hospital and Barrow Neurological Institute, a hospital-based human tissue biorepository. From a shared vantage point, we will discuss the two biorepositories, which are at different points on the road towards sustainability and face different challenges, to provide lessons to be used by other biorepositories that are on their own path towards sustainability.

Overview of Each Biorepository

DNASU Plasmid Repository

The DNASU Plasmid Repository (DNASU) is a not-for-profit DNA repository located in the Virginia G. Piper Center for Personalized Diagnostics at the Biodesign Institute at Arizona State University (ASU). Originally established at

the Harvard Institute of Proteomics in 2006 as the PlasmID Repository, the repository moved and re-established itself at ASU in 2009 as DNASU.^{7–9} The overall goal and mission of DNASU (<https://dnasu.org>) is to facilitate research by providing high quality, annotated plasmids and resources to the research community and to support research scientists by functioning as a centralized facility to distribute plasmids that they create as part of their research.⁹ Plasmids are circular pieces of DNA, each of which contains one or multiple genes, and serve as a useful experimental resource to have stored in and distributed by a centralized repository. DNASU also distributes hundreds of empty vectors—plasmids that do not contain a gene insert, but rather, are used either as experimental controls or for inserting the researcher’s gene of interest.

The DNASU plasmid repository falls under a many-many model, where the plasmids are deposited by many sites and distributed to many researchers. The benefits to a researcher of receiving materials from a repository are a significant time and cost saving and an increased quality and availability of the materials. For a depositor, submitting plasmids to a centralized repository provides a mechanism to fulfill their obligations to funders and journals to share data and resources created from grants or used in publications and to provide a dedicated archive of their own precious resource at an independent location.

The plasmids available in DNASU have been created by the LaBaer Laboratory, where DNASU is housed, or have been deposited by over 30 institutions including individual researchers and consortia, such as the ORFeome Collaboration and the NIH-funded initiatives, the Protein Structure Initiative (PSI) as part of the PSI-Materials Repository (MR) and the Integrated Glycotechnology Repository.^{10–15} DNASU currently has nearly 6000 registered users and distributes over 219,000 plasmids to researchers in 48 US states and 50 countries. On average, DNASU fills 155 orders per month containing anywhere from one to several plasmids or predefined collections containing 500–12,000 plasmids (Fig. 1).

The Biobank Core Facility

The Biobank Core Facility (the SJHMC/BNI Biobank) is located at St. Joseph’s Hospital and Medical Center (SJHMC) and the Barrow Neurological Institute (BNI) (<http://BarrowNeuro.org/Biobank>) in Phoenix, Arizona. Established in 2005, the SJHMC/BNI Biobank was originally developed as a biorepository to collect human tissue and biofluids exclusively to support local SJHMC/BNI research. However, the

FIG. 1. Distribution of plasmids from DNASU. Breakdown of the distribution of nearly 9000 orders shipped from DNASU by type of institution (A) or location of institution (B) to which the order was shipped. Note that five orders were shipped to Africa, representing 0.05% of all orders shipped.

scope quickly expanded, and the SJHMC/BNI Biobank's current goal is to support research that will improve patient care by providing specimens and related services to all researchers both within SJHMC/BNI and outside investigators to study human diseases and to develop improved treatments.

The SJHMC/BNI Biobank has been successful at developing numerous high quality methods for tissue collection. They typically consent patients to collect tissue and blood in the operating room as part of a procedure, such as a biopsy or excision. In collaboration with surgeons, neurologists, and pathologists, the SJHMC/BNI Biobank collects tumor tissue from various sites, blood, biopsies, bile, or cerebrospinal fluid (CSF), with the most common diseases being glioblastoma multiforme, chordoma, cavernous malformations, meningiomas, multiple different types of non-brain cancer (breast, ovarian, lung, melanoma, colon, pancreatic, liver, esophageal), Barrett's esophagus, multiple sclerosis, amyotrophic lateral sclerosis, and samples supporting research into conditions involving headaches.

The SJHMC/BNI Biobank has grown over the past 10 years to consent over 1000 patients and collect 8000–10,000 biospecimens per year. With over 60,000 specimens currently stored and available for research, the SJHMC/BNI Biobank has distributed over 4000 biospecimens to researchers at SJHMC/BNI, to select external collaborators, and to government and companies through targeted grants and contracts. In particular, the SJHMC/BNI Biobank has received federally-funded contracts to provide tissue to the NCI-funded Cancer Genome Atlas Project (TCGA), supplying high quality tissue that has contributed to over 200 publications, and has also provided tissue to patient advocacy groups such as the Agioma Alliance and the Chordoma Foundation.¹⁶

Sustainability Plans and Implementation

DNASU Plasmid Repository

DNASU was established at ASU based on detailed planning that had been done for two prior grant proposals, both of which were funded. The economic goal for DNASU was to be financially sustainable exclusively from cost recovery, supplemented by grants. As part of an academic institution and established as a non-profit core facility, DNASU focused on keeping the costs of its services as low as possible, while still remaining financially sustainable. The fundamental goal was to facilitate and accelerate biomedical research by making DNA plasmids readily available. At present, it remains a very low cost DNA repository. Through the course of biorepository growth, improvements that affect operational and social sustainability have also been made.

Financial sustainability. From its inception, DNASU sought to develop a sustainable financial model for plasmid distribution. It regarded two types of costs, operational and growth. Operational costs increase based on user demand (e.g., consumables, personnel time for order fulfillment, etc.). In some circumstances, both rent and utilities would also have to be recovered, but that was not applicable to DNASU since it is located at an academic institution where these costs are absorbed by the university. Therefore, DNASU established a nominal re-charge fee based on the size and complexity of the order, with the intent to cover operational costs.

One convenient reality of storing plasmids, as opposed to human biospecimens, is that they are a renewable resource. The plasmids themselves are stored as a glycerol stock in bacteria. These can be kept with minimal loss of viability for an indefinite amount of time at -80°C and can be replicated by inoculating media, which is incubated overnight where the bacteria (and the internalized plasmid) replicate exponentially. This significantly lowers the cost for storing, processing, and picking plasmids for distribution.

The addition of automation further lowers cost by automatically tracking all items in the inventory (>200,000 plasmids), significantly reducing personnel time for finding and picking samples, and most significantly, reducing error rates. Even though uncommon, correcting errors is time intensive. Therefore, a fixed standard cost based on technician time and the materials required for storing and replicating the plasmids can be charged that nearly completely recovers operational costs (Fig. 2). The re-charge fee for plasmids does not include shipping. However, because plasmids can be shipped at room temperature overnight without significantly affecting sample quality, the cost of shipping is modest (Table 1).

Within this cost recovery model, operational costs for plasmid storage and distribution are covered, but other important costs required for repository growth are not. For example, the costs accompanying annotating new plasmids and updating the associated informatics (i.e., the staff time and effort in maintaining a well-curated database of all of the plasmids, details about their biological contents and their physical storage locations so that neither information nor material ever get mixed up) are not included in the re-charge fee.

It also does not include the costs of DNASU website development and maintenance, plasmid archiving, plasmid management and maintenance (e.g., replicating plasmids after six freezer/thaws to ensure viability), and the BioStore freezer storage system maintenance. Furthermore, the cost of a DNA sequencing quality check of plasmids before inclusion in DNASU is not embedded in the costs. One of the reasons that the DNASU re-charge fee is so low is because many of these growth costs are not included; however, this also means that additional revenue sources were needed to support these activities.

One key method to supplement funding for DNASU's growth has been applying for and procuring grants. For example, the National Institute of General Medical Sciences (NIGMS) funded DNASU for 10 years to function at the PSI-MR.^{7–9} Within this collaboration, DNASU evaluated the full-length DNA sequence of the gene inserts for over 90,000 plasmids from PSI researchers and significantly improved the DNASU website and database to support the distribution of these plasmids. In addition, DNASU was awarded an American Recovery and Reinvestment Act (ARRA) grant to enable the purchase of a Brooks automated freezer storage system.

Notably, DNASU has never received direct institutional funding; therefore, it has remained sustainable exclusively through cost recovery and grants. Considering that the research grants were primarily intended to supplement academic and government research, DNASU has charged a somewhat higher re-charge rate to for-profit institutions. This additional \$10 per plasmid allows DNASU to re-invest additional funds to support repository operations as listed above.

Operational sustainability. Improvements in operational sustainability include the addition of the Brooks BioStore

FIG. 2. Organizational structure of DNASU (A) and the SJHMC/BNI Biobank (B). Biorepository staff are funded from a variety of sources. Because DNASU is part of an academic center and the SJHMC/BNI Biobank Director runs a research laboratory, funding from multiple grants covers the salary for certain positions (e.g., database developer and QC team) that are not exclusively dedicated in the biobank (shown by positions with the solid outline). The SJHMC/BNI Biobank has two directors: the clinical director is a neuropathologist, the Principal Investigator on the Institutional Review Board (IRB) protocol for the Biobank, and is responsible for the management and release of tissue. The Biobank Director is a research scientist responsible for overseeing standard operating procedures and quality measures of the samples and other research services of the Biobank. SJHMC/BNI biobank receives institutional support, which along with recharge fees and grants/contracts, funds the majority of the staff managing the day-to-day biobank operations.

automated freezer-storage system with an automated picking robot to pick plasmid glycerol stocks, which decreases human error and increases sample distribution quality. Before the addition of automation, DNASU had a low but measurable error rate when distributing plasmids. To decrease this error and to accommodate the growth of DNASU from 60,000 to over 200,000 plasmids over several years, the BioStore provided a reliable system to decrease picking errors while also increasing picking speed. Additionally, this automation allows cherry picking of individual plasmids

without thawing whole plates and organizing plasmids in a preferred order for user requests, thus improving collection quality and customer satisfaction. Furthermore, this automation allows the creation of log files and the ability to track storage time and access frequency, also improving quality.

Database updates have also improved operations by automating activities such as invoicing, querying, and order processing. A key operational improvement for DNASU was the development of an expedited material transfer agreement (MTA), in which institutions are invited to sign a simplified universal agreement that covers all contents of the repository in advance.⁷ Once the institution is a signatory, any member of that institution can obtain a plasmid from DNASU by simply clicking agreement on the webpage, as there is already a signed document from the institution on file. This shortens the turn-around time from ordering to shipping from several weeks or months to only a few days by eliminating the time required to review and sign an MTA.

Finally, DNASU is working toward CAP Biorepository Accreditation as an indication to the researchers who request plasmids that they will be of high quality since they are stored and distributed based on current best practices.

Social sustainability. The social aspect in Biobanking 3.0 relates to the many stakeholders in biobanking, including the ethical and informational obligations to the patient. For DNA banking there are no patients and therefore no ethical issues, such as patient consent or privacy, which are found with banking of human tissue samples. However, DNASU has committed to social sustainability by supporting its research customers through outstanding customer service. In addition, DNASU has found creative ways to reach customers through linkouts on other websites and social media.

Impact. The success of DNASU's sustainability efforts has been tracked by continued growth of the plasmid collection, website page views, number of plasmid requests, and overall revenue. The impact of this effort is evident in the over 200 publications that have used plasmids from DNASU over the past 6 years.

The Biobank Core Facility

The SJHMC/BNI Biobank began its operations over 10 years ago without a detailed business or financial sustainability plan. During this time, the SJHMC/BNI Biobank's collection, storage, and distribution efforts were funded by the Barrow Neurological Foundation, various contracts for tissue (e.g., the TCGA), and one large contract from the Arizona Biomedical Research Commission (ABRC).

In 2014, the institution committed to further expansion and growth of the Biobank, and hired a dedicated program manager who was previously the Scientific Liaison for DNASU. In the past, the SJHMC/BNI Biobank was managed as a side project by individuals with other full-time jobs at the hospital, though there was always consistent involvement of a neuropathologist as the principal investigator and an experienced staff of full-time coordinators carrying out the day-to-day work of the biorepository.

The full-time program manager took over this part-time role and is responsible for managing day-to-day operations, handling budgets, managing IRB submission and reporting, applying for and administering grants and contracts, updating policies and procedures, overseeing the program coordinators, and providing community outreach services

TABLE 1. EXAMPLES OF FEES FROM THE DNASU PLASMID REPOSITORY AND THE SJHMC/BNI BIOBANK CORE FACILITY

	<i>DNASU Plasmid Repository</i>	<i>SJHMC/BNI Biobank</i>
Product(s)	DNA Plasmids	Tissue, blood, or CSF samples, stained and unstained slides, clinical information, collecting samples, storing samples, etc.
Product Cost	Academic: \$43 per plasmid or \$1600 per 96-well plate For Profit: \$53 per plasmid or \$2000 per 96-well plate	Frozen Tissue Sample: \$100–\$500 Blood product: \$60–\$300 Slide (H&E stained): \$20–\$100 Sample storage (per box per year): \$40–\$300
Shipping	\$15 (domestic), \$30 (international), or provide FedEx account number	Paid by recipient and depends on product and amount of dry ice needed

The fee ranges for several products and services offered by the SJHMC/BNI Biobank are listed. The range depends on the requestor (e.g., collaborator, not-for-profit institution, or for-profit company) and the specifics of the specimen or service is being requested (e.g., volume of sample, extent of clinical data requested, –80°C storage versus liquid nitrogen storage, etc.)

and marketing the available tissue/biofluid samples to scientific investigators and pharmaceutical companies. She is also responsible for working with Biobank leadership to develop and drive the Biobank's growth.

As a first step to developing the roadmap for this growth, a business plan (what the SJHMC/BNI Biobank called a Strategic Roadmap) was generated that highlighted goals and objectives within the three pillars of sustainability. The vision outlined in the Roadmap is one of expansion, building upon past success and the clinical strengths found within SJHMC/BNI, while also considering each of the key stakeholders: the patients, the funders, and the researchers. Therefore, the SJHMC/BNI Biobank recognizes that financial sustainability for a tissue biobank may be untenable in the current market and grant environment (see more below). Rather, its approach to sustainability ensures that value is added for each of these stakeholders so that the Biobank can enable research and have the broadest impact on scientific discovery^{2,3} (Fig. 3).

Financial sustainability. A number of publications have discussed how cost recovery cannot exclusively cover the operational costs of a biorepository.^{17–21} Analyses have found that, at most, 5%–25% of operation costs could be recovered through distribution fees because the actual cost of collecting and distributing tissue is prohibitive for the requesting researcher.^{22,23} Even with aggressive marketing, the demand for biospecimens varies and is irregular based on individual researcher needs, research funding, and availability of required samples.²⁴

Furthermore, even in ideal circumstances, only a percentage of collected samples will be distributed, which would necessitate adding non-distributed specimen collection and storage costs into the cost recovery fees, making biospecimens even more expensive. Researcher perception that biospecimens should be a free or inexpensive resource further limits the ability for a biorepository to completely recover costs through cost recovery efforts.²² In a variety of studies, the factors described above have contributed to

FIG. 3. Summary of the SJHMC/BNI Biobank Core Facility's Strategic Roadmap. The strategic goals for the Biobank Core Facility are based on the three aspects of biobanking sustainability: operational (to improve efficiency), social (to improve acceptability), and financial (to improve funding). Each goal is listed at the *top*, objectives for each goal are listed *below*, with specific activities to accomplish that goal bullet-pointed to the *right* of the objective. *Asterisks indicate that more information about the activity is detailed in the marketing strategies/plan table (not shown here).

developing models that optimize financial sustainability through a variety of revenue sources including institutional support, grants, user fees, and collaborations/contracts with commercial entities.^{5,24,25}

The SJHMC/BNI Biobank took this approach, making its financial sustainability goal to *optimize* the ability of the repository to become financially sustainable. This goal both acknowledges that complete financial sustainability may not be as tenable as it is for DNASU, but provides numerous pathways towards that goal (outlined in Fig. 3) including implementing cost recovery along with applying for grants and contracts, increasing marketing, and developing new services.

Creating and implementing cost recovery is complicated for the SJHMC/BNI Biobank, especially in comparison to DNASU where the processes and fixed costs for storing and distributing samples are relatively straightforward and low cost. Conversely, the SJHMC/BNI Biobank fee schedule that is under development has over 30 individual processes (e.g., patient consenting, entering clinical data into the database, picking samples, etc.) that each require staff time and supplies (Fig. 2). These processes are then combined to calculate the true cost for each specimen or service with the final cost ideally including overhead, equipment depreciation costs, and administrative fees.²⁵

The proposed cost recovery model will be tiered such that the cost, for example, to collaborators is lower than to external and for-profit organizations, to reflect collaborators' ongoing intellectual contributions to the biorepository and increased impact through shared publications. The cost recovery model will also include a range of costs for a particular biospecimen. This range will be based on, for example, the volume of sample requested, the amount of clinical information requested (if more than the standard clinical data provided with each sample), or nonstandard review of pathology reports for sample selection (Table 1). All of this information will be included in a policy to define the rationale behind the fee schedule and procedurally codified in a standard operating procedure outlining how to invoice and receive payment for these services.

Operational sustainability. The goal for achieving operational sustainability is to develop policies and procedures that improve biospecimen quality and increase the efficiency of biorepository operations. Specific objectives include improving and validating the quality of samples and streamlining operations to save money and reduce waste. Similar to DNASU, one main goal is to apply for CAP Biorepository Accreditation, which will affirm to the SJHMC/BNI Biobank's stakeholders that biospecimens are collected, processed, stored, and distributed with the quality and consistency that are defined in current evidence-based best practices.

One notable lesson learned from DNASU that translated seamlessly into the SJHMC/BNI Biobank's strategic roadmap is the use of automation and technology to increase efficiency and decrease human error. For example, inputting patient clinical information into a specimen tracking database will be streamlined by automating upload of select clinical data (e.g., demographics, diagnoses, and pathology reports) directly from the electronic medical record (EMR). Not only does this add value to the samples by increasing the amount of clinical annotation associated with each specimen, it also saves considerable time in manually entering information into the database.

Another example is implementing electronic informed consent (ICF). We calculated that over 330 hours are spent annually copying and filing paper-based patient ICFs. By signing the ICF on a tablet, the consent can be emailed to the patient (or printed, if they don't have email), attached to the EMR, and stored in the biospecimen tracking database associated with the patient information. This eliminates printouts, reduces filing time by over 90%, and the money saved, over ~\$15,000 in coordinator time and printer paper, can be used to build and improve upon other aspects of biorepository operations. Both of these automation and technology solutions will become even more important as the SJHMC/BNI Biobank grows and requires the tracking of more patient information and documentation.

Social sustainability. The goal of social sustainability is to cultivate a positive perception of the biorepository and its activities with the public/tissue donors, researchers, and clinicians. One of the first items implemented to achieve this goal was to change the name of the biorepository, which was previously the Human Specimen Procurement Service, because it did not accurately reflect the purpose and activities of the biorepository and was not well-recognized even within the institution. The new name "Biobank Core Facility @ St. Joseph's Hospital and Barrow Neurological Institute" better reflects its role as a biorepository that provides biospecimens and services to support research.

Although the simplicity of the DNASU cost recovery model cannot be applied to the SJHMC/BNI Biobank, many of the marketing and outreach techniques were transferrable. These include, for example, developing an easy-to-use website that provides clear information to all stakeholders (including the public) to better promote and market specimens and services, writing publications to describe the repository, creating promotional pamphlets, posters, and presentations to outreach to researchers and the public, and linkouts from websites promoting biospecimen resources or disease-specific foundation websites. All of these action items are currently in the process of implementation.

Impact. In addition to traditional marketing and outreach activities, the Roadmap outlines methods to track the impact of the biorepository for each of the stakeholders (researchers, funders and the public). Examples of metrics include tracking the number of collected samples, the number of distributed biospecimens, and the number of grants and contracts submitted/received. In addition, metrics that support the SJHMC/BNI Biobank's goals of high sample quality and the impact the SJHMC/BNI Biobank is having on science are tracked through, for example, researcher satisfaction with distributed samples, biospecimen quality control results (e.g., pathology review of histological slides or the RIN score of RNA isolated from frozen tissues before distribution), and publications.

Challenges

DNASU Plasmid Repository

DNASU has been financially sustainable, covering costs through re-charges and grants, nearly since its inception and usage and impact metrics, like publications, have been tracked since its early days. This has provided data to anticipate how many plasmids will be distributed annually

(revenue), to project growth (future revenue), to measure impact, to justify expansion, and to provide data for grant applications. Trends over the past 5 years show steady growth in the number of registered users for DNASU and the number of orders (on average) being placed each month. That being said, it is a challenge to predict when and if the market for plasmids will be saturated, whether the growth trend will continue, and whether this additional revenue can be relied on in the future.

Even with a cost recovery model that funds current activities, DNASU's challenge is that it cannot grow without external grants. Grants for biorepositories, including DNA repositories, are not common and often target specific collections, sample needs, or activities that may or may not be within the scope of a particular organization. When DNASU's funding from the NIGMS PSI-MR grant ends in 2016, DNASU will need to identify new and innovative sources of revenue or raise cost recovery prices to cover some necessary development and growth activities. Currently this grant funding allows for sequence verification of new plasmids and website development to accommodate the needs of both biorepository staff and researchers. Depending on the availability of funding, DNASU may decrease the scale and scope of any proposed new growth.

The Biobank Core Facility

In the development of the Strategic Roadmap, one of the main challenges was predicting the need for biospecimens through market research. Market data are expensive (if purchased) or time consuming (if collected through extensive surveys) but are essential to forecast potential future revenue. To overcome this challenge, market data were collected from publications, including analyses of cancer researchers' publications using biospecimens over the past 20 years.^{5,25-28} In addition, researchers at SJHMC/BNI were surveyed to identify their biospecimen and related service needs. These data informed the decision to expand the SJHMC/BNI Biobank based upon specific recommendations of what internal and external researchers wanted and needed.

A related challenge was a lack of biorepository metrics, such as number of samples collected, samples distributed, and publications using samples from the SJHMC/BNI Biobank, because they had not been tracked in the past. Therefore, when developing the Strategic Roadmap, benchmarks could not be developed to measure success. Therefore, it was proposed that the metrics from the first year of implementation will provide the benchmarks for the repository's activities. The Roadmap will then be updated to reflect goals based on these benchmarks for the upcoming years.

Besides the challenges in writing the Roadmap itself, the majority of the challenges moving forward will be in implementing the proposed sustainability plan. For example, the SJHMC/BNI Biobank did not have an established fee schedule or cost recovery policy when the Roadmap was written and are in the process of developing this policy now. Human samples are not to be sold for profit, so accurate cost calculations for the collection, processing, storage, and distribution of samples are necessary to attain financial sustainability.

Other implementation challenges are related to the SJHMC/BNI Biobank's specimen tracking database. Previously, a custom-created specimen tracking database was used for biospecimen tracking; however, it was not user-

friendly, had inflexible queries, did not have extensive customization options to store new types of samples or clinical data, and was no longer supported by the vendor. Therefore, a new database solution has to be identified and implemented before many of the proposed goals and objectives laid out in the Roadmap can be tackled.

Lessons Learned

The DNASU Plasmid Repository and the SJHMC/BNI Biobank differ in the details of their operations, their business planning needs, and their specific operational challenges. However, there are similarities worth noting that shape their shared view of sustainability. Both are situated in non-profit settings, and act as non-profits themselves. Both are part of a larger institution, and to different degrees, each receives some institutional support. Perhaps most importantly, the goal for each is to accelerate research and to leverage its resources to allow more research, both in terms of providing raw material for research and to enable stronger applications for research funding. From this vantage point, they have identified broad lessons learned that may help other biobanks on their path toward sustainability.

1. It doesn't matter how anyone else defines sustainability. The goals for sustainability will likely be different depending on the biorepository. For DNASU, affordability, financial sustainability, and accuracy are the main sustainability goals. For the SJHMC/BNI Biobank, all three aspects of sustainability are essential, especially considering that financial sustainability may not be achievable. Adding operational and social sustainability to the sustainability plan allows the SJHMC/BNI Biobank to achieve success for its stakeholders (e.g., the institution and funders) as it moves towards the goal of financial sustainability.
2. When defining sustainability, consider the entire ecosystem. It is possible that neither DNASU nor the SJHMC/BNI Biobank will recover all costs, but their availability in the institution and in the community may enable researchers to be more competitive at obtaining grant support for their research because of ready access to specimens. The increased grant funding for the institution may offset some of the losses sustained by the facilities' operations. Moreover, the goodwill arising from providing an important service needed to address important biomedical questions contributes to social sustainability.
3. Planning for the sustainability of your biobank is a must. Both institutions engaged in significant planning to achieve success. For DNASU, this preceded distributing the first plasmid. For the SJHMC/BNI Biobank, adding the Strategic Roadmap has been particularly valuable because: 1) it provides an opportunity for program leadership to define direction of the biobank; 2) it provides an outlet to reduce the complexity in biobanking by organizing new ideas, proposals, and changes for the biobank in one document; 3) it provides hospital or institutional leadership with an understanding of the vision and goals of the biobank moving forward to ensure that their goals are aligned; 4) it provides justification for purchasing and staff hiring; 5) it defines methods to improve operational, social and financial sustainability; and 6) it aligns and excites staff with the overall mission/vision and direction of the biorepository. Furthermore, the physical act of creating a

business plan provides an opportunity to pause from day-to-day activities to reflect and think about the current state of the biobank, to outline the vision for the future, and to brainstorm methods to achieve this vision.

4. Create the right business plan for the organization. Just as the definition of sustainability may differ for each biobank, the complexity of the business plan will likely differ as well. For the SJHMC/BNI Biobank, a detailed roadmap was both useful to write and the details helped sell the Biobanking 3.0 model to leadership and justify the expenditures required for growth. Because of this, the Roadmap included the following sections: an executive summary, a market analysis, a program description (including a description of the organization and management, see Figure 2 for more details), a strengths, weaknesses, opportunities, and threats (SWOT) analysis, detailed descriptions of goals and objectives, a marketing plan, business financials, key performance indicators (the metrics we will use to track impact) and a timeline for implementing these plans. For DNASU, which is more embedded in an academic environment, similar elements were evaluated and included in proposals put before planning committees and in grant proposals. In addition, for progress reports and for its steering committees, financials and metrics were reviewed annually to stay on track.
5. Allow the business plan to be a living document. The SJHMC/BNI Biobank intentionally called its business plan the Strategic Roadmap. The term roadmap envisions a path or journey, which by definition, is fluid and implies navigating twists and turns. Each biobank is taking their own journey, will encounter their own roadblocks, and will navigate its own twists and turns. When hitting a bend in the road (such as the loss of a large grant), the flexibility to explore new opportunities and directions is quite valuable. For the SJHMC/BNI Biobank, it was valuable to create a roadmap because new path was about to be taken. A roadmap is also a living document that can be amended or adjusted in the face of change. Similar to resiliency in an ecosystem, which allows the ecosystem to absorb disturbance and still retain its viability, the roadmap allows for adjustment in the face of change or other external disturbances that all biobanks encounter.
6. Sustainability is complicated. To anyone who has thought about sustainability in biobanking, this statement is self-evident. Internal and external resources and pressures constantly change and finding the “capacity to endure” is always a challenge. Even when financially stable, funding may be lost, markets may change, and adjustments in the plan may be needed. This complexity can be embraced by building flexibility into an informal sustainability plan, strategic roadmap or business plan, and by designing this plan with your biobank’s exact needs in mind.

Acknowledgments

The authors thank Jason Steel, Andrea Fischbeck, Amit Sharma, Daniela Garcia, and Mitch Magee at the DNASU Plasmid Repository. DNASU receives funding from the National Institute of General Medical Sciences [U01 GM098912] and the Virginia G. Piper Charitable Trust. The authors also thank Beth Hermes and Rosy Singh from the Biobank Core Facility @ St. Joseph’s Hospital and Barrow Neurological Institute. The Biobank Core Facility receives

funding from the Barrow Neurological Foundation and the Arizona Biomedical Research Commission.

Author Disclosure Statement

No conflicting financial interests exist.

References

1. Development WCoEa. *Report of the World Commission on Environment and Development: Our Common Future*. Oxford, UK: Oxford University Press; 1987; Available from: <http://www.un-documents.net/our-common-future.pdf>. Last accessed 30 November 2015.
2. Elkington J. *Towards the Sustainable Corporation: Win-Win-Win Business Strategies for Sustainable Development*. California Management Review. 1994; p. 90–100.
3. Slaper TF, Hall TJ. The Triple Bottom Line: What Is It and How Does It Work? Indiana Business Review 2011; Spring: 4–8.
4. Mackenzie J. The old care paradigm is dead, long live the new sustainable care paradigm: How can GP commissioning consortia meet the demand challenges of 21st century healthcare? London J Prim Care. 2011;4:64–68.
5. Simeon-Dubach D, Watson P. Biobanking 3.0: Evidence based and customer focused biobanking. Clin Biochem 2014;47:300–308.
6. Watson PH, Nussbeck SY, Carter C, et al. A framework for biobank sustainability. Biopreserv Biobank 2014;12:60–68.
7. Cormier CY, Mohr SE, Zuo D, et al. Protein Structure Initiative Material Repository: An open shared public resource of structural genomics plasmids for the biological community. Nucleic Acids Res 2010;38:D743–749.
8. Cormier CY, Park JG, Fiocco M, et al. PSI:Biologymaterials repository: A biologist’s resource for protein expression plasmids. J Struct Funct Genom 2011;12:55–62.
9. Seiler CY, Park JG, Sharma A, et al. DNASU plasmid and PSI:Biologymaterials repositories: Resources to accelerate biological research. Nucleic Acids Res 2014;42: D1253–1260.
10. Lamesch P, Li N, Milstein S, et al. hORFeome v3.1: A resource of human open reading frames representing over 10,000 human genes. Genomics 2007;89:307–315.
11. Yang X, Boehm JS, Salehi-Ashtiani K, et al. A public genome-scale lentiviral expression library of human ORFs. Nat Methods 2011;8:659–661.
12. Labaer J, Qiu Q, Anumanthan A, et al. The Pseudomonas aeruginosa PA01 gene collection. Genome Res 2004;14: 2190–2000.
13. Murthy T, Rolfs A, Hu Y, et al. A full-genomic sequence-verified protein-coding gene collection for Francisella tularensis. PLoS One 2007;2:e577.
14. Park J, Hu Y, Murthy TV, et al. Building a human kinase gene repository: Bioinformatics, molecular cloning, and functional validation. Proc Natl Acad Sci USA 2005;102:8114–8119.
15. Yu X, Bian X, Throop A, et al. Exploration of panviral proteome: High-throughput cloning and functional implications in virus-host interactions. Theranostics 2014;4:808–822.
16. Brat DJ, Verhaak RG, Aldape KD, et al. Comprehensive, integrative genomic analysis of diffuse lower-grade gliomas. N Engl J Med 2015;372:2481–2498.
17. Colledge F, Elger B, Howard HC. A review of the barriers to sharing in biobanking. Biopreserv Biobank 2013;11:339–346.
18. Colledge F, Persson K, Elger B, Shaw D. Sample and data sharing barriers in biobanking: Consent, committees, and compromises. Ann Diag Pathol 2014;18:78–81.

19. Fortin S, Pathmasiri S, Grintuch R, Deschenes M. 'Access arrangements' for biobanks: A fine line between facilitating and hindering collaboration. *Public Health Genom* 2011;14: 104–114.
20. Luque JS, Quinn GP, Montel-Ishino FA, et al. Formative research on perceptions of biobanking: What community members think. *J Cancer Edu* 2012;27:91–99.
21. Mascalcioni D, Dove ES, Rubinstein Y, et al. International Charter of principles for sharing bio-specimens and data. *Eur J Human Genet* 2015;23:721–728.
22. Albert M, Bartlett J, Johnston RN, Schacter B, Watson P. Biobank bootstrapping: Is biobank sustainability possible through cost recovery? *Biopreserv Biobank* 2014;12:374–380.
23. Clement B, Yuille M, Zaltoukal K, et al. Public biobanks: Calculation and recovery of costs. *Sci Translat Med* 2014; 6:261fs45.
24. Warth R, Perren A. Construction of a business model to assure financial sustainability of biobanks. *Biopreserv Biobank* 2014;12:389–394.
25. Vaught J, Rogers J, Carolin T, Compton C. Biobankonomics: Developing a sustainable business model approach for the formation of a human tissue biobank. *J Natl Cancer Instit Monog* 2011;2011:24–31.
26. Braun L, Lesperance M, Mes-Massons AM, Tsao MS, Watson PH. Individual investigator profiles of biospecimen use in cancer research. *Biopreserv Biobank* 2014;12: 192–198.
27. Cole A, Cheah S, Dee S, Hughes S, Watson PH. Biospecimen use correlates with emerging techniques in cancer research: Impact on planning future biobanks. *Biopreserv Biobank* 2012;10:518–525.
28. Hughes SE, Barnes RO, Watson PH. Biospecimen use in cancer research over two decades. *Biopreserv Biobank* 2010; 8:89–97.

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