Toward Sustainable Collaborative Software Development: A Case in Higher Education

Full papers

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Abstract

Unmet needs in the area of enterprise applications have led to a new type of system development. Community source is collaborative open source development among multiple institutional partners, typically to achieve mutually desired outcomes. By examining a real world community source project – Kuali, this study addresses the challenges community source faces for sustaining in a large and complicate community. We apply modularity theory to understand how such challenges can be addressed to enhance the sustainability of a collaborative software development community. The matrix is developed to demonstrate both of existing modularity and lacking of modularity in the Kuali community. A proposed matrix is suggested to enhance modularity and establish an organic roof for sustainable collaborative software development.

Keywords

Community source, open source, collaborative software development, modularity, sustainability

Introduction

Due to an increasingly intense and rapidly changing business environment, organizations often struggle to find application software in the commercial marketplace that can be customized for their specific needs or processes. At the same time, the cost of in-house development is often prohibitively high and many organizations find it impractical to acquire the necessary competence for building software themselves (Mithas and Krishnan 2008). Facing this conundrum, organizations seek a more effective way of achieving the software functionality that they desire.

A new approach to enterprise application software development is community-based open source, or simply “community source” (Wheeler 2004). These communities are formed based on principles of shared investment and collaborative action to achieve mutually desired goals. Collaborative communities require members to limit their autonomy in the interest of directed action toward shared objectives (Wheeler and Hilton 2012).

Since collaboration requires continual alignment and investment around shared strategic goals, collaborative communities experience a number of inherent challenges to coordination and sustainability that are not as prominent in other organizational settings. A change in goals or vision among the members of a collaborative community might shift behaviors and commitment to the point of community dissolution. There is a clear need for a theoretically rigorous and practically relevant framework for understanding organizational mechanisms in community source projects. In this study, we analyze a real
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world community source project called Kuali to better understand the mechanisms of community collaboration and the processes involved in developing and sustaining the community as it grows. We apply modularity theory in the context of community source development and examine how communities achieve sustainability through the modular design of social and economic structures. Furthermore, we examine how modularity can be applied among collaborating parties in community-level and project-level activities.

The research questions that guide our study are as follows:

- What are the challenges to sustaining community source development in a changing environment?
- How can such challenges be addressed to enhance the sustainability of a collaborative software development community?

This research offers several contributions. First, we integrate research on both modular organizational design and software development in an effort to understand community source development in a growing environment. Second, we develop an analytical matrix to map the functional units of a collaborative development community to the functional categories of work executed in their development efforts. Third, building upon our analytical findings, we propose an organizational structure which provides the organic roof for sustainability of a collaborative community.

In the next sections of the paper, we first introduce the Kuali initiative and review the literature on modular design, with particular emphasis on a general modular systems theory, followed by a discussion of the research methodology employed. The fifth section of the paper presents the findings from our analysis, including the challenges faced in the management of the focal community source project and the development of a matrix to describe the current organizational structures of community source. We then turn to a discussion of the insights that flow from our analysis, centered on the development of revised matrix which highlights ways to enhance the modular design in community source. The paper concludes with the brief articulation of implications.

The Kuali Case

Kuali is a comprehensive suite of administrative software that meets the needs of high education sector. The original motivation for the Kuali project was that existing financial systems used in the universities were outdated and too difficult to maintain. Commercial products are often too expensive and hard to customize; some schools and colleges realized that they need to operate expensive "shadow systems" to provide needed features absent from currently available ERP packages. On the other hand, building a financial system in house is equally daunting and can only be considered by the largest universities. The Kuali project provides an attractive alternative to the "buy or build" dilemma (Liu et al. 2010). It pools institutional resources to develop an open source financial system, thus dramatically reducing the cost of managing fiscal data and processes in higher education. The Kuali project started with migrating Indiana University's financial information system to a web-based platform in 2004. Indiana University and the University of Hawaii led the effort to build educational software under Kuali. Its partner institutions are colleges, universities, and interested organizations that share a common vision of open, modular, and distributed systems for their software requirements. There are currently more than seventy partners in the Kuali project. One of the very important components of the Kuali effort is the Kuali Commercial Affiliates program. Commercial Affiliates provide for fee guidance, support, implementation, and integration services related to the Kuali software.

Kuali has been growing rapidly during the past eight years. Increased interest in Kuali can be measured in part by the change in the number of Kuali partner institutions. When the Kuali project was first initiated, there were five partners and only one affiliate. By now, there were more than seventy partners and 12 affiliates.

The initial mission of the Kuali project was to develop a baseline system for financial services. This mission has later been expanded to include eight systems (Figure 1). The most mature project is Kuali Financial Systems (KFS). Research Administration and Middleware Workflow are also mature and installed fairly widely across the country (www.kuali.org).
Modularity Theory

Modularity in Design

Complexity is an inherent characteristic of systems in which multiple parts interact in dynamic ways to achieve certain ends. Specifically, complexity emerges from both the diversity of components that make up a system and the interactions and interdependencies between those parts (Langlois 2002). One commonly-employed strategy for addressing complexity in designed systems is an emphasis on modularization (Ethiraj and Levinthal 2004; Pil and Cohen 2006). While the concept of modularity has a long history, recent research reflects a renewed interest in the value of modularity for the design of diverse social and technical systems (Baldwin and Clark 2000; Ethiraj and Levinthal 2004; Pil and Cohen 2006). Precise definitions of modularity vary widely (Seok 2006), yet a general description is that modularity in the context of system design reflects an emphasis on decomposing a system into multiple, discrete sets of components, with clear and limited mechanisms for communication or interaction between different sets.

This general description includes several critical features. First, to achieve modular design, we must be capable of taking a whole system and breaking it into discrete subsets. This process of segmenting a system into distinct sets of relatively-independent components is the fundamental concept of decomposition (Simon 1962).

Second, the relative independence of the resulting subsets must be enforced. One of the defining characteristics of modular designs is that the degree of interaction between components within a module (i.e., a subset of components) greatly exceeds the interactions between separate modules (Seok 2006), reflecting the principle of self-containment (Gunnar and Maratsos 1992).

Third, while interactions between modules are less intense than those within modules, a mechanism for communication and relationships between modules must exist. In modular design, this is achieved through the creation of interfaces (Baldwin and Clark 2000). Other information or visibility of action occurring within a module should be hidden from other modules within the system. This principle of information hiding (Parnas 1979) reinforces that relative independence of modules in a system.

Finally, as a by-product of both self-containment and information hiding, modular systems are generally characterized by loose coupling. The concept of loose coupling reflects conditions in which the elements of
a system interact or respond to one another in meaningful ways, but they also maintain a degree of independence (Sanchez and Mahoney 1996; Weick 1976). Loose coupling enables continuous change in designs (Sanchez and Mahoney 1996).

Organizational Modularity

In a series of studies, Schilling (Schilling and Steensma 2001; Schilling 2000) has developed a general modular systems theory which addresses the conditions under which modularity tends to emerge or increase in the design of organizational forms. This theory states that pressures toward or away from modularity are a reflection of multiple factors, including the heterogeneity of both inputs and demands, the benefits of asset or skill specificity, the presence of market standards, the pace of technological change, and the competitive intensity within a marketplace (Schilling 2000). To illustrate the application of the theory, Schilling and Steensma (2001) highlight multiple examples of more modular organizational forms that have emerged in recent years, including contract manufacturing, alternative work arrangements (e.g., contract-based or temporary employment), and interorganizational strategic alliances. Figure 2 provides an overview of the general modular systems theory.

Figure 2. General Modular Systems Theory

Within this model, the heterogeneity of inputs and demands are primary drivers for increased modularity. In environments marked by heterogeneous inputs, organizations will tend to move toward more modular forms, because this heterogeneity increases the value of the reconfiguration and adaptation that modularity affords. Similarly, heterogeneity of demands in the marketplace, will promote a movement toward modularity because diverse demands can be better addressed with the potential for dynamic reconfiguration. The tendency toward or away from more modular organizational forms is a reflection of the perceived balance between forces favoring loose coupling (i.e., modularity) and the gains to be achieved through tight coupling (i.e., synergistic specificity) of components.

The model also posits a number of additional forces which moderate the influence of heterogeneity of inputs and outputs on the emergence of modularity. Schilling and Steensma (2001) refer to these collectively as catalysts. The availability of market standards enhances a trend toward modularity in that such standards reduce specificity and the potential gains associated with it. A rapid pace of technological change within an industry will similarly enhance the tendency toward modular organizational forms. Finally, industries marked by high levels of competitive intensity will tend to foster modular forms.
Research Methodology

In this research, we adopt a longitudinal case study methodology (Lee 1989; Yin 2009). Our case inquiries were conducted in accordance with prevailing case study field procedures, including the development of a case study protocol prior to data collection, triangulation using multiple sources of evidence, and the maintenance of a chain of evidence (Paré 2004; Yin 2009). The data collection effort included semi-structured interviews with Kuali participants, direct observation of project events, milestone review presentations and minutes of meetings, and formal project documentation. Interview transcripts, observational field notes, and documentary evidence were coded using NVivo, a qualitative data analysis tool. The data collection and analysis were conducted in line with grounded theory methodology, including adherence to the principles of constant comparison and open, axial, and selective coding (Glaser and Strauss 1967; Strauss and Corbin 1998).

Our examination of the Kuali initiative began in 2006. We conducted formal interviews in three different periods of time. During all three interview periods, respondents were encouraged to discuss their Kuali participation in an open-ended fashion. We asked respondents to share their specific experiences in the project, reflecting upon their activities, problems encountered, lessons learned, how they or others interacted, steps taken to resolve problems, and general perceptions of the benefits and challenges of the community source development experience. We further asked for respondents' perceptions of project success and project control. Most of the questions were open-ended and non-directive. In each of the interview sessions, the researchers allowed for flexibility to focus on particular questions, factual information and evaluative comments, and to skip others, based on a respondent’s personal experience and expertise. Appendix 1 shows respondent types and counts of interviews conducted.

Our data analysis consisted of multiple phases of coding that were recursively executed. The first round of coding involved thematic analysis of the data using the open coding approach of the grounded theory method (Corbin and Strauss 1990; Glaser and Strauss 1967). In this initial process, we employed constant comparison to identify persistent patterns in the experiences and perceptions of the respondents. The second phase of analysis involved axial coding (Corbin and Strauss 1990; Glaser and Strauss 1967) in an effort to discern core themes around the topics of Kuali participant interactions, challenges encountered, project control mechanisms, and changes in the Kuali experience. The final phase of coding involved selective coding (Corbin and Strauss 1990; Glaser and Strauss 1967) and comparisons with other development environments.

Open and axial coding was conducted following each of the first two data collection periods. The coding structure developed following the first round of data collection was used as a foundational framework for analyzing the second data set. In line with the principle of constant comparison, we modified the coding structure in light of the new responses. Data analysis following the third round of data collection involved only axial (i.e., building upon the earlier analyses) and selective coding. Open and axial coding of interview transcripts and field notes were collaboratively executed by two of the three researchers. Subsequent selective coding was conducted by two of the three researchers, with the resulting code structure and coded segments reviewed amongst all members of the research team.

Findings

Growth-Oriented Challenges in Community Source

The dramatic growth experienced by the Kuali community reflects both areas of opportunity and significant challenges. While the community has courted the participation of new institutions in an effort to share resources, reduce costs, and minimize risks, such growth engenders the need to redesign coordination processes as the complexity of collaboration within and across projects increases. In Table 1, we summarize the prominent growth-oriented challenges highlighted by Kuali respondents.

<table>
<thead>
<tr>
<th>Challenges</th>
<th>Description</th>
<th>Illustrative Statements</th>
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<tbody>
<tr>
<td>Community Governance</td>
<td>The role of the Kuali Foundation in directing the activities of the community</td>
<td>“The foundation has to remain strong or even get stronger. I think they have to recognize and promote to other institutions the better”</td>
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</table>
is a recurring debate as the community grows and projects proliferate.

installations, the better successes, the more cost effective and sustainable results that we are seeing.” – Commercial Affiliate Executive

<table>
<thead>
<tr>
<th>Commercial Affiliate Roles</th>
<th>For-profit commercial affiliates create an ecosystem of services for delivering Kuali software systems. However, the growth of CAs (and competition between them) raises concern for some members.</th>
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<tbody>
<tr>
<td>“We need more commercial affiliates … because the demand is increasing, and we don’t have enough depth and breadth in our current commercial affiliates.” – Kuali Project Lead</td>
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<td>“One of the things that the foundation has done that I think is an error is that they’ve encouraged a lot of commercial affiliates to join. Unfortunately, some [CAs] have very little experience. Some of the implementations weren’t that good. That doesn’t help the movement.” – Commercial Affiliate Executive</td>
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<tr>
<th>Maintaining the Family Atmosphere</th>
<th>The sense of a family atmosphere has been a persistent strength of the Kuali community. Several respondents express concern that growth has hindered this family atmosphere.</th>
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<tbody>
<tr>
<td>“In the early stage in the Kuali, I felt like we were very close, like a family. When I attended Kuali Days, I knew 90 percent of the people there. Now, when I walk around, I don’t know most of the people. It’s a good thing for the community to get bigger. However, sometimes I regret that we lose the family sense in the community.” – KFS Development Leader</td>
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<tr>
<th>Cross-Project Knowledge Sharing</th>
<th>As projects proliferate, the ability to share insights or lessons-learned across projects has not always been effective.</th>
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<tr>
<td>“Both KFS and the Kuali Coeus [research administration] were based on existing systems … that had best practices and functionality built in … Kuali Student went the route of saying, ‘We want to start from scratch.’ They could have had systems and best practices, but they said no, they wanted to start from scratch.” – Kuali Top Management</td>
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<tr>
<th>Project Coordination</th>
<th>The increasing number of development partners puts pressure on the Kuali organization for project management across partner institutions.</th>
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<tr>
<td>“The number of development partners is starting to get too large. The number of developers is too large to manage effectively … and high turnover rates for developers delay our progress … Managing a virtual team is not easy. Our developers work in different locations, different times. They have two types of boss: one from the Kuali foundation, another from their own university. I need to approach them very carefully.” – KFS Project Manager</td>
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Table 1. Summary of Growth-Oriented Challenges

Application of the General Modular Systems Theory

In applying the general modular systems theory (Schilling and Steensma 2001) to Kuali case, we see significant impetus for the adoption of modular organizational structures in the community source context. We briefly review the evidence in the Kuali case for each of the core constructs in the Schilling and Steensma (2001) model.

Heterogeneity of Inputs. The heterogeneity of inputs within an environment includes the diversity of technological options available and differentiation in institutional capabilities. In Kuali, both factors suggest high heterogeneity. The diversity of Kuali technological options is high, because of a wide range of legacy systems and vendor platforms, multiple development options, and diverse functionality with platforms. First, the technology environments of member institutions vary widely. The Kuali community reflects a broad gamut of educational institutions – from large public universities to small liberal arts colleges. Similarly, the technological environments with which Kuali systems must integrate are markedly diverse, ranging from large enterprise platforms to homegrown applications.
Secondly, the Kuali technologies themselves heterogeneous. The Kuali community employs an array of technologies, including open source software components, workflow automation, and service-oriented architecture (SOA). At the center of the Kuali system is the Kuali enterprise service bus (KSB), the core SOA concept that coordinates interactions between application modules and various lower-level services. Kuali also has a modularized middleware infrastructure called Rice. Kuali’s service-centric approach makes it possible to “develop once and use anywhere and on any platform.” Kuali started as a financial system and has evolved to an umbrella suite of administrative higher education systems.

Finally, the Kuali community prides itself on the diversity of development approaches that it enables, as the following comment illustrates:

“Kuali is fully scalable, so it is as beneficial to a campus of 8,000 as it is to a campus of 80,000. Further, the modular model of Kuali offers incomparable flexibility by allowing an institution to select the pieces it needs, when it needs them. Over time, the institution’s needs will change and so can the solution.” – VP of Business Services, Development Partner

As this comment highlights, the capabilities of the member institutions vary widely. The institutional partners include large, small, public, and private universities, as well as companies. Not surprisingly, the larger universities tend to have more technological resources and diversely-skilled personnel than smaller institutions. In addition, access to personnel differs across the member institutions based on geographic or regional idiosyncrasies. In light of these observations, it is clear that differentiation in the capabilities of institutions is high in the Kuali community.

**Heterogeneity of Demands.** Significant customer heterogeneity in terms of desired functions and scale is observed in the Kuali community. This heterogeneity of demands is evidenced by the emergence of multiple Kuali platforms with varying functionality and focus. The Kuali Foundation is now home to eight distinct projects in varying stages of maturity. With the exception of the KFS platform around which the community was initially formed, each project was initiated based the perceived information needs of a subset of member institutions. The diversity of needs and motivations is frequently noted by Kuali participants:

“Kuali Mobility [mobile device connectivity] came together with lightning speed. Officially announced June 15th, we put it into production at Indiana University on August 15th. So, the developers just literally lived and breathed this project. Cornell came in as an investor. The University of Michigan and Cambridge University in the UK came on and they ‘slipped pizza under the door.’” – Kuali Top Management

**Catalysts.** In the general modular systems theory, catalysts that moderate the impact of input/demand heterogeneity include the availability of standards, the pace of technological change, and the competitive intensity in the marketplace. In Kuali, these catalysts are again fairly prominent. System capabilities are in a state of constant flux due to the speed of technological change. As a community focused on software development and implementation, Kuali participants consistently recognize this market dynamic. Accordingly, system flexibility plays a critical role in enhancing the robustness of system development.

For Kuali, the degree of competitive intensity can be assessed at multiple levels. In higher education, competitive intensity is generally high, because institutions are trying to attract and matriculate the same students. In Kuali, this level of competition tends to be downplayed as universities collaborate to address shared needs, but a second level of competitive intensity is noteworthy. In the IT platform space, competitive intensity is high because a few large players are vying for enterprise business. This is the space that Kuali has entered by offered institutions an alternative to the commercial software vendors. The juxtaposition of Kuali with these dominant market players is a consistent focus in community discussions:

“When you purchase a ‘canned package,’ you must accept that, to a large degree, the decisions around what will be available in that package will be made by the vendor, not by you the buyer. In contrast, Kuali is built on a framework that is inherently user-centric. The community that builds the product is the same community that will use the product.” – VP of IT, Development Partner
Since Kuali systems are designed for the institutional niche of higher education, the availability of standards for data management and retrieval are quite high. While the need for specific software functionality varies by member institution, the data storage and reporting needs of the member institutions are largely consistent. In addition, standards in the domains of data management and software development (e.g., CMMI, SOA) are inherited from the domains of software engineering/IT management.

**Synergistic Specificity.** The final element of the general modular system theory is the countervailing force of synergistic specificity – i.e., performance advantages (or cost savings) achieved through integration of particular resources or activities. In Kuali, the forces favoring synergistic specificity are low. There is limited scale efficiency gained through creating a single, tightly-coupled configuration of functions, because individual institutions have varying demands.

Considering the Kuali experiences holistically, this analysis suggests that the conditions encountered in community source heavily favor the adoption of modular design.

**Modularity in Kuali**

Given the impetus for modular design highlighted in this analysis, it is important to consider both the evidence of existing modularity in Kuali and areas where modularity is undermined by tight coupling or the absence of cohesion in the roles of functional units. To support this assessment, we develop a matrix to map Kuali functional units to the functional categories of work executed (Table 2). At the community-level, key Kuali functional units include the Kuali Foundation, Application Roadmap Committee, and Technology Roadmap Committee. At the individual project level, the key functional units include the Project Board, Functional Council, Technical Council, Project Management, Subject Matter Experts (SMEs), Testing Team, and Commercial Affiliates. The functional work categories in Kuali include governance, project coordination, system analysis, system design, development, implementation, and maintenance. Each of these categories includes multiple task areas reflecting a more granular level of analysis.
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Table 2. Key Responsibilities by Kuali Functional Units

As the matrix reveals, the existing Kuali structure reflects a certain degree of functional modularity, with several categories of work primarily covered by a small set of functional units. Furthermore, over the life of the Kuali community project, new units have been created to foster greater delineation of roles and responsibilities. The Functional Council, which operates at a project level, was established because of concerns that the determination of design requirements be driven by user representatives rather than by technical personnel. This approach reflects the desire for high cohesion. Cohesion refers to the degree to which activities within a given module belong together, with the corollary that a given module should not bear too many distinct responsibilities within a system (Yao et al. 2005). Similar efforts at enhanced cohesion are seen in the Application and Technology Roadmap Committees, which were created to guide functionality determination and technical resources at the community level.

Despite the enhancement of modularization in Kuali, the matrix suggests areas where greater modularity might be helpful. Indeed, we observe several tasks which are addressed by multiple functional units. For example, Marketing, Project Integration, Project Planning, Project Evaluation, and Quality Assurance are each executed to some degree by at least three separate units, in some cases across community- and project-level boundaries. The need for significant interconnections to ensure that these activities are executed in a coordinated fashion suggests unnecessarily tight coupling and a lack of cohesion. Similarly, cohesion is undermined by the extension of a given unit’s duties across functional categories. In particular, the matrix reveals that the Functional Council(s) and Commercial Affiliates have responsibilities in several distinct areas.

Thus, despite the fostering of modular design in several facets of the Kuali community, opportunities for increased modularity remain. We contend that these opportunities could significantly enhance the
effectiveness of the community’s efforts. Drawing upon our findings, we turn to this question of community enhancement in our discussion.

**Discussion**

Revisiting the growth-oriented challenges encountered by the Kuali community (see Table 1), we perceive that several of these challenges derive from the existence of tight coupling and lack of cohesion within the community. The need for greater clarity around community governance and the role of commercial affiliates exemplifies issues that can arise when unit cohesion is compromised. The challenges encountered with cross-project knowledge sharing underscore the limitations of knowledge transfer within the broader community. In the language of modularity, this implies an inadequacy of interfaces between distinct units (i.e., modules) that operate at the project level. The need for improved project coordination to integrate diverse development teams similarly signals a lack of effective interfaces between distinct developer groups. Finally, the difficulty of maintaining a family atmosphere suggests that community growth has increased the relational complexity across the community and undermined the close interactions previously experienced within a given functional unit. Based on our analysis, many of these challenges could be addressed through a renewed focus on the modular organizational design of the community. In Table 3, we present a revised matrix of Kuali’s functional distribution incorporating a number of recommendations for enhancing community modularity.

First, in light of the challenges with role ambiguity, we argue for greater role segmentation. For example, rather than distributing Kuali marketing functions across multiple functional units, the Kuali Foundation could take ownership of this critical role. Similarly, we propose the clarification of ownership for other tasks by limiting them to one – or in some cases, two related – functional units. These revised ownership proposals apply to Project Evaluation (Functional Council), Quality Assurance (Testing Team), Project Planning (Functional Council/Project Management), and Software Development (Development Teams/Commercial Affiliates). By clarifying roles and ownership, the revised structure enhances cohesion and reduces tight coupling within the community.

Second, we propose the elimination of the Project Board unit. Currently, the Project Board requires representation from each development partner. As a result, the size and complexity of the Project Board has grown dramatically. At the same time, the functional tasks addressed by the Project Board are also covered by one or more other functional units. Therefore, the elimination of this organizational structure could be achieved without compromising essential tasks. This action would also eliminate a prominent form of tight coupling and reduce overall complexity.

<table>
<thead>
<tr>
<th>Functional Categories and Components</th>
<th>Kuali Functional Units</th>
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</thead>
<tbody>
<tr>
<td><strong>Governance</strong> [Community-level activities]</td>
<td></td>
</tr>
<tr>
<td>Community Coordination</td>
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</tr>
<tr>
<td>Policy Setting</td>
<td>✓</td>
</tr>
<tr>
<td>Licensing</td>
<td>✓</td>
</tr>
<tr>
<td>Marketing</td>
<td>✓</td>
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</table>
Finally, we propose the creation of one new functional unit within Kuali, the Kuali Knowledge Base. This group would be tasked with managing only the Community Coordination function, i.e., providing guidance, documenting lessons-learned, and coordinating community-wide activities. To borrow the language of object-oriented software design (a quintessentially modular discipline), the Knowledge Base would function as an interface class by coordinating the communications between the other functional units. Once again, the creation of this unit would clarify interactions between groups and reduce the prevalence of tight coupling.

Our suggestions for enhancing the modular design of the Kuali community help to address several challenges that the community confronts. Concerns over role ambiguity for various units could be dramatically reduced by reducing overlap and increasing cohesion in responsibilities. The introduction of the Kuali Knowledge Base addresses concerns about new project development and coordination between institution-based teams by creating a consistent interface mechanism. Finally, the maintenance of a family feeling is reinforced by greater cohesion within functional units, which again function as organizational modules. As noted earlier, one of the defining characteristics of modular systems is that
interactions within modules significantly exceed connections between modules. Thus, clarifying identifies and responsibilities within modular units fosters closer interpersonal interactions. At the same time, the Knowledge Base could ensure that all members of the community stay abreast of community-wide developments.

**Conclusions**

To the best of our knowledge, our work presented in this paper is the first academic research applying modular organizational design to the community source domain. By rethinking community source development using modular principles, this study offers an in depth understanding of the mechanisms for sustaining collaborative system development. The findings from this study can help community source efforts to identify and address several challenges in existing organizational structures. The proposed Kuali structure matrix provides guidelines for enhancing modularity and enabling more stable community growth under an “organic” roof. Community source as an emergent model of collaborative system development is still in an early stage. The main limitation of this study relates to the question of generalizability of findings. Our data collection was constrained to the higher education sector and companies affiliated with that sector. Accordingly, it is unclear whether our findings could be generalized to all types of companies. In the future research, we plan to study this collaborative software development phenomenon outside higher education. We sincerely hope that this study can attract more researchers’ interest in studying sustainable community source development.

**REFERENCES**


APPENDIX 1

Respondent Types and Counts of Interviews Conducted

<table>
<thead>
<tr>
<th>Description</th>
<th>1st Round Interviews (October 2006)</th>
<th>2nd Round Interviews (November 2008)</th>
<th>3rd Round Interviews (November 2012 - May 2013)</th>
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<tr>
<td>Kuali Foundation</td>
<td>4</td>
<td>6</td>
<td>8</td>
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<tr>
<td>Founding Partners</td>
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<td>2</td>
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<tr>
<td>Development Partners</td>
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<tr>
<td>Deployment Partners</td>
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<tr>
<td>Commercial Affiliates</td>
<td>1</td>
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<tr>
<td>Total</td>
<td>10</td>
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