



# Creating an Optimal Environment for the Development of Cyberinfrastructure

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## Introduction

Open source software (OSS) development has flourished, successfully integrating into information systems and providing new ways to develop software (Sharma, Sugumaran, & Rajagopalan, 2002; Moody, 2001; DiBona et al., 1999). A prime example of OSS is cyberinfrastructure (CI). Although past studies have conducted research on what motivates users to participate in OSS and CI and the advantages of these continued developments, research has yet to be done on exploring what factors create an optimal environment for the development of CI (Moqri et al., 2018; Krogh, 2012). This study explored the elements that can shape an optimal environment for CI development, specifically in Universities.

## Literature Review

### I. Optimal Workplace Environment

#### A. Promotion of Collaboration

Collaboration can have many beneficial results, including increased productivity (Rodenbush, 2011), knowledge sharing (Oskarsdottir & Oddsson, 2017), and the development of meaningful relationships (Oskarsdottir & Oddsson, 2017). Researchers also note that it is important for an organization to allow employees time to work in isolation (van Sprang, 2012).

#### B. Meeting Employee Needs

Employees need organizations to meet their needs. By adopting an employee-centric attitude, organizations can optimize their performance and productivity as a whole. In a qualitative study, the author found that as a result of the provision of learning opportunities, employees experienced personal growth and improvement, leading to improvement in employee performance (Rodenbush, 2011). Essentially, by understanding and meeting employee needs, through training and allotment for flexibility, autonomy, and isolation, employees exceed the expectations of their organization.

#### C. Conducive Leadership

The type of leadership that exists in a work environment can either enhance or reduce employee performance. For example, in a series of focus group interviews, it was revealed that managerial support, a form of social support, is important to improving an employee's perceptions of 'optimality' in the workplace (Rodenbush, 2011). However, there is currently no consensus on what the most conducive type of leadership is for an optimal workplace environment.

#### D. Clear Organizational Values

Having clear organizational values can have many beneficial outcomes, including productive organizational culture (Andrade, 2013; Oskarsdottir & Oddsson, 2017) and increased innovation (Blakey, 2015) to name a couple. An organization should first have clear organizational values (Andrade, 2013) and then make them clear to its employees (Blakey, 2015) in order to achieve said outcomes.

#### E. Beneficial Physical Environment

In a mixed methods study, the following workspace stimulators were found to be helpful: limited noise or interruptions, placement of managers within close proximity to particular team members, design that encourages trust, and inspiring decor that promotes creativity (Blakey, 2015). In addition, a study that used structured interviews revealed that, for newer generations such as Generation Y, having a desirable, comfortable, and safe physical workspace is a deciding factor for new talent (Earle, 2003). Overall, creating an optimal physical workspace needs to be a priority for knowledge-based organizations, should they desire to increase productivity and talent recruitment.

### II. Optimal Environment Specifically for OSS and Applicable to CI

#### A. Collaboration

CI exists because of collaboration (Scacchi, 2010). Through collaboration, users can further advance each other's research and increase shared knowledge, leading to a more sustainable and higher quality CI. Having other users contribute to others' findings is ideal as it allows for more conversations and efforts into moving one's ideas forward.

#### B. Freedom and Self Innovation

One area of particular importance that influences users' participation in OSS and CI projects is the freedom to freely access, learn, revise, and redistribute new information and knowledge (DiBona, Cooper, & Stone, 2005; DiBona, Ockman, & Stone, 1999; Fogel, 2005). Having this freedom of choice and expression is needed to encourage user participation in OSS; the most frequently reported reasons for why users participate in OSS is to learn and extend knowledge (Elliot & Scacchi, 2005; FLOSS, 2002; Scacchi, 2007). Therefore, encouraging a space where users can freely, access, modify and build upon each other's ideas and promote self innovation is valuable.

#### C. Networking Support and Outreach

Although access to these systems is open to all, there is a general skill and expertise required to contributing to these projects, such as knowledge in handling and transferring data, resolving open issues in the system, and understanding the system architecture (Ovaska, Rossi, & Martin, 2003). Therefore, having training and support services available is instrumental in teaching users how to properly access files and store their data sets. Additionally, through networking and understanding available resources, users are able to find individuals who are interested in the same areas of research and connect (Scacchi, 2010). These connections can lead to collaborations, which are highly encouraged and ideal in developing CI. Even though areas of expertise in CI may vary, this diversity can promote insightful perspectives and solutions to different problems and questions that may arise. Furthermore, this can lead to a community of users, all interested in the same goal of continually improving CI.

## Research Question

**RQ1:** How can Universities create an optimal work environment that enables the development of cyberinfrastructure?

## .Methodology

Participants: ( $N = 124$ ; Male=97, Female=26) → ( $N=20$  participants, Male=15, Female=5).

Professions: Administrators (n=2), Directors (n=4), Researchers (n=4), Technologists (n=6), Professors (n=2), and Computational Scientists (n=2).

Open Source Coding → Themes and Concepts Emerged

## Findings

Throughout our coding process, six common themes were found: Policies, Incentives, and Rewards; Organizational Culture; Funding; Human Resources; Training, Support, and Outreach; and Cyberinfrastructure Development. These themes connected to make a model, with Policies, Incentives, and Rewards and Organizational Culture serving as preconditions for the process of Funding leading to the development of Cyberinfrastructure. Generally, findings suggest that funding, human resources, training, and support are important components to providing an optimal environment that enables the development of cyberinfrastructure. In our paper, we propose a linear order to the factors that influence the development of CI. Beginning with funding, this can affect human resources, and in turn impact the training and support. Consequently, this can interrupt the development of CI. Policy, incentives, and rewards, as well as organizational culture, are often overlooked preconditions to the development of CI. We report on the specifics of these themes in the following subsections.

### Policies, Incentives, & Rewards

- While policies, incentives, and rewards are seemingly nonessentials for cyberinfrastructure diffusion, many interviewees believe that these three components are important preconditions for successful development.
- “We have a policy of an open space. People are more than welcome to come in and sit their user 3D TV[00:20:02]and collaborate on projects, grants, proposals.” (Computational Scientist, VA)
- “We’re coming up with recognition and incentives to encourage people [i.e., scientists] who [data share]. There’s always been a small group of early adopters or just enthusiasts who have done that, even though it hasn’t been necessarily in their professional benefit. But they recognize the value of doing that, the contribution to the [scientific] community. And, increasingly, we’re seeing desire to expand that and build that. So you need a rewards/recognition incentive system to help [scientists] do that.” (Geologist, AZ)

### Organizational Culture

- Allowing an administrator to have some freedom to play, promoting networking with others, and encouraging mentor-mentee relationships allow for an optimal environment.
- “I’m taking a statistics course right now, and that helps me keep current with new trends in the field and what areas, sort of like gaps in skills and competencies that I’d like to amend. Freedom to attend workshops and conferences, access to the institutional literature. So these are all important things.” (Technologist, AZ)
- “Without that collaboration and being networked with all of these different organizations and individuals, I don’t think that I’d be quite as successful in what I do.” (Liaison, NC)
- “[My mentor and I] have weekly meetings. We discuss about what’s going on, what are the problems that I am facing, be it people’s problem, be it resources problem. We discuss that with him and he tries to solve it as much as he can.” (Consultant, IA)

### Funding

- The foundational need for cyberinfrastructure diffusion is funding and, consequently, resources. Without funding, human resources are unable to support training, support, outreach, and ultimately, cyberinfrastructure diffusion.
- “It all boils down to funding at some point. You know, as a regional university, we don’t have a lot of money to actually, you know, hey, I want to spend half a million dollars, you know, on a high-performance computing cluster and a really fat internet pipe to the rest of the universities in Oklahoma, so on and so forth.” (Mathematician, OK)

### Human Resources

- Diversity in expertise and having enough manpower is essential to the continued development of CI. We need experts, but experts who can bring different skills and talents to the table.
- “Having access to experts is helpful. [It allows] for when one expert gets stuck, you can find somebody else who might know it. It’s a big and important thing for when experts get stuck, [to have] a community they can fall back on.” (Research Assistant Professor, NE)
- “An optimal work environment would [include] having individuals who have different competencies across the stack, from the back end to the front end.” (Computer Scientist, AZ)
- “I just don’t feel like we have enough manpower to actually do what we need to do... hiring [more] people would alleviate some of the load that we have.” (Consultant, UT)

### Training, Support, & Outreach

- Education is needed for both consumers and users. We need education to spread the knowledge of CI. Through this extended knowledge, more people can become aware of CI, seek to learn more about it, and especially for users, it helps to know what resources are available to them to understand the capacity of what they can do in CI.
- “[Creating] a series of trainings that progress would be really useful because it’s the idea of creating a situation to help them become self-sufficient. You don’t want new students to grab onto things, not fully understand it, and use them incorrectly. That can be very problematic.” (Interim Director of Research Computing, TX)
- “Education and public awareness is essential to cyberinfrastructure...there’s education for people who’ve been doing it and there’s education for people who are just consumers of it...Education is just as important as computers in cyberinfrastructure.” (Computational Biologist, NY)
- “[Having] a central group that’s going to provide services for all, [helps] tremendously. This is critical in driving people to be able to effectively leverage the resources in order to do their research and move their science forward.” (Infrastructure Architect, St. Louis)

### Cyberinfrastructure Development

- The diffusion of cyberinfrastructure is the outcome of interest in our model. With adequate funding, human resources, training, support, and outreach in place, cyberinfrastructure diffusion is made possible. Additionally, suitable preconditions, including policies, incentives, rewards, and organizational culture, enable cyberinfrastructure diffusion to reach its full potential.

## Conclusion

The findings are significant because they suggest that optimal workplace environments for CI share similarities and differences in comparison to optimal workplace environments in general. A practical implication is that organizations can use the model of our findings by assessing which components they are insufficient in. A major theoretical implication is that we contribute to the development stage of the Innovation-Decision Process, suggesting that the current development stage is too adopter-centric and not innovator-centric enough.

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