Better Healthcare through
Better Design of Healthcare Research and Development

Abstract

One of the major benefits of a government funded research center or lab is the infrastructure it can provide investigators to enable them to stimulate research and training in high priority areas. Most research centers and labs represent complex organizations that must juggle a variety of different funding streams, projects, physical infrastructure, and human resources. Managed well, such organizations can find themselves in a virtuous cycle that leads to an increasing trend of cutting edge research, innovation, and funding that could ultimately have a large impact on society. Poorly managed, research and development organizations can find themselves in a vicious cycle of decreasing funding and quality of research that may ultimately threaten the safety of research. Improving the design, planning, and management of research centers and labs could have significant benefits on making the research and development process more efficient. This paper describes the development and application of system dynamics model to support the design of research center and accompanying management plan. The research and development (R&D) model represents both the current and projected projects that would be needed given a growth scenario, and includes a number of sectors including staff, funding, space, and human resources.

Keywords: research and development, project management

This is an applications paper that describes the development and use of a system dynamics model for designing and managing the growth of a health and human services research and development center. Most studies on health and human services have largely focused on identifying and evaluating innovations in health services such as identifying disease mechanisms and new therapies; make services safer, more efficient and accessible; reduce disparities; and, increasingly improving the quality of health services. Many of these efforts are supported through government funded research centers and labs. However, very little if any research has focused on improving the design and management of health and human services research and development.

Research and development centers and labs are dynamically complex systems that must manage an unpredictable flow of resources and portfolio products to produce innovations that ultimately lead to measurable changes in the systems they target. Research centers and labs provide critical infrastructure that enable investigators to collaborate on projects, providing training and mentoring opportunities, and shorten the cycle time to develop and scale up research. However, research centers and labs are vulnerable to fluctuating resources, the unpredictability that comes with largely supporting staff on soft money, and the tendency to develop organizational inertia and focus on sustaining innovations that make it difficult to adapt to changing environments and stay on the cutting edge of research. There are often variable delays in funding being released to projects and hiring that can have significant nonlinear effects on the ability to start projects on time and stay on schedule that can compromise compliance and safety, lead to no-cost extensions that require institutional subsidies, and ultimately threaten the quality of the science being conducted. These challenges have arguably contributed to growing concern about the effective design, planning, and management health services research and development centers with increasing expectations from review panels to demonstrate better design and planning of the management core for center research proposals.

System dynamics has a long tradition of contributing to a better understanding of research and development, and more generally, project management dynamics. Roberts (1964) seminal work on research and development in the defense industry was placed squarely within the larger context of understanding how to improve efficiency of public resources to improve national security, and more generally the production of public goods such as defense, health and education. More recently, system dynamics has been used to understand research and development in automotive industry (Ford and Sobek 2005), construction industry (Ford and Bhargav 2006), and concurrent software development (Rahmandad and Weiss 2009). Indeed, one of the most successful applications of system dynamics has been in the more general area of project management (Lyneis and Ford 2007).

This paper describes the development and application of a system dynamics model of research and development that is being used to improve the design and management of several research and development centers working on problems in health services research. The focus of this paper is on describing the model and its use in the design of health services research center. Key features of the model include consideration of feedback effects relating tangible and intangible resources, representing multiple projects by different phases of work and status (e.g., proposal development, pending, active, rejected, completed), development of human resources, varying delays on funded and project activity, different levels of funding and indirect cost recovery, growth targets and potential projects that would need to be developed in order to meet those targets, and the varying probability of winning an award.

Background

The initial motivation for the health services research and development (HSR&D) model came from an organizational crisis in a large, publically funded health care facility that managed approximately $30 million of health services research and development involving both animal and human subjects. A national review of health facilities and their compliance to safety and reporting requirements resulted in research at numerous facilities being shut down or halted. The client initially inquired about whether it would be possible to use system dynamics to help research administration staff design a process for developing and maintaining policies, estimating resources (e.g., people, space, fiscal) needed to sustain an active program of research, identify quality measures, and identify early warning indicators of impending problems.

Meeting with stakeholders indicated strong support for the project even though the staff was under extreme stress and time schedule demands for addressing the immediate crisis. A group of external organizational development consultants were also brought in (not involved with this project) that involved extensive interviews at this critical time, but yielded few if any insights or usable recommendations for the staff. Follow-up meetings with research staff led to a project description with buy in, but some concern that investigators who were not part of the original meeting would not be interested in this approach. Omission of investigators as the primary customers from this effort was seen as a potential and major barrier to the success of the project.

Meanwhile, the investigators were in the process of developing a research and development enhance project proposal to expand the infrastructure for supporting health services research and develop at the facility. This group was also encountering a crisis involving a set of resource constraints including an acute shortage of research space, difficulty recruiting and retaining new investigators into the facility, lack of support in preparing grant submissions, shortage of skilled research staff to manage projects and data, and delays in the release of awarded funding to hire staff and start research. The lead on this project was therefore approached to see if the model being developed for the R&D administration staff could be used to address these issues as well.

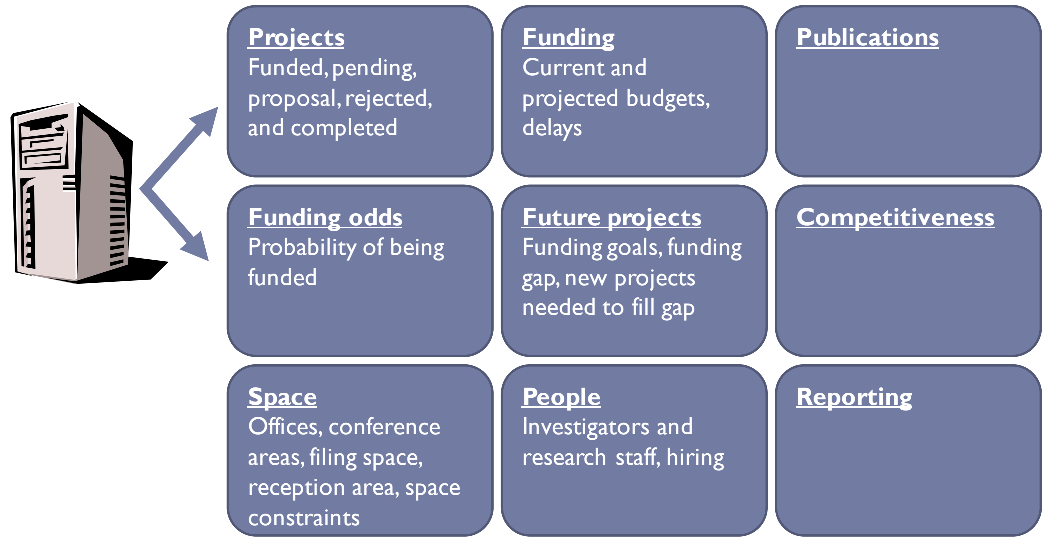
After several meetings with investigators to understand the challenges they were facing, a preliminary system dynamics simulation model was developed and presented to the investigators. The purpose of this preliminary model was to introduce basic concepts of system dynamics and illustrate how some of their concerns could be modeled as a dynamic problem. The primary focus of this presentation was to enable the investigators to develop buy-in and consensus on the purpose of the modeling. This initial presentation of the model was met with some skepticism, but over the course of a several discussions, led to framework on how to proceed. Subsequent meetings with individuals led to a refinement of the basic concept that would integrate an existing database that they were developing for tracking projects and human resources with the Vensim model, which was developed and shared into a proof-of-concept simulation model that could be shared with the investigators for feedback and refinement, as well as illustrating how a system dynamics simulation model could be used to project resources for existing projects as well as the projects and resources that would need to be developed in order to meet growth goals. This proof-of-concept model was also used to illustrate how a simulation model could be integrated with the existing database and the added value of a research infrastructure.

Health Services Research and Development (HSR&D) Model

The HSR&D model was developed using Vensim DSS and a combination of Microsoft Excel and Access for storing project data. The model represents projects by different phases of work where activity and resources within any given phase are considered homogenous. Most projects in this field are defined by year-long project phases, and resources are generally fungible within any given year. The model represents both existing and potential projects. *Existing projects* are projects that have been defined with well defined budgets, scientific aims, and schedules. These can be projects that are in the proposal stage, pending, active, completed, or rejected proposals. An Excel worksheet or Access database can is used to store project details for existing projects, including start and stop dates for each project phase, current status (i.e., proposal, pending, active, completed, or rejected), funding, indirect or overhead rate, and full time equivalent (FTE) staffing for investigators and support staff. *Potential projects* are projects that have not been defined, but need to be developed in order to meet projected growth goals for funding and research.

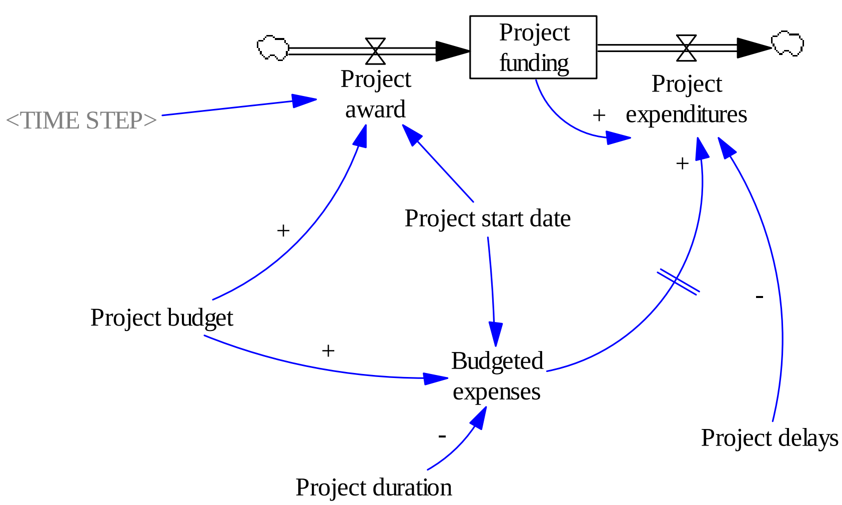
An overview of the major sectors in the HSR&D model is shown in Figure 1 below. The model pulls data from the Excel or Access database project table and runs a simulation of projected trends for funding, people, space, and productivity under various scenarios and growth plans. The present position of the recent center and projected trends can easily be reevaluated by running simulations as information about project status is updated as funding decisions are made about pending projects, new projects are submitted, and other projects completed. Importantly, the model includes both the basic accounting calculations that are needed to project resources over time, and the feedback mechanisms that couple and impose constraints between tangible and intangible resources.

Figure 1 Overview of major sectors in HSR&D model



To track and calculate projections for projected resources, all existing projects are represented in the model regardless of their status. Figure 2, for example, shows the project funding stock, which is arrayed by projects. Expenditures are then selected and aggregated by their status (active, pending, proposal) to generate projected expenditures over time.

Figure 2 Project funding sector



Expenditures for pending projects are weighted by the probability of getting funded to arrive at a projected gap in funded research. This is then used to calculate the number of future submissions that are needed in order to close the funding gap (shown in Figure 3). These are potential projects that are not yet defined, but need to be created in order to meet goals for funded research. The probability of funding is currently treated as an exogenous variable, but this will be made endogenous as research productivity in the form of peer reviewed publications affects the competitiveness of grants. The total for existing and future projects is used to estimate the staffing, space, and other needs for the research center.

Figure 3 Future projects sector

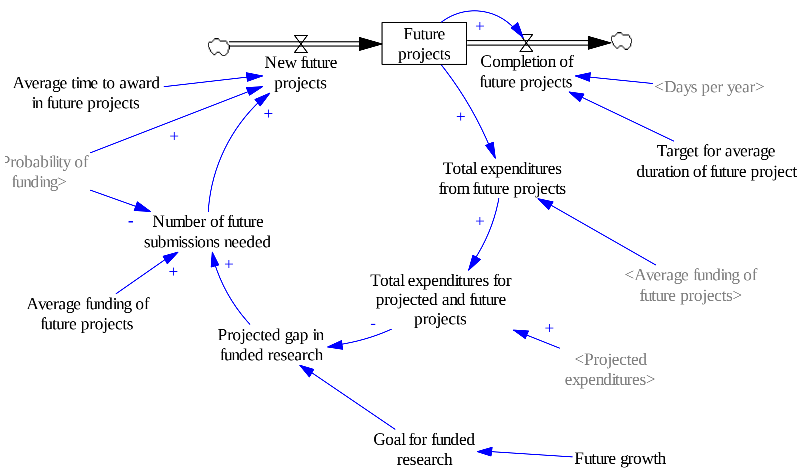


Figure 4 Human resources sector

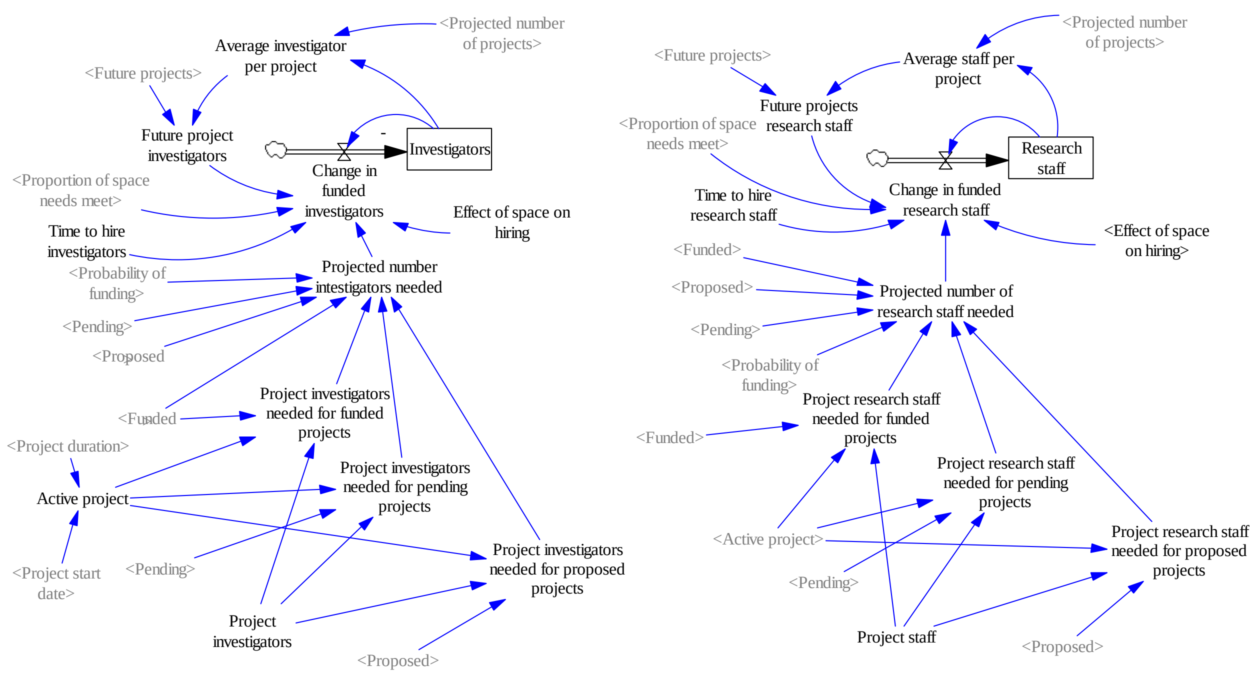


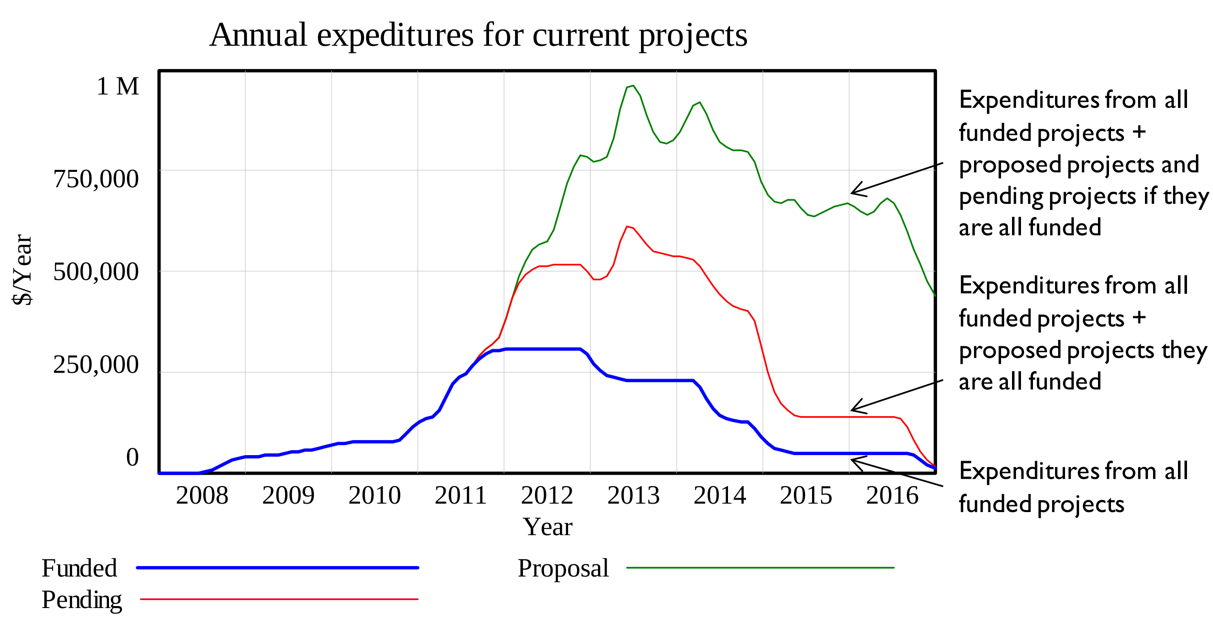
Figure 4 shows the two main human resource stocks, investigators and research staff. The number of investigators and research staff needed is a function of the total projected projects (existing and future projects). The time to adjust the number of investigators and research staff to meet this need is dependent upon a variety of factors, including the availability of space to house investigators and researchers.

The current model has passed a number of basic tests including dimensional consistency, extreme conditions test, and done an adequate job of representing some of the key mechanisms discussed by stakeholders. Current efforts are underway to compare the model against historical data, which will be completed by April 2010, and undergo additional refinement and testing as simulation scenarios are run to support the design and planning of the research center.

Simulations

One of the main advantages of this approach is getting a better temporal view of the resources dynamics. In one sense, these are uncomplicated structures representing simple stock and flow accumulations, but both Warren (2004) and Sterman (2002) have pointed out that even simple stock accumulations can be hard for people to see and manage without the aid of computer simulations. Figure 5 shows the annual expenditures for the research center given a hypothetical set of research projects. The blue line shows the expenditures of funded projects, the red line shows the expenditures from all funded projects and pending projects if they are funded, and the grey line shows the expenditures from all potential projects if every proposed and pending project is funded.

Figure 5 Annual expenditures



To illustrate the use of the model for planning purposes, a simple growth scenario is considered where the research center seeks to increase funded research to a level of $1 million per year in externally funded research (green line in Figure 6). The blue line represents the current portfolio of projects including both the active projects and the pending and proposed projects weighted by their probability of being funded. In the current version of the model, this probability is based on the historical average rate of being funded, but the next version of the model will make this endogenous and include other factors such as the publication productivity of researchers and consider potential future scenarios such increased competition for funding in tight fiscal environments. The gap between the red line and blue line in Figure 6 is the number of new projects that must be created in order to meet the growth goal.

Figure 6 Expenditures based on growth scenario

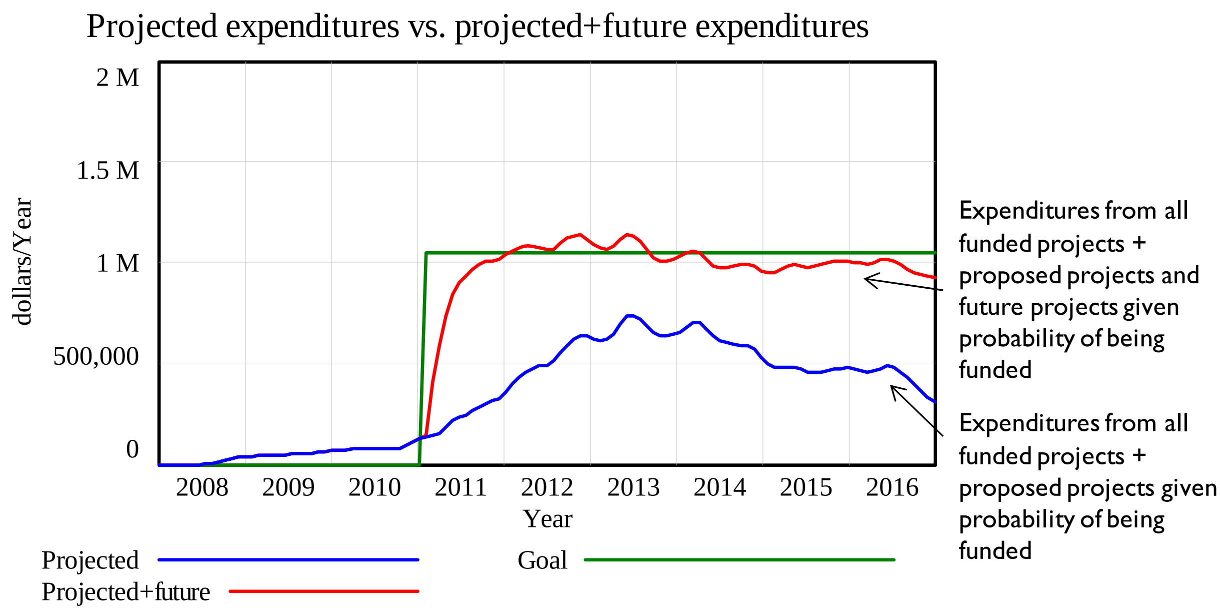


Figure 7 Human resources in growth scenario

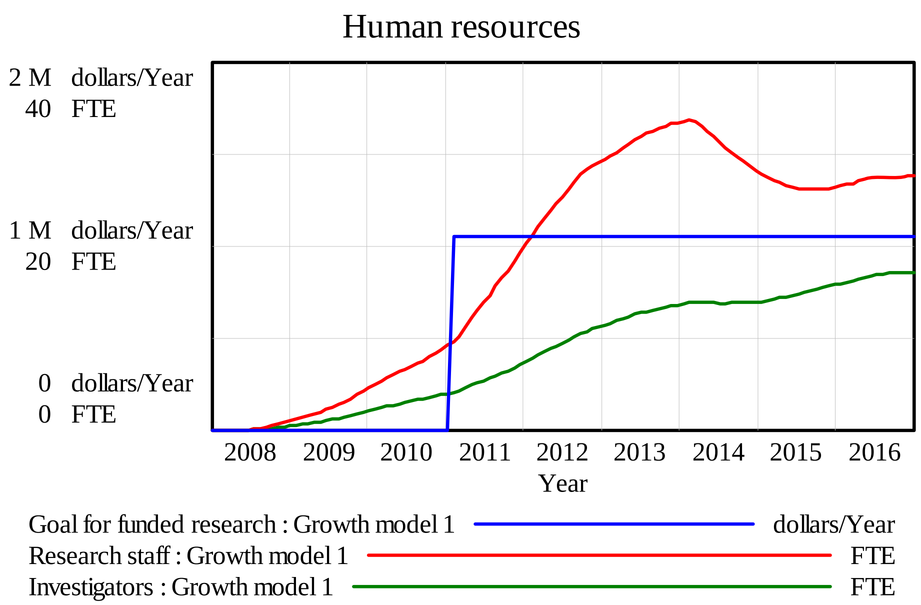
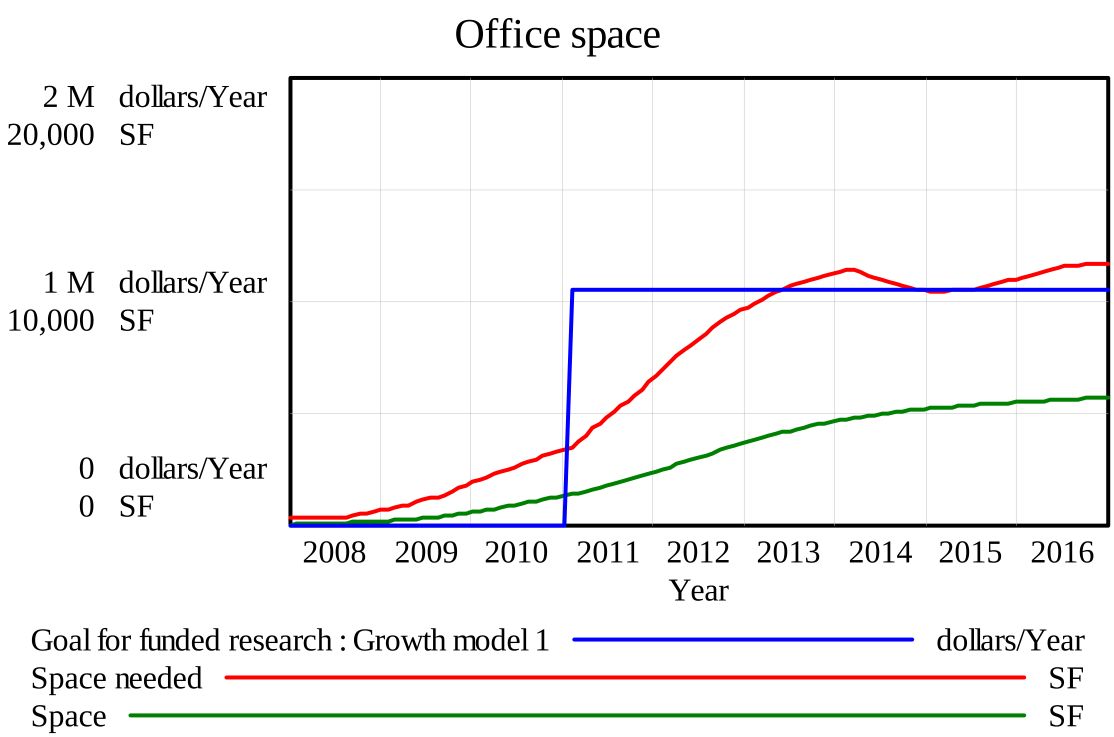


Figure 7 shows the growth in human resources including FTE research staff (red) and investigators (green) under the current growth scenario (blue line). Figure 8 shows the corresponding need and office space for investigators and research staff. The assumption is that there is a fixed amount of space for investigators and research staff to occupy. As needs for new investigators and staff grow, space constrains hiring and increases turnover, which slows the rate that investigators and staff can be added. This impacts project schedules and productivity. In the current model, these are not yet impacting the ability of the research staff to provide support on research compliance and budget reporting, nor affecting the probability of being funded. As these additional linkages are included, the feedback effects are likely to become and more complicated.

Figure 8 Office space needed and available under growth scenario



Conclusion

Managing space and physical resources may seem mundane topics for research, but failure to adequately address what are ultimately very dynamic situations familiar in system dynamics can have significant implications on the efficiency, quality, safety and ultimately long term impact of research centers on health services. Some of the important insights gained in the modeling process include both organizational learning by investigators, a sharper focus on what the measurable performance goals for the center should be, deeper insights into how some of the key dynamics relating tangible and intangible resources can impact the ability to meet performance goals for the research center,

Some of these initial insights developed with stakeholders in the modeling process that have important implications for how research centers are managed. For example, while it is easy to see how space constraints and staffing are related, the model helped stakeholders see some of the unintended consequences of not being able to quickly ramp up research activities after funds are released. For example, space constraints create disincentives for new staff to join the health care facility as an employee, effectively increasing the barriers to adding research capacity, and slowing the ramp up for the research project. While frustrating, it's often not seen as a problem that has larger resource implications for the research facility or investigator beyond adding a delay since funds will still be available for when staff are hired. There may also be more dramatic situations where the funding is allocated late and will expire if not spent in its entirety. This is particularly true for this facility where by the time the awards were released, there was not enough time to hire and process new employees to complete the research. In either case, the prevailing thinking among non-researchers is that these schedule delays at the start of a project do not impact the availability of resources, and that these projects can be completed under no-cost extensions with little consequence to the research infrastructure or quality of research. It's important to stress that the dominant logic in many non-profit research centers is "You can always go for a no-cost extension."

However, the process of building the model quickly revealed the error in this logic. Administrative overhead as an expense is proportional to expenditures (e.g., expenditures on staff, space, etc.), but the resources provided to support the research as a cost is related to the activity of conducting the research. Stretching projects out over time effectively means that there is less administrative overhead to cover a fixed amount of research activity. This creates a resource gap that plays out in several ways, including less space for research staff, fewer resources to review and manage budget and compliance issues, and fewer resources to secure future funding. Some of these "feed back" to increase delays even further. For example, fewer resources to review research protocols mean even longer delays in starting data collection, which delays data analysis and reporting even further, and may force another project to seek and enter a no-cost extension. This can essentially create a vicious trap where the initial benefits of a center to provide research infrastructure begins to eat away and actually hinder research and development. In desperate situations, this may lead to shifting of resources in an effort to make up some of these gaps only to delay dealing with the actual problem.

Another example of an important dynamic insight recognizing the tendency of research centers to focus on the immediate funding gap by applying for future funding, only to have the delayed resources and costs lead to an overshoot and potential collapse that is hard to avoid and manage. This can essentially lead to cycles of "feast or famine" in research centers, and incentivize a shifting of resources that stabilize research infrastructure and create organizational inertia that ultimately threatens the ability of the research center to produce innovations, and undermines the very mission of the center, its effectiveness, and ultimately the sustainability of the HSR&D research center.

Equally important was a much more explicit discussion about goals for organizational performance and productivity related to the HSR&D center. The modeling of growth goals and scenarios forced a much more rigorous discussion about what the metrics should be in the proposal for evaluating the performance of the center, and what kind of impact investigators expected the center to have on these metrics. For example, should the goal of the center be to simply increase research from one level to another (i.e., the step change shown earlier) or should the center aim to start a pattern of linear or maybe exponential growth? To what extent would this initial effort be sustainable? What would be limits to growth that would kick in, and when would they appear?

The development of this model continues, but it has already led to a more generic model by involving several strategic partners in the parallel development of similar models for managing multiple nonprofit research and development projects. During the next several months, the existing model will be revised to include a better representation of projects by project phases, include a basic Access database for managing project information, and have a better set of structures for managing the human capital in research centers. Many of these elements can be customized to fit the specific needs of nonprofit R&D centers and labs. This revised model will be used to help design and manage the research management infrastructure for two separate HSR&D centers and research lab.

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