Better Healthcare through
Better Design of Healthcare Research and Development

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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, health care, 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

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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

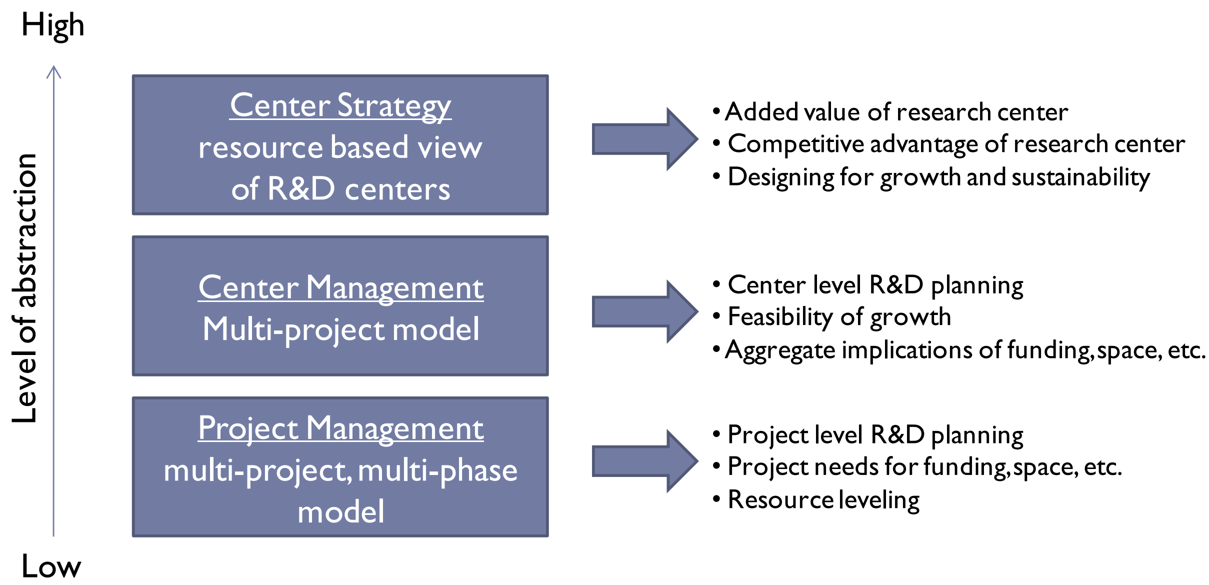
Creating and maintaining an organizational culture and climate that moves beyond meeting minimal requirements of protecting human subjects to one of promoting research integrity involves successfully managing a complex system of resources (Committee on Assessing Integrity in Research Environments 2002; Katz and Kahn 1966; Pfeffer and Salancik 1978). These resources include both the intangible resources such as public trust in funded research, the reputations of the research facilities and investigators, and tangible resources such as the financial, physical, and human resources needed to conduct, monitor, and ultimately promote research integrity. While resources are frequently acknowledged as a potentially important determinant of research integrity (e.g., Committee on Assessing Integrity in Research Environments 2002; Committee on Assessing the System for Protecting Human Research Subjects 2001; Federman, Hanna, and Rodriguez 2002), the emphasis on solutions tends to focus on creating additional systems within research organizations for more effectively training and monitoring the understanding of individual investigators and research staff. However, such efforts can also impose additional demands on resources that can impact the conduct of research including delays in getting financial resources available in a timely way to hire qualified research staff, more time allocated to monitoring and compliance and less time to designing adequately resourced research projects, and schedule delays on projects that can create pressure to compromise research integrity. Such pressures are often cited in public accounts of the more egregious violations of research integrity (Bor and Pelton 2001; Carey 2010).

Additional resources to support research and development infrastructure are likely to be scarce, and many research and development organizations relying on external funding are likely to face even more competition for limited resources. These dynamics are likely to pose some major challenges for research organizations, and create incentives that slow or even erode an organizational climate and culture that promotes research integrity. Moreover, efforts to promote research integrity through additional requirements or policies that impose resource demands could exacerbate an already challenging situation, and in some cases, push organizations past a "tipping point" where they are caught in a vicious circle of cutting corners in an effort to be more competitive and secure future resources in order to survive. Such dynamics have been found in other efforts to improve organizational performance and can lead to "capability traps" where organizations are unable to make the investments to improve capabilities (Repenning and Sterman 2002).

New approaches, measures, and models are needed to better understand the dynamic interplay between organizational culture, climate, and resources that influence research integrity in publically funded research. Such approaches will need to explicitly consider of units conducting research and development as complex systems that are dynamic. New methods such as a the computer simulation may be needed to be applied to develop better organizational theories can be empirically tested (Davis, Eisenhardt, and Bingham 2007). Both tangible and intangible resources will need to be considered explicitly along with how their configuration within an organization influences outcomes (e.g., Morecroft 2002). Needed are models that help us understand health services research and development as a dynamic resource system underlying the organizational culture and climate of publically funded research and development organizations to promote research integrity.

Health services research and development (HSR&D) can be conceptualized at three different levels of abstraction: center strategy, center management, and project management (see Figure 1). Each emphasizes a different aspect of HSR&D. A center strategy model would focus on the overall approach and business case for a research center or lab with an emphasis on understanding the added value of a research center, the competitive advantage of a research center, and designing for growth and sustainability including research integrity. A center management model takes a multi-project focus and addresses problems such as planning R&D, aggregate implications of multiple projects on staffing, space, and other resources, and helps assess the feasibility of different plans for growth. At the project management level, the emphasis of a model is on understanding how multiple projects and phases interact over time with the goal of managing and leveling resources for specific resources. Dynamic resource problems in HSR&D can occur at all three levels and can pose organizational problems for sustainability of R&D centers and labs as well as threatening research integrity.

Figure 1 Different models, different insights

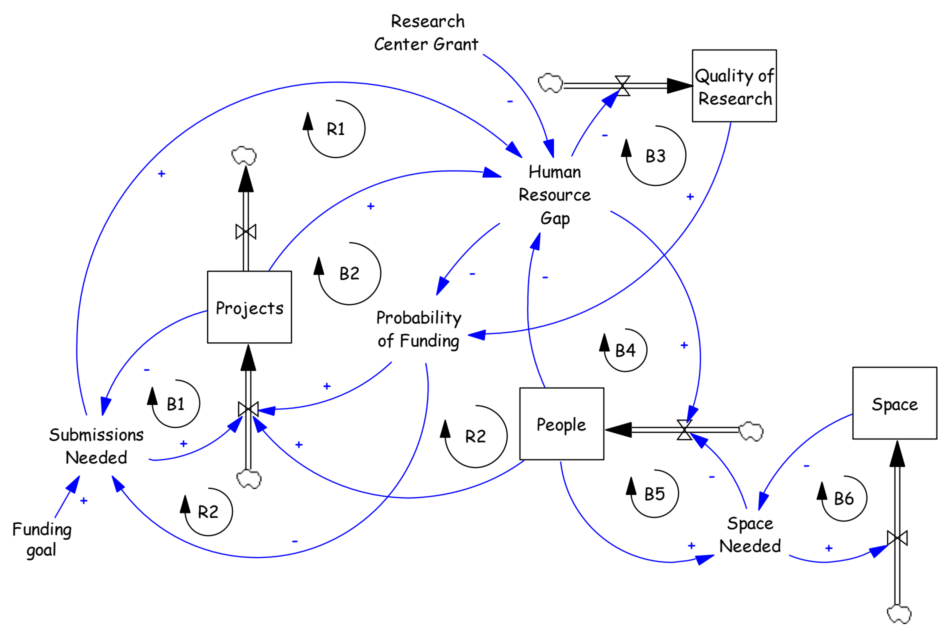


Health Services Research and Development Model

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 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.

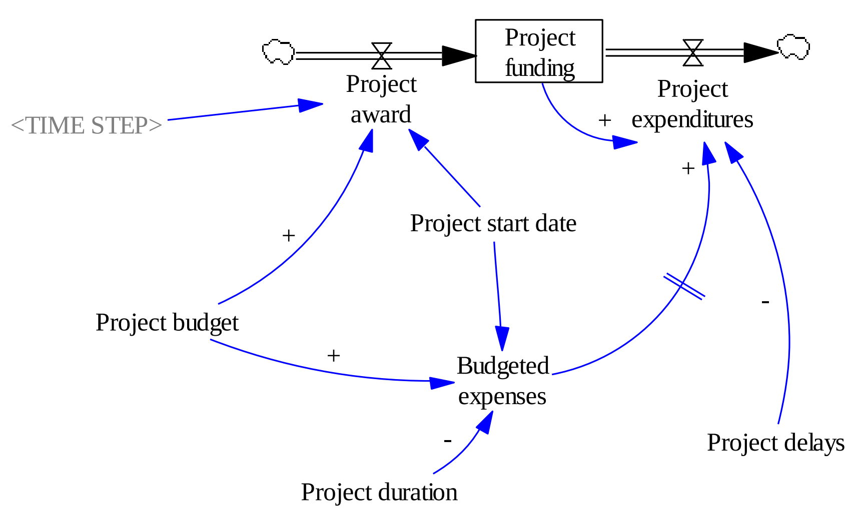
An overview of the feedback system relating the main resource stocks in the HSR&D model is shown in Figure 2 below. The model pulls data from the Excel database project table and runs a simulation of projected trends for funding, people, space, and productivity under various scenarios and growth plans. 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 2 Conceptual overview of main resource stocks 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 3, 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 3 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 4). 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 4 Future projects sector

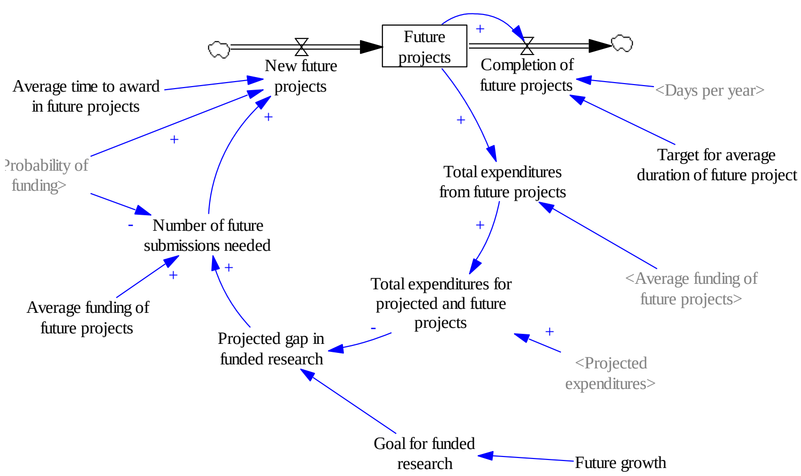


Figure 5 Human resources sector

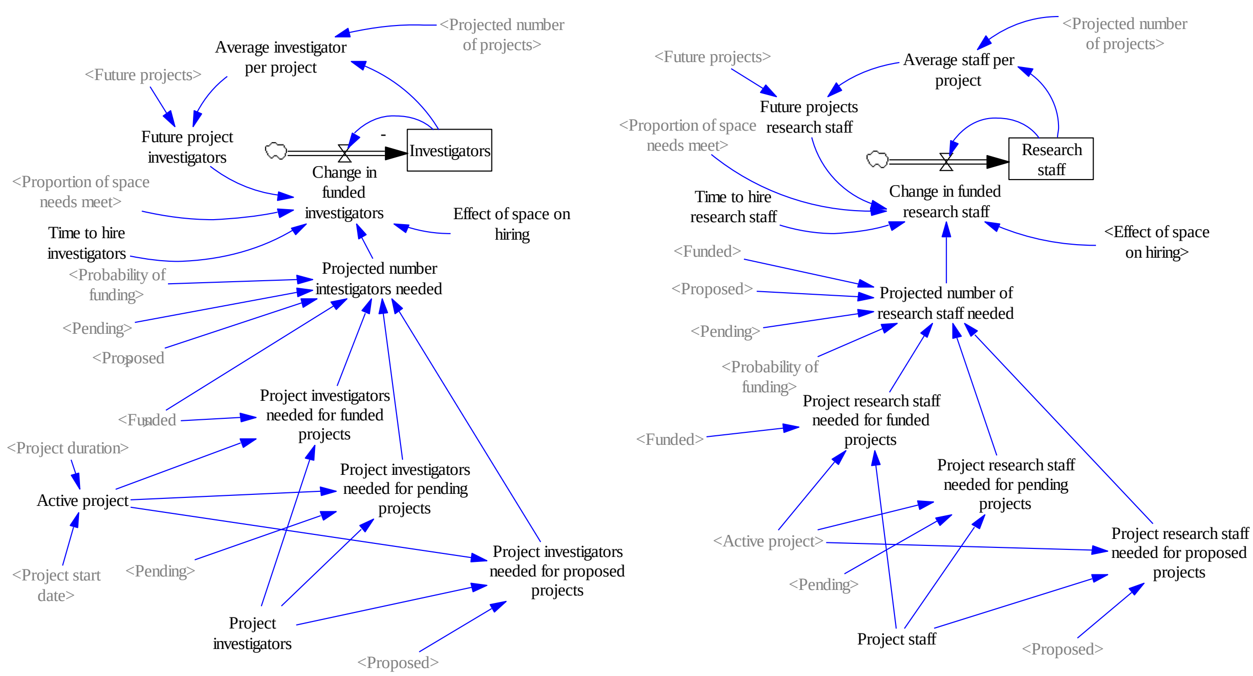
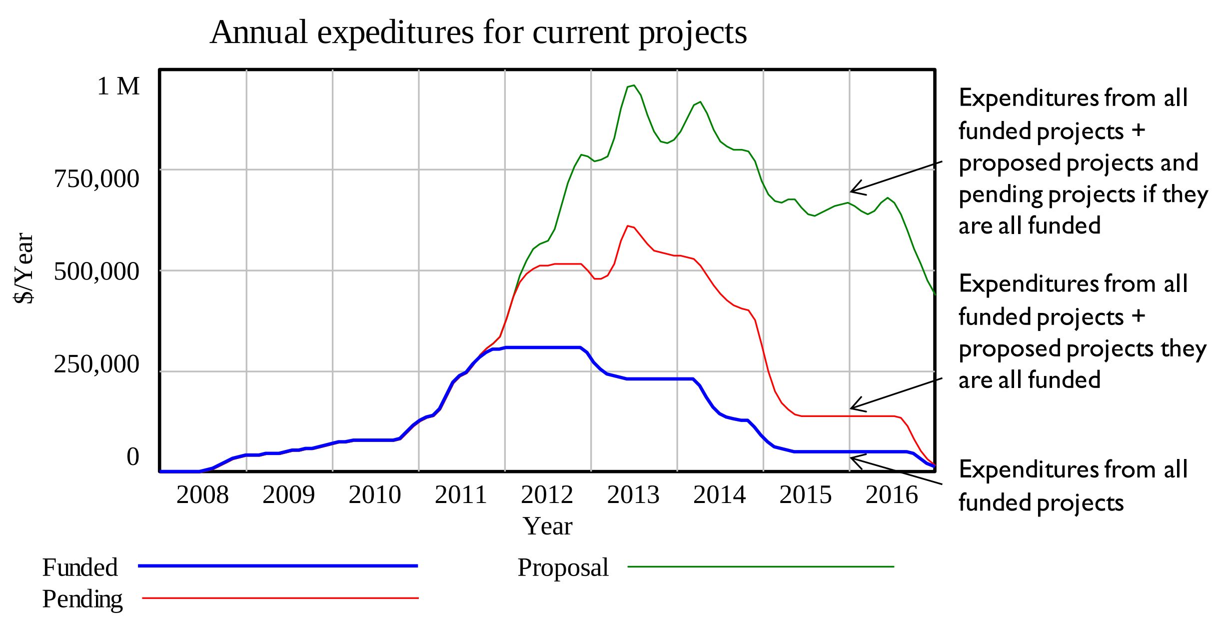


Figure 5 shows the two main human resource stocks considered in this mode: investigators and research staff. The number of investigators and research staff needed is a function of the total projected projects (existing and future projects). The time to adjust the number of investigators and research staff to meet this need is dependent upon a variety of factors, including the availability of space to house investigators and researchers.

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 6 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 6 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 7). 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 7 is the number of new projects that must be created in order to meet the growth goal.

Figure 7 Expenditures based on growth scenario

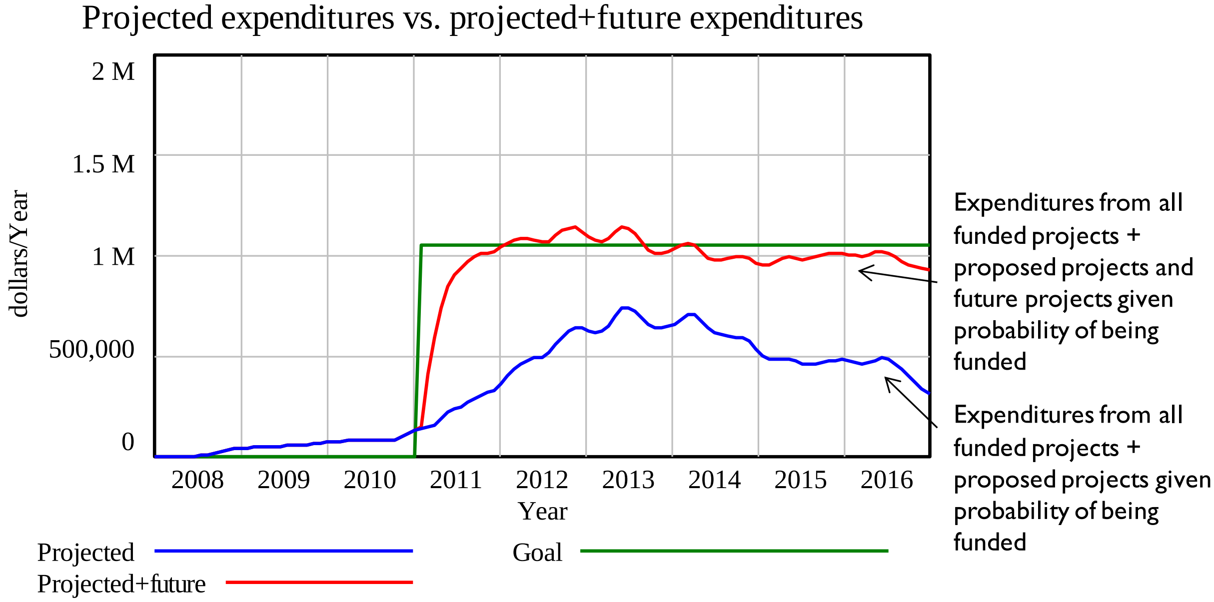


Figure 8 Human resources in growth scenario

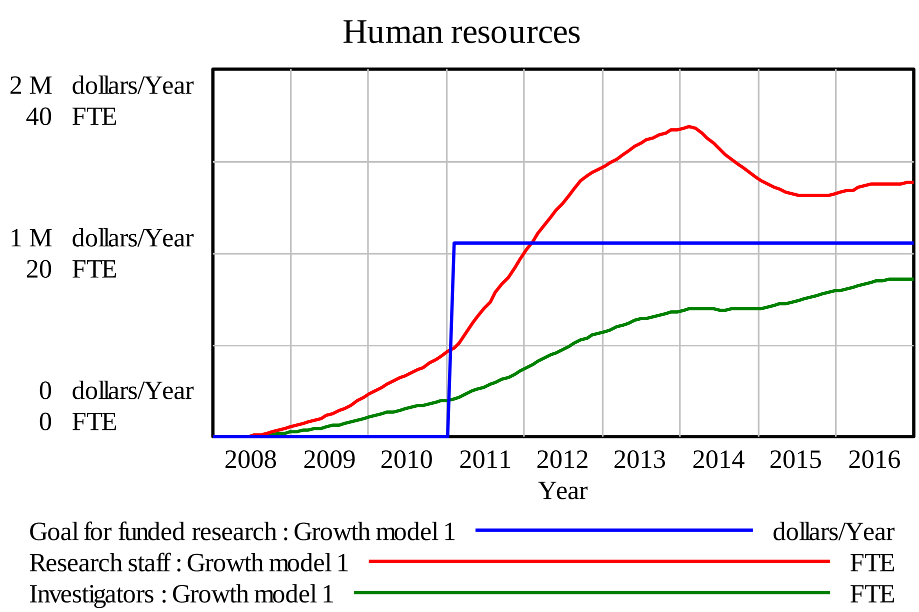
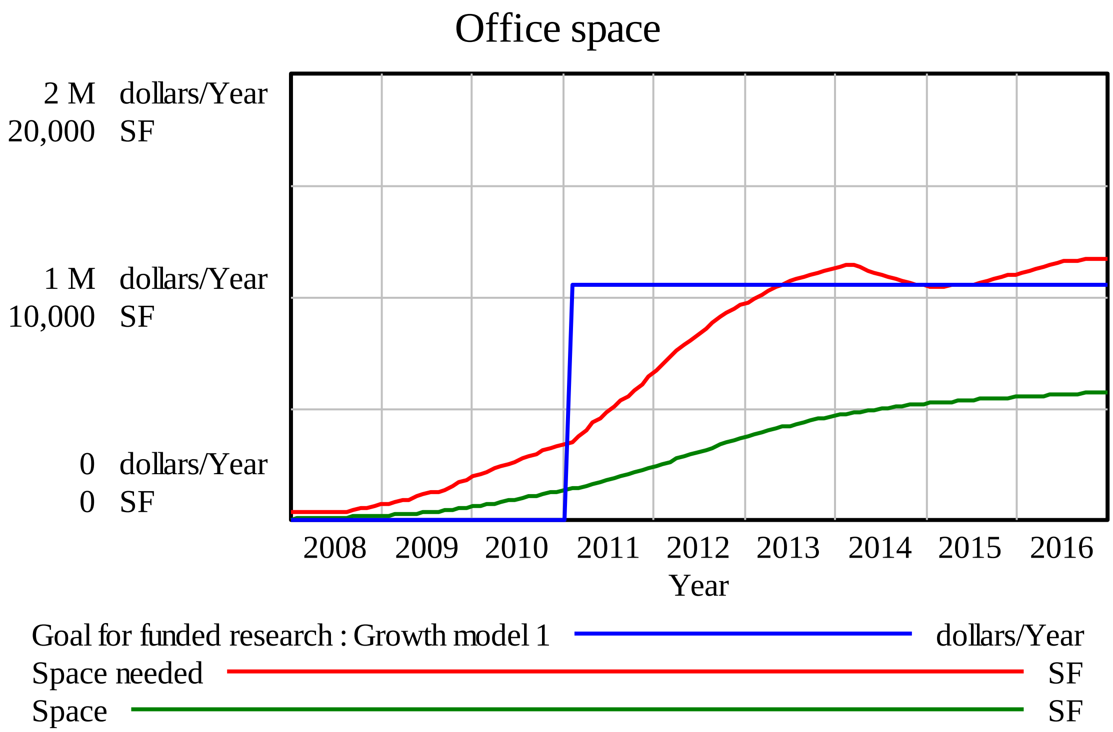


Figure 8 shows the growth in human resources including FTE research staff (red) and investigators (green) under the current growth scenario (blue line). Figure 9 shows the corresponding need and office space for investigators and research staff. The assumption is that there is a fixed amount of space 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 9 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 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 illustrate 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 is 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 in situations where there is not enough time to hire and process new employees to complete the research. In either case, the prevailing thinking among non-researchers is often 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. That is, the dominant logic in some research centers is often "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 is a much more explicit discussion about goals for organizational performance and productivity related to the HSR&D center. 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? And, what are the metrics used to measure the performance of a HSR&D center?

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. Many of these elements can be customized to fit the specific needs of nonprofit R&D centers and labs. Future work should focus on a more comprehensive approach to understanding dynamics at different levels of abstraction that enhance or undermine research and development productivity and integrity.

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