ANALYSIS OF FACTORS CONTRIBUTING TO SOFTWARE DEVELOPMENT IN SRI LANKAN UNIVERSITIES

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Abstract

In this paper we present a set of factors contributing to develop software systems within universities. We discuss; how to initiate a university project that has a commercial value, how to develop a complete software solution and the requirements to implement the system. To find the answers, case study research methodology was used. According to the results, problem identification, team, interested community, development skills and resources and sustainability. Specific success and failure factors in each of those aspects are discussed according to the Sri Lankan context. Our findings will be especially useful for academics who would like to contribute useful software systems to the nation as outcomes of their research intelligence. These factors can also be used to propose sustainable systems development methodologies for entrepreneurial universities.

Keywords: Systems development, Case study research, Entrepreneurial universities.
1 INTRODUCTION

Thesis, journal and conference publications are the conventional outcomes of university projects. Most of the computer science projects start with a research problem that can be solved with a software invention. The objectives of universities have become more entrepreneurial (Etzkowitz 2003) and therefore, they are focusing on economically and socially valuable production of knowledge. In the field of applied computer science many research outcomes can be implemented as systems, so that they could be used to satisfy actual needs.

It is identified that the systems development methodologies used in a considerable number of established software inventions started through universities were unstructured at the beginning (Dias et al. 2013). In most of those projects, there is a “tipping point” of transformation, from unstructured to structured methodologies (Dias et al. 2013). After reaching the tipping point, the system sustainability is almost certain. A company could be formed and methodologies can be standardized. There can be formal organization structures and specific job roles. Till that point formal practices are rarely used.

In this study our objective is to figure out, what are the success factors during the path to reach the tipping point. The ultimate goal of this research is to help increasing the amount of useful software systems come out through university research in Sri Lanka.

1.1 Research Problem

Annually, more than eighty final year undergraduate and postgraduate computer science research projects happen in the university where this study takes place. All those projects start with a valid research problem. In order to graduate, it is needed to submit the thesis explaining a suitable solution. Although the pass rate is more than seventy out of eighty (87%), only a very less amount (less than 5%) of them continue to develop a working system that could satisfy actual consumer needs. Researchers focus on solving the problem theoretically and evaluating it using various methods such as prototypes. In Sri Lankan although most of the projects terminate at that point, research commercialization is an established subject in countries such as Australia, United States, Iran, Japan, etc. (Carayannis et al. 1998; Colyvas et al. 2002; Etzkowitz 2003; Tanha at el. 2011; Farsi, Modarresi and Zarea 2011). Even in Sri Lanka there are a few successfully implemented systems as well as systems that have tried to implement but could not succeed due to various reasons. Thus, "sustainability of software systems come out through university research in Sri Lanka" is our main problem of investigation.

For the ease of studying, we have divided this problem into three different sub questions;

1. How to initiate a software engineering research that can be implemented successfully?
2. How to develop a system within a university?
3. What are the necessities for implementation?

In this research we came up with a set of measurable metrics to divide successes and failures. Systems that are implemented and using by its end users are considered as successes. Whereas, projects that were terminated, before implementation and use by the actual end users are considered as failures.

2 LITERATURE

Research is considered as original work in answering a question or solving a problem (Guyette 1983). The main goal of university research is to build and publish new knowledge to the community (Mathiassen 2002). According to Skinner (1917) all research should be scientific. Most of the time university research open new paths to progress in the industry (Skinner 1917). Government research focus more towards charitable goals (Skinner 1917), thus if the university projects are funded by the government, the outcomes will serve to the growth of the entire society.
As said by Guyette (1983), if the research is about a community need it becomes more exciting. According to Guyette (1983), when initiating a research project, things that have to be considered are a research topic, an issue or a concern, purpose of the project and the resources such as time, people and funds. Discussing with a community group, experts of the area, other researches and victims of the actual problem help to clarify requirements and resources needed (Guyette 1983). According to Hargadon (2003), innovations happen when seeking new or better solutions for problems. Innovations can be brilliant new ideas and also application of already exist ideas of other disciplines to solve problems in a totally different discipline (Hargadon 2003). According to Hargadon (2003), skilled people, ideas and objects are the three essential elements of every technology.

They have also mentioned that organizational structure is significant for a company who practices technology brokering (Hargadon 2003). In university context, project team is the more suitable terminology for organization structure. According to Cohen and Bailey (1997), a team can be defined as a "a collection of individuals who are interdependent in their tasks, who share responsibility for outcomes." They have also noted that cross-functional teams, i.e. members from different disciplines and functional units lead to enhance project success. In universities research professors' responsibility is to develop a research culture in their areas of expertise (Kroeze et al. 2010).

However, evolution of universities has transformed from a teaching focused entity to a teaching, research and economic development enterprise. They are now focusing on generating new firms through Research and Development (R&D) in order to make employment and productivity growth (Etzkowitz 2003). Research groups have started to operate as firm like entities, where professors are considered as team leaders and research students assist them. Such academic institutions translate research results into intellectual property and economic activity (Etzkowitz 2003).

Farsi, Modarresi and Zarea (2011) have discussed a list of obstacles and solutions for commercialization of university research under four different subjects; organizational, institutional, environmental and internal. Intellectual property laws, financial capability, skilled personal and communication networks are identified as essential inputs for commercialization (Farsi, Modarresi and Zarea 2011). Five main problems were identified by Tanha at el. (2011) in Iran universities. They are; researches are not aligned with actual needs, lack of solid intellectual property laws, lack of expertise in evaluation of ideas, inadequate market relationships and lack of investments (Tanha at el. 2011). These problems and their solutions are considered when developing a hypothesis for our study.

Spin-offs from research laboratories is an establish way of implementing technological innovations in developed counties such as United States and Japan (Carayannis et al. 1998). Technology originator, entrepreneur(s), parent organization and venture investor are the four major roles in spin-off process (Carayannis et al. 1998). According to their results in most of the cases technology originator will become the entrepreneur at the end. They have also identified that spin-offs are not very visible at the very beginning, or often underestimated (Carayannis et al. 1998).

In addition to spin-offs and research entities, some universities have build networks with industrial partners in the ways of licensing agreements and joint ventures (Farsi, Modarresi and Zarea 2011; Etzkowitz 2003; Siegel et al. 2003). According to Siegel at el. (2003) the roles involved in this process can be university scientists and administrators, government, industry scientists, R&D managers and entrepreneurs. It is said that there is a social value of industry-university partnerships, which results in economic development, new jobs and opportunities for research students (Siegel et al. 2003). According to Siegel at el. (2003) it is very important to have a properly functioning technology transfer office in any entrepreneurial university. Other important fact is all kinds of relationships build with the industry partners and how well the communications happen over cultural gap between academia and the business world (Siegel et al. 2003).

There are many research available about technology transfer offices in universities (Farsi, Modarresi and Zarea 2011; Colyvas et al. 2002; Tanha at el. 2011; Carayannis et al. 1998; Etzkowitz 2003). In entrepreneurial universities these offices play a major role in commercialization process. According to Colyvas et al. (2002) it is important to have a technology transfer office to handle intellectual property...
rights, licensing and marketing activities for research commercialization. For any new product, in order to implement, it is essential to have a set of end users who are looking forward to use the product. According to Slater and Mohr (2006), it is important to identify possible early adopters and hold them to the product.

In the literature section we have discussed; how innovations happen, evolution of entrepreneurial universities, research labs, software licensing through technology transfer offices, university-industry partnerships and start-up organizations. A summary of literature review is given in Table 1.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Factors concerned</th>
<th>References</th>
</tr>
</thead>
</table>
| 1 Project initiation | 1.1 Topic/issue/concern - community need  
1.2 Resources - time, people, funds  
1.3 Associated community group - experts of the area | Guyette 1983 |
| 2 System development | 2.1 Skilled personal  
2.2 Ideas  
2.3 Objects  
2.4. Team structure | Hargadon 2003 |
| 3 Implementation | 3.1 Immediate end user adoption  
3.2 Intellectual property licensing  
3.3 Financial capability  
3.4 Skilled personal - Originator, entrepreneur(s), parent organization and investor  
3.5 Communication networks  
3.6 Technology transfer offices  
3.7 Marketing activities  
3.8 How well the communications happen over cultural gap between academia and the business world  
3.9 Research groups as firm like entities  
3.10 Industry-university partnerships  
3.11 Start-up firms | Slater and Mohr 2006  
Farsi, Modarresi and Zarea 2011  
Farsi, Modarresi and Zarea 2011  
Colyvas et al. 2002; Farsi, Modarresi and Zarea 2011  
Colyvas et al. 2002  
Siegel et al. 2003  
Etzkowitz 2003  
Siegel et al. 2003  
Carayannis et al. 1998 |

Table 1. Factors contributing to systems development in universities based on literature findings

3 METHODOLOGY

Research methodology is designed in a way to answer the three research questions mentioned in the research problem section. This research is conducted with the use of qualitative research methods. As the research questions are mainly focused on "HOW" aspect, the recommended methodology is case study research (Yin 2014).

One international and four local cases were used in this study. International case was used to understand the global nature of software spin-offs come out through university research. Two successful, one ongoing and one failed project were selected as local cases. Success and failure factors are identified from those cases in order to overcome failures and achieve success in ongoing and future projects.

The data required for local cases was collected through interviews, observations and relevant documentation they have formulated for the projects. Project names and some specific information are anonymised to ensure participants confidentiality. We interviewed 5-7 people who played different roles. Research teams usually consist of 8-10 members. The book "The Google Story: For Google’s 10th Birthday" was used to gather data in Google™.

First we went through literature in this area and identified the significant aspects contributing to systems development within universities (Table 1). These aspects are discussed under three different stages namely; project initiation, system development and implementation in order to answer above
three research questions. In the case by case analysis, problem identification, team, interested community, development skills and resources and sustainability are identified as most significant aspects amongst the aspects found in literature. Then, cross case analysis method was used to identify the specific success factors in those significant aspects in Sri Lankan universities. These success and failure factors were not identified by previous researchers in Sri Lankan context.

A summary of selected cases is given in Table 2.

### Table 2. Selected cases

<table>
<thead>
<tr>
<th>Category</th>
<th>Case</th>
<th>Project</th>
<th>Duration</th>
<th>Parent organization</th>
<th>Current status</th>
<th>Target beneficiaries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local</td>
<td>1</td>
<td>Maritime training system</td>
<td>2008-2014</td>
<td>Sri Lankan university</td>
<td>Trying to implement</td>
<td>Maritime trainers and students</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>E-health system</td>
<td>2008-2011</td>
<td>Sri Lankan university</td>
<td>Terminated after pilot implementation</td>
<td>General public</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Language technology project</td>
<td>2004-2014</td>
<td>Sri Lankan university</td>
<td>Implemented and using</td>
<td>General public</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Finger print system</td>
<td>2008-2014</td>
<td>Sri Lankan university</td>
<td>Implemented and using</td>
<td>Police officers</td>
</tr>
</tbody>
</table>

### 3.1 Case 1: Maritime training system

Maritime training system was initiated by a set of academics in a Sri Lankan university based on a requirement came from the management of Sri Lanka Navy. Later, the requirement was less prioritized because of the criticality of war by the Navy. However, few interested researchers continued to develop the system. Research students contributed components to the system over past six years since 2008. There are number of publications and awards for the research and the system. Although, the system could not be implemented at Navy premises, currently they are planning to deploy it at another maritime training institute. A brief summary of the case is given in Table 3.

### Table 3. Case 1 summary

<table>
<thead>
<tr>
<th>Significant aspects</th>
<th>Case description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem identification</td>
<td>High cost of maritime training in real environment. Identified by the Navy management.</td>
</tr>
<tr>
<td>Team</td>
<td>Academic supervisors (3), maritime officers (2), researchers (5).</td>
</tr>
<tr>
<td>Interested community</td>
<td>Maritime officers, general public.</td>
</tr>
<tr>
<td>Development skills and resources</td>
<td>Completed by the researchers and software developers. Funded by university and government organizations.</td>
</tr>
<tr>
<td>Sustainability</td>
<td>Planning for pilot implementation. Ongoing research.</td>
</tr>
</tbody>
</table>

### 3.2 Case 2: E-health system

E-health system is a research project started by a set of academic and health care specialists in Sri Lanka. Not having the specialist care for patients in Sri Lankan rural villages was their initial problem. Research students came up with a state-of-the-art technological solution and developed a complete system. They had selected a rural hospital and a central hospital to do the pilot implementation. Although the implementation was a success, end users have not used the system continuously. A brief summary of the case is given in Table 4.

### Table 4. Case 2 summary

<table>
<thead>
<tr>
<th>Significant aspects</th>
<th>Case description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem identification</td>
<td>Unavailability of specialist care for patients in rural villages. Identified by the specialist doctors.</td>
</tr>
</tbody>
</table>
3.3 Case 3: Language technology project

Language technology research project is a foreign funded project to develop language related technologies in Sri Lanka. Funds were approved for a research proposal written by a qualified set of Sri Lankan academics. Their research team consisted of expert supervisors and advisors of the field, research students from language and computer science disciplines. In addition, they interacted with the blind community from the beginning as they were the most benefited users from systems like text-to-speech converters. The foreign funded projects were finished and deployed on time and they have been used by the end users since then. However, continuous research is happening in this area as they have been receiving government funds. A brief summary of the case is given in Table 5.

<table>
<thead>
<tr>
<th>Significant aspects</th>
<th>Case description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem identification</td>
<td>Lack of language technology resources in Sri Lanka. Identified as a timely need by the international communities and Sri Lankan researchers.</td>
</tr>
<tr>
<td>Team</td>
<td>Language specialists (2), academic supervisors (1), researchers (4).</td>
</tr>
<tr>
<td>Interested community</td>
<td>Sinhala language specialists, blind users, general public.</td>
</tr>
<tr>
<td>Development skills and resources</td>
<td>Completed by the researchers. Funded by foreign and Sri Lankan government organizations.</td>
</tr>
<tr>
<td>Sustainability</td>
<td>Initial projects were implemented successfully. Upgrades and ongoing research are happening with the help of government funding agencies.</td>
</tr>
</tbody>
</table>

Table 5. Case 3 summary

3.4 Case 4: Finger print system

Finger print identification system is started with a requirement came through Sri Lankan police officers, to analyse and identify the fraud related finger prints. The project team consisted of academic researchers, consultants and software developers. They received the support and feedback from people who play different roles in Sri Lanka police. The project was funded by the Sri Lankan government. At present, the system is successfully implemented and used by the end users for their actual need of finger print analysis. Now the university researchers are studying on future improvements in fraud based software systems while doing the maintenance of the current system. A brief summary of the case is given in Table 6.

<table>
<thead>
<tr>
<th>Significant aspects</th>
<th>Case description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem identification</td>
<td>Difficulties in analysing and identifying fraud related finger prints. Problem raised by the police officers.</td>
</tr>
<tr>
<td>Team</td>
<td>Academic supervisors (2), consultants (1), researchers (2), software developers (4).</td>
</tr>
<tr>
<td>Interested community</td>
<td>Police officers in different levels.</td>
</tr>
<tr>
<td>Development skills and resources</td>
<td>Completed by the researchers and software developers. Funded by Sri Lankan government.</td>
</tr>
<tr>
<td>Sustainability</td>
<td>Initial system were implemented successfully. Maintenance and research for future improvements are happening.</td>
</tr>
</tbody>
</table>

Table 6. Case 4 summary
3.5 International case: Google™

Page and Brin, the founders of Google®, were students working on student projects at Stanford University when they invented the first version of Google search engine (Vise and Malseed 2008). They had published their Ph.D. thesis through this research. They had first implemented a prototype of a comprehensive search engine for internal use at their university. Google.stanford.edu became popular around the campus by word of mouth. As the number of users increased very fast they needed more resources. First, they were funded by some projects at Stanford (Vise and Malseed 2008). Later, they were funded by the owner of Sun Microsystems and they have started a start-up organization which has now developed as a world class organization. A brief summary of the case is given in Table 7.

<table>
<thead>
<tr>
<th>Significant aspects</th>
<th>Case description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem identification</td>
<td>Difficulties in searching through entire web.</td>
</tr>
<tr>
<td></td>
<td>Identified by the researchers themselves as their own need.</td>
</tr>
<tr>
<td>Team</td>
<td>Academic supervisors (1), researchers (2).</td>
</tr>
<tr>
<td>Interested community</td>
<td>University staff, general public.</td>
</tr>
<tr>
<td>Development skills and resources</td>
<td>Completed by the researchers. Funded by some projects at Stanford.</td>
</tr>
<tr>
<td>Sustainability</td>
<td>Initial system were implemented successfully inside their own university.</td>
</tr>
<tr>
<td></td>
<td>Start-up organization were created and now have become a growing world class organization.</td>
</tr>
</tbody>
</table>

Table 7. Case 5 summary

4 CROSS CASE ANALYSIS

During the case by case analysis we identified problem identification, team, interested community, development skills and resources and sustainability as the most significant aspects in Sri Lankan university projects. Here we have analysed those aspects across the cases to understand specific success and failure factors.

4.1 Problem identification

In case 3 and 5 the problem was identified by the research themselves and they can also be considered as the end users, since those systems are made for general public. In the other successful project (case 4), problem was raised by the police officers who are facing the problem in their day today work life. In case 1, the requirement came through Navy management, thus actual end user input was very less at the beginning. In case 2, the requirement was totally identified by the specialists in the field. Therefore, we can say that, when the research problem is identified and raised by the end users, there is a more success rate than it is identified by the other parties.

4.2 Team

In almost all the teams, there are academic supervisors and researchers. In case 3 there were language specialists. In case 4 there were consultants and software developers. In case 5 there were none except researchers and their supervisor. In other two projects there were top ranked people in the field such as maritime officers and health care specialists. Thus, input from the experts might have contradicted the real need of the actual end users.

4.3 Interested community

In table 1 we listed the target beneficiaries of 5 cases respectively; C1. maritime trainers and students, C2. general public, C3. general public, C4. police officers and C5. general public. When considering the interested community in each project, in case 3, 4 and 5, we understood that their actual beneficiaries/end users are listed. Although, the maritime officers and general public are listed for case
1 maritime trainers and students are not there. Same way, general public is not listed under case 2, even if there are health care specialists and government. Thus, the end user community build around the project can be identified as a very critical success factor.

### 4.4 Development skills and resources

Almost all the projects were developed by the researchers. There were software developers in some of them. All the projects were funded by government organizations or other university projects. We could not find any specific success or failure factors relevant to development skills or resources for system development as they were available in all cases.

### 4.5 Sustainability

Even after several drawbacks, case 3 and 5 are successfully implemented and are used by the general public. Even the Google™ was initially rejected by so many investors. Case 4 is successfully implemented at the user premises. All three projects are maintaining and improving while doing continuous research. Case 1 will achieve sustainability in the future as they are doing research and trying to implement in different new user sites. Case 2 had given up after the first pilot project. Thus, enormous interest and never give up quality can be identified as a success factor.

### 5 DISCUSSION

According to the case study's findings, answers to the three research questions can be summarized as follows (Table 8). The project team and the interested community are identified as significant aspects in entire project lifecycle. Thus, the projects' people can be identified as the most important consideration. Apart from them, problem identification, development skills and resources and sustainability are recognized as important in project initiation, system development and implementation stages respectively.

<table>
<thead>
<tr>
<th>Stages</th>
<th>Identified significant aspects to be considered in each stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Project initiation</td>
<td>Problem identification, team, interested community</td>
</tr>
<tr>
<td>2 System development</td>
<td>Team, interested community, development skills and resources</td>
</tr>
<tr>
<td>3 Implementation</td>
<td>Team, interested community, sustainability</td>
</tr>
</tbody>
</table>

*Table 8. Significant aspects relevant to three stages of a project*

As identified in the cross case analysis, success and failure factors related to each aspect are summarised in Table 9.

<table>
<thead>
<tr>
<th>Aspects</th>
<th>Success factors (C3,C4,C5)</th>
<th>Failure factors (C1,C2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Problem identification</td>
<td>By the end users/actual beneficiaries</td>
<td>By others</td>
</tr>
<tr>
<td>Team</td>
<td>Mainly consists of researchers and academic supervisors</td>
<td>Input from the experts might have contradicted the real need of the actual end users</td>
</tr>
<tr>
<td>Interested community</td>
<td>End user community</td>
<td>Not having the end user involvement</td>
</tr>
<tr>
<td>Development skills and resources</td>
<td>Availability of development skills and resources</td>
<td>-</td>
</tr>
<tr>
<td>Sustainability</td>
<td>Enormous interest and never give up quality</td>
<td>Giving up at the middle</td>
</tr>
</tbody>
</table>

*Table 9. Success and failure factors*

Our findings will be especially useful for academics who would like to contribute valuable software systems to the nation as outcomes of their research intelligence. There can be many future research paths arise from this research. These factors can be used to propose a suitable software development methodology for entrepreneurial universities. Our findings can be applied to find reasons for attempted projects that were unable to implement. This can also be used to design university curriculum in a way that motivate students to develop and implement their conceptual systems. This may guide them to select the projects as their interests, knowledge and skills.
6 ACKNOWLEDGMENTS

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