FLEXIBLE DOCTORAL PROGRAMS FOR INTERNATIONAL FACULTY: A REFINED MODEL WITH PRELIMINARY RESULTS

Bopaya Bidanda[1], Larry J. Shuman[2], Jay Rajgopal[3], Mary Besterfield-Sacre[4], and Claudio Rubial[5]

Abstract – *Based on anecdotal evidence from universities in Latin America and Southeast Asia that wish to increase their percentage of engineering faculty with earned doctoral degrees, a flexible Ph.D. program was established in 1999 at the University of Pittsburgh. Since then, we have learned that a number of non-US universities wish to provide a career path for faculty that allows them to focus on current issues and provide them with the education necessary to conduct high-level independent research. However, given their workloads and faculty shortages it is extremely difficult for these institutions to grant their faculty a protracted leave of absence of four or more years to complete their education abroad. In this paper we present a model that is sufficiently flexible to accommodate these students' unique circumstances, yet maintain all elements of academic rigor. Key factors enabling such approaches are the growth in Internet based technology as a sophisticated means of rapid and interactive communication. This paper details a number of academic issues, preliminary results and challenges from student, programmatic, and faculty perspectives along with strategies for the delivery of these programs. These programs also help to jumpstart regional economic development by providing these educators the training opportunities in entrepreneurship and economic development, which they can take back to their home region. A typical doctoral program is dissected into its components and a program developed at the University of Pittsburgh is specified.*

Index Term – Entrepreneurship, Flexible Ph.D., Industrial Engineering, Public Policy

THE NEED

As the economies of newly developed regions have expanded, there is a corresponding need for well-educated engineers and trained entrepreneurs who are familiar with the latest technological advances and current economic development models. The technology and educational infrastructure of these regions must be upgraded in parallel with the economic infrastructure. An infusion of technology coupled with the development of infrastructure can help jumpstart any regional economy. However, these are typically capital intensive steps and, in many areas of the world, often cost prohibitive. We propose an alternative model - one that would help jumpstart a region's economy by judiciously investing in human capital though well educated doctoral level engineers (both industry and academic) who are familiar with innovative aspects of industrial engineering (IE) relevant to the region's economy.

Our underlying hypothesis (and overall goal) is that the process of regional infrastructure and technology development can be accelerated by educating a cadre of faculty who will then provide academic leadership within their home institutions and corporations for the next generation of entrepreneurs and engineers. We believe attracting a core group of outstanding engineering faculty into an innovative Industrial Engineering educational program can do this. The academic experience will expand beyond the traditional programmatic boundaries so that returning students will be well positioned to make an impact and provide a multiplier effect in their home regions. These students would be exposed to economic development models to understand the dynamics of regional economic effort and suggest models for them to employ in their own environments. In addition to industrial engineering and economic development, the educational programs can be customized to include modules in public policy, product innovation and entrepreneurship.

WHY INDUSTRIAL ENGINEERING?

The following are motivating factors for initiating such a program within an Industrial Engineering program:

- IE programs enable students to develop not only the technical and analytical skills needed for engineering entrepreneurship, but also to focus on "professional

[1] Bopaya Bidanda, University of Pittsburgh, Department of Industrial Engineering, 1048 Benedum Hall, Pittsburgh, PA 15261 bidanda@engrng.pitt.edu
[2] Larry Shuman, University of Pittsburgh, School of Engineering, 323 Benedum Hall, Pittsburgh, PA 15261, shuman@engrng.pitt.edu
[3] Jay Rajgopal, University of Pittsburgh, Department of Industrial Engineering, 1048 Benedum Hall, Pittsburgh, PA 15261 rajgopal@engrng.pitt.edu
[4] Mary Besterfield-Sacre, University of Pittsburgh, Department of Industrial Engineering, 1048 Benedum Hall, Pittsburgh, PA 15261 mbsacre@engrng.pitt.edu
[5] Claudio Rubial, Universidad de Montevideo, Uruguay

skills," such as teamwork and communication, that are critical to the success of a fledgling organization. The added support of coursework from schools of business and public policy allows students to acquire additional requisite skills within a cross-cultural context.

- Industrial Engineers tend to integrate the other engineering disciplines through the problem solving methodologies in which they are trained.
- Industrial Engineering principles and tools are especially broad in scope and can be applied in a diversity of settings including manufacturing, the service industry, the public sector, a medical environment, etc.
- Academic Industrial Engineering programs typically require significantly fewer resources to develop and maintain. They are less laboratory intensive and can utilize certain existing course offerings from mathematics, statistics, business, etc.

THE ACADEMIC CONCEPT

Candidates for the flexible doctoral program will focus their academic efforts on the newer, emerging areas of industrial engineering. In addition to earning a Ph.D. degree, these students also may earn a certificate in public policy. They will complete at least one course in entrepreneurship, and have the option of taking additional courses in product realization. Part of the program will include periodic economic development briefings by national and local professionals. Research topics will be chosen in such a manner as to have an impact on regional economies and/or meet local industrial needs.

After receiving a customized education and acquiring a Ph.D. degree from the University of Pittsburgh, these educators will be in an ideal position to return to their home regions as trainers, either in academia or industry, educating the next generation of engineering students. In this manner, they can provide a multiplier effect by serving as catalysts for the education of other students and by developing and growing organizations that support local economies. The proposed concept was developed by the University of Pittsburgh industrial engineering faculty [1].

We have designed the program so that students entering with an MS degree can complete coursework and qualifier requirements for the Department's flexible doctoral program in no more than four semesters of on-campus residency. Ph.D. students would then return to their home country to complete their dissertation requirements, utilizing the internet and other electronic communication options and possibly returning during the summer months.

This concept will allow the home regions to build a core group of technologists who, in turn, can help develop a multiplicity of industries, ranging from pharmaceuticals, semiconductors, textiles, electronics, toys and games, value-added agricultural products, etc. As successful companies grow, a large industrial labor force will be created which will help sustain the middle and upper middle classes of these countries.

THE FLEXIBLE PH.D. PROGRAM COMPONENTS

This program is directed at high quality candidates who already have a Master's degree. It is anticipated that these students will be faculty members who will return to their institution after completing the residency portion of this program. (In fact, that is one of the strong selling points of the program – the student must return after two years and will finish his/her dissertation at the home institution.)

At the University of Pittsburgh, Ph.D. candidates can transfer up to 30 credits of coursework from their prior Master's degree; the exact number of credits depends on the field in which the Master's degree was awarded as well as the specific courses that the student has taken. Since the Ph.D. program requires 54 credits of coursework (in addition to 18 credits of dissertation research) this would mean that the typical doctoral fellow would need to take between 30 and 36 credits of additional coursework (i.e., 10 to 12 courses) at the University of Pittsburgh. Specific courses to be taken would be determined jointly by the student, his or her academic advisor and the graduate program director and would depend on the student's prior background and academic/research interests. Ph.D. candidates would normally complete 30 credits of coursework (i.e. 10 courses) over three semesters at the University. After the student's Ph.D. committee has accepted his/her dissertation proposal, the candidate can return home to complete the proposed research agenda. The widespread use of the Internet makes this doctoral model feasible; something that would not have been possible less than a decade ago. Because of the University of Pittsburgh's strong international focus, with its five national resource centers (Latin American Studies, Western European Studies, Eastern European Studies, East Asian Studies, and International Business), participants in the flexible program, are encouraged to take three policy based courses from their home region and a course in entrepreneurship. Figure 1 and Table 1 show a typical academic path and course of study for the flexible Ph.D. program.

It should be emphasized that the proposed model described above is not universal. Different students have their own unique requirements (e.g., English language skills) and there may be minor differences in the exact sequence of events as well. Moreover, the above model is typical of most engineering doctoral programs in the U.S. Beyond an undergraduate degree the whole process could last anywhere between four and five years.

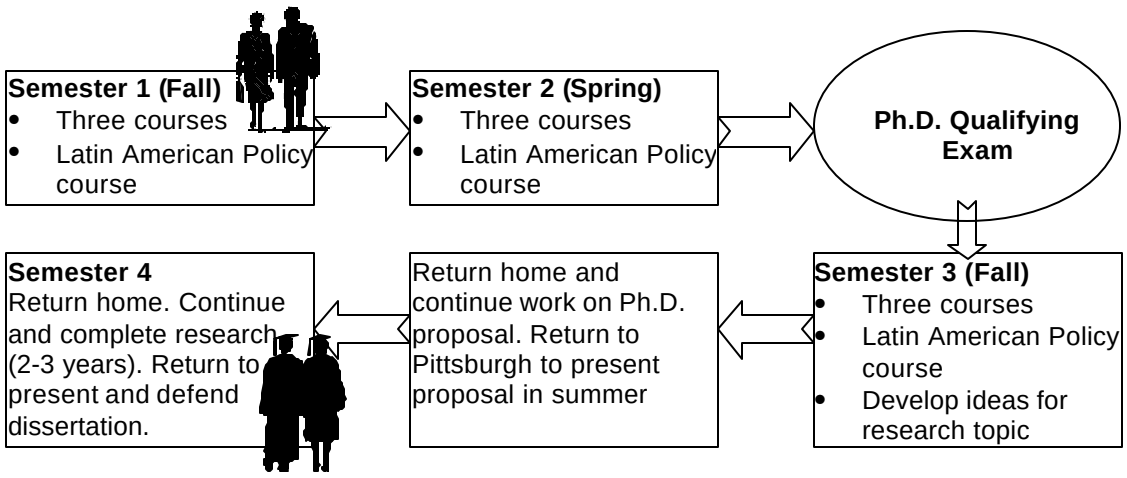

FIGURE 1.
ACADEMIC PATH FOR DOCTORAL PROGRAM

TABLE I
SAMPLE FLEXIBLE DOCTORAL PROGRAM WITH FOCUS ON PRODUCT DEVELOPMENT AND MANUFACTURING INNOVATION

YEAR 1		
Fall	**Spring**	**Summer**
IE 2088: Digital Systems Simulation **IE 2083**: Production & Inventory Control **IE 2055**: Facilities Layout & Material Handling **ECON 1610**: Latin American Economic Development	**IE 2082**: Linear Optimization **IE 2051**: Computer Aided Manufacturing **IE 2084**: Cost Management for Advanced Manufacturing **PS 2374**: Political Economy of Development	*Pass Ph.D. Qualifying Examination in May; then return home.* *Preliminary Work in developing a topic for Ph.D. dissertation.*
YEAR 2		
Fall	**Spring**	**Summer**
IE 2039: Entrepreneurship for Engineers **IE 2055**: Automation in Manufacturing & Product Design **IE 2089**: Rapid Prototyping **BECN 2017**: International Trade & Investment *Refine dissertation topic*	*Return home and work on developing a proposal for dissertation.*	*Come to Pittsburgh and present and defend proposal*
YEAR 3		
Fall	**Spring**	**Summer**
Dissertation Research	*Dissertation Research*	*Come to Pittsburgh to provide update on research*
YEAR 4		
Fall	**Spring**	**Summer**
Dissertation Research	*Complete research and start writing document*	*Come to Pittsburgh to finish write-up and defend dissertation*

(NOTE: This is merely *one* sample program. Other courses may be taken if more appropriate to the student's background. Programs can also focus on a) Information Systems Engineering, b) Product Development and Manufacturing Innovation, c) Computer Modeling and Operations Research, and 4) Engineering Management.)

SAMPLE AREAS OF STUDY

Areas of research will be chosen by the student such that:

- They broaden the student's background by focusing on the intersection of industrial engineering with complementary fields, and
- Are relevant to the economic needs of the candidate's home region.

While specific research topics to be addressed by doctoral candidates are difficult to predict in advance (since they are an individual's choice), these students will generally choose topics based on the research strengths of the department. At the University of Pittsburgh, these include:

- **Information Systems Engineering**. Automated Data Collection (ADC) is a good example of an innovative topic with a variety of research areas that can be utilized in the flexible program. The University of Pittsburgh has an ADC laboratory that was the first of its kind in the country [2-4]. The focus of this laboratory is on productivity improvements and efficiency through the use of five state-of-the-art data collection technologies: bar codes, magnetic stripe readers, radio frequency identification (RFID), radio frequency data collection (RFDC), and vision systems. Research projects have included 1) the development of performance standards for two-dimensional barcodes, 2) advanced HAZMAT rapid identification and tracking feasibility, 3) a test and evaluation of current border crossing cards and permanent resident cards for the US Immigration and Naturalization Service, and 4) development and implementation of disease management databases. Depending on the individual student, and the needs of the home region, potential areas of interest include innovative applications of global positioning systems, product and people tracking systems, RFID systems for wildlife management, or sensor based inventory systems.
- **Product Development and Manufacturing Innovation**. The School of Engineering's Swanson Center for New Product Innovation offers a unique, seamless cutting edge product development and research facility. It consists of four inter-connected laboratories a) the Design and Multimedia laboratory, b) the W.M. Keck Rapid Prototyping and Reverse Engineering Laboratory, 3) the Kresge Rapid Manufacturing Laboratory, and 4) the Swanson Micro-Electro-Mechanical Systems (MEMS) Laboratory. Students can move from concept to alpha prototype to beta prototype to small batches of a final product in a full semester or, as quick as two weeks. Research projects have included the development of a diversity of product design methodologies ranging from a real-time radon detector to a new type of power lift tailgate for a pick-up truck. In addition, a new national initiative on e-Product Realization, based at the University of Pittsburgh, is gaining momentum. Development of products that cross-national and cross-cultural boundaries are areas of interest that can be tested and validated using the home region of the doctoral candidates and the University of Pittsburgh.
- **Computer Modeling and Operations Research**. Several current research areas for Computer Modeling and Operations Research application exist. One example is renewable energy. With the expected increase in power demand in developing economies over the coming decades, the optimal design and operation of wind farms is of great importance. The reliability and design of distributed power generation is another possibility for generating energy with reduced environmental impact. A third example is organ transplantation logistics. The University of Pittsburgh is a world leader in organ transplantation, particularly liver transplantation. Industrial Engineering faculty are actively involved in the logistics of organ transplantation. One project is considering travel time explicitly in organ allocation decision process. Since organ viability decreases with time, this project seeks to minimize the travel time for organs while ensuring good matches between donor and patient. Another project is the optimal design of transplantation regions. Organs are offered at the regional level before becoming available at the national level. Our preliminary results indicate that using an optimal design can triple certain types of organ transplants and similar techniques could be applied to regions around the world.
- **Engineering Management**. Examples of research in this area include the development of corporate governance models for enterprises and the application of activity-based costing systems for small manufacturers that will be especially applicable in an entrepreneurship-based environment.
- **Cost, Schedule and Risk Tradeoffs:** Another area of interest is the intersection between engineering ethics, costs, risks, and schedules. When schedule and cost pressures increase, risks also tend to increase. As a result, engineers and managers may find themselves facing an ethical dilemma. If unresolved, the consequences may be very costly and even life threatening. To mitigate this type of situation from developing engineers must learn how to recognize these potential dilemmas and know how to both accurately assess and then communicate risks. This is particularly important in developing countries. For example, a combination of organizational factors and poor management may have recently led to the loss of the world's largest oil drilling platform in Brazil [5]. At the University of Pittsburgh, we have been studying such

situations and ways to prevent them for a number of years [6].

THE FLEXIBLE PROGRAM: A STUDENT PERSPECTIVE

Claudio Rubial, the Chief Administrative Officer at the University of Montevideo and a faculty member in the Business School is pursuing a doctoral degree through the flexible program. His comments on his experience in general, along with specific issues of interest follow.

It is common for Latin-American universities to employ many part-time professors without Ph.D. degrees. These universities have a strong need to increase the skills and knowledge base of their faculty while simultaneously ensuring that they remain as full-time teachers - a crucial prerequisite for this is a doctoral degree, ideally obtained at a premier institution in the United States. The faculty members are usually very competent with excellent teaching aptitude and significant experience in their chosen professional areas. They are normally 30 to 40 years old, and typically, married and have children.

From a personal standpoint, a traditional Ph.D. program that entails at least 4 to 5 years of full-time dedicated study in addition to moving abroad and uprooting a whole family is a daunting proposition. From the institution's point of view, this represents the loss of a scarce resource for an extended period of time. A program that successfully addresses these issues is thus highly desirable; the University of Montevideo wholeheartedly endorses the flexible program and feels it is the first link in a chain of universities that will seek out the Flexible Program. Key issues to consider in establishing such a program include:

A) **Advising and Mentoring**. It is of great value for the degree-granting institution to know the candidate's previous training, varied interests, needs and objectives from the onset of the application process. This knowledge will help achieve the best timetable and in turn allow the candidate to derive the maximum possible benefit from the program.

B) **Transfer of Credits**. Institutions must have the necessary infrastructure in place to give candidates the fullest possible transfer of previous experience - academic or experiential. For example, if a student has a MBA degree, a basic course in Engineering Management is probably a replication of previous experience; such a candidate would be better served by spending more time to topics of special interest.

C) **Focus on Research**. Candidates would be best served by focusing early in their studies on subjects that will help in their dissertation research. It is important for them to choose an appropriate advisor to their own needs during the first term.

D) **Students**. It is important for faculty whose students are in the flexible program to recognize that they may have very different backgrounds than traditional students, because of their age, maturity, interests and experience. They are typically more studious and better motivated and therefore can achieve more in less time.

E) **Interlocking Schedules**. The ability of returning home during the summer is very attractive both for the student and for the home institution. In cases where the country of origin is in the Southern Hemisphere, academic calendars are different from those in the United States. Candidates not only can return home, but also are able to take on their allotted classes in their usual teaching positions, thus rendering it easier for the university to justify their time away. (Many US universities may overlook this point.)

D) **Financial**. It is important to identify funding sources for these programs early in the process. Many universities interested in sending their professors to such a program, are smaller institutions that do not have access to sabbatical funds or tuition grants. Additionally, candidates may be married and with children thus adding to the expenses of participating in such a program.

CONCLUSIONS AND IMPACT

The flexible graduate program in Industrial Engineering can educate international faculty to be leaders with a global and social perspective towards systems engineering. A program can be designed that focuses on the development of theory and analytical tools and techniques, which in turn can be applied to problems that impact communities around the world. The program can also have a strong impact on research in industrial engineering by:

- Encouraging the field to focus more on public policy issues
- Encouraging the field to focus more on systems aspects of global problems
- Providing an innovative, high quality graduate research education to prospective trainers in industrial engineering
- Jump starting economic development
- Establishing natural growing links with universities from other countries that can become the core of academic cooperation agreements that benefit both parties, including exchanges both for professors and for students, internships abroad, joint investigations, etc.

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