The application of the Functional Resonance Analysis Method (FRAM) to evaluate factors affecting times-to-completion and graduation in graduate studies

Hussein SLIM, Sylvie NADEAU, François MORENCY

Department of Mechanical Engineering, École de technologie supérieure Montréal, Québec, Canada

Abstract. The issue of attrition and graduation delays in higher education is almost as old as higher education itself. The impact of attrition on students, educational institutions, governments and economies is substantial. Despite the existence of many studies on attrition, the results fail to agree on what factors are actually relevant or primarily influential. To provide a new perspective on this issue, the Functional Resonance Analysis Method (FRAM) was applied to evaluate a case study in higher education. This approach enables the analyst to understand attrition as an outcome of the performance variability of students, supervisors and universities. The application of FRAM shows how the combination of functional variability (resonance) might cause or add up to the issues and how to identify sources of variability within the analyzed system.

Keywords. Assessment, graduation, graduate studies, performance, education, functional resonance analysis

1. Introduction

Despite the continuously rising number of graduate students, the current economic and academic developments worldwide show a growing demand for more higher education graduates and researchers (AUCC 2011). In Canada, the labor market demand for graduate degree holders increased from 600,000 to more than 1.3 million employees between 1990 and 2009 (AUCC 2011). Unfortunately, not all students, who enroll in graduate programs, graduate successfully or on time. Over the years, times-to-completion in graduate programs have increased in an alarming way. The median time to obtain a Ph.D. degree in Canada is 11 years after obtaining the bachelor degree (Elgar 2003). Graduation rates in most disciplines are critically low at around 50% (Elgar 2003). The adverse impact of attrition and graduation delays is reflected in many aspects on students, universities and governments. On the individual level, it means loss of time, less career chances and less potential income for affected students (Declou 2013). On the institutional level, it could result in less governmental funding for universities, less productivity in general and additional wasted resources invested in students who fail to finish on time or at all (Declou 2013). The improvement of graduation times and rates would certainly be translated in more efficient applications of the allocated resources for research. Therefore, universities and policy makers are increasingly interested in reducing attrition in graduate programs and improving graduation rates.

Studies addressing the issues of attrition and graduation delays fail however to provide comprehensive findings or agree on what factors are primarily decisive for a successful and timely completion of graduate programs (Bair & Haworth 2005). Attrition rates are different between different universities and even between disciplines within one university depending on the nature and structure of the fields and programs of study (Bair & Haworth 2005). Additionally, the differences in findings can be attributed to the different contexts and settings of the conducted studies themselves. The populations, methodologies, environments and other systemic characteristics differ from study to study and accordingly the findings. Graduate programs are complex systems, in which many influential factors interact and combine to affect the graduation process (Latona & Browne 2001). To provide a better evaluation of the factors causing or influencing attrition and delays, the complexity of graduate programs has to be considered. In many cases, the true reasons for failure are not obvious or easily identifiable. Failure cannot be simply attributed to singular events that cause students to experience delays or dropout. Rather, failure should be understood additionally from a systemic perspective. Therefore, the Functional Resonance Analysis Method (FRAM) (Hollnagel 2004 & 2012) was applied in this study to provide a new approach for the evaluation of attrition and graduation delays in graduate studies. The application of FRAM was conducted in an exploratory manner to analyze a theoretical but realistic case study. The provided analysis shall provide an example for the usefulness of FRAM and demonstrate how it can be applied to examine and evaluate graduate programs for causes of attrition and graduation delays.

2. Method

The first step in our study is to provide a scenario, which will be used for the analysis of a research-based master's program. The case study and the FRAM model were constructed relying on the expertise of two professors and after consulting the guidelines of a medium size Canadian university. In the selected scenario, a student applies for admission in an engineering program. After contacting a professor and agreeing on the subject of research, the student contacts the university to inquire about conditions, required papers and documents. The application will be submitted after fulfilling all requirements and the university evaluates the submitted application using a checklist of requirements for the applying student. Admission conditions can be but are not limited to the following: submission of academic records by the previous university; providing proof of English proficiency (IELTS, TOFEL); providing proof of French proficiency otherwise requirement to complete a French course at the university; providing proof that the professor agreed to act as the director of thesis; requirement to attend preparatory courses if found necessary; specific admission requirements that correspond to the selected major.

The evaluation process focuses merely on the submitted documents and cannot test the student's true skills. The student submits an IELTS certificate with an acceptable score (six or more). The IELTS exam consists of four parts: listening, reading, writing and speaking (IELTS 2017). The IELTS test evaluates the above-mentioned skills on a rating scale from zero to nine (IELTS 2017). The student has good listening, reading and speaking skills, which results in an acceptable total score. The writing skills of the student however are inadequate for academic writing. Upon admission, the student shall plan and outline the complete research program with the

guidance of the supervisor. The student has to attend a weekly meeting with his/her supervisor, enroll for courses, comply with university requirements, register for workshops and preparatory courses, etc. The student is required to pass courses with acceptable grades above the minimal required average to conclude the program on time. A correct evaluation of the student's skills is essential to determine whether he/she can pass courses and succeed in his/her research work. In the first session, the student enrolls in two courses, which require reading, understanding scientific literature and writing skills. Insufficient language skills could in this case produce an unsatisfactory grade or even failing the course. Consequently, the student would be required to repeat the course in the following session, which would cause delay. Also writing scientific articles, literature reviews and the main thesis requires adequate linguistic skills. The student enrolls additionally to three credits of research work. He/she is required to start searching scientific databases and work on the literature review of the thesis. Upon reviewing the first written texts, the supervisor requires attending library workshops and courses to learn utilizing needed software and scientific databases, understand rules and regulations and be familiarized with the context of research programs. The supervisor requires additionally attending preparatory and language courses to improve technical and linguistic skills. If the student's skills are not sufficient, then the effort to obtain needed skills and compensate the deficiency will be larger. If the student does not admit or is not aware of his/her lack of needed skills, then he/she will not usually attend extracurricular courses to avoid additional payments. As a result, passing courses and providing required scientific texts might be delayed.

The focus of the analysis is directed to variability in regular activities and tasks that resonate and combine to degrade performance. To perform the FRAM analysis on the above-presented case, the functions of the FRAM model must be identified and described as a first step. A FRAM function is described in the form of a table listing all its aspects, which represent five input values (Input (I), Preconditions (P), Resources (R), Time (T), and Control (C)) and one Output (O) (Hollnagel 2012). The output of an upstream function is linked to a downstream function as one of the five input aspects. Functions are classified in FRAM into three categories: organizational, technological and human functions. Secondly, the sources of variability within the constructed model are to be determined and characterized. Variability in the basic FRAM model is characterized through a linguistic scale in terms of timing (early, on time, too late and omission) and precision (imprecise, acceptable and precise) (Hollnagel 2012). The likelihood and impact of the output variability implied by the assigned linguistic scale can be different between functions depending on the class or type of the respective function. Thirdly, the resonance and impact of the identified functional variability throughout the system is to be determined and described by analyzing the couplings between functions (For more information on the principles and features of FRAM, the reader is invited to consult the FRAM website: *http://www.functionalresonance.com*).


3. Results

A checklist of requirements for the applying student is used to control if the student comply with the conditions for admission. The score of the IELTS exam is sufficient for admission, but the score does not really reflect the writing skills of the student. The student is admitted and the function "**Evaluation**" produces an "**acceptable**" output. Consequently, the functions "**Pass Courses**", "**Write Literature Review**",

"**Write Scientific Papers**" and "**Write Thesis**" receive an "**acceptable**" precondition. The student is not able to pass required courses on time and the function "**Pass Courses**" produces a "**too late**" output. The student is not able to write a proper literature review. Improvement is required and attending additional language courses is necessary. The function "**Write Literature Review**" produces an "**imprecise**" output. In the following sessions, the student will be required to write scientific articles for publication in a scientific journal or at a scientific conference. The "**imprecise**" literature review and "**acceptable**" evaluation delay the provision of scientific papers. The additional requirement to improve linguistic skills delays the writing of scientific papers. The reviewing process before and after the submission of an article to a scientific journal might extend, if the written material was not good enough. The function "**Write Scientific Papers**" produces a "**too late**" output. The "**imprecise**" literature review and "**acceptable**" evaluation prevent the provision of the thesis on time until the required quality is provided. The function "**Write Thesis**" consequently produces a "**too late**" output. The function "**Conclude Program**" receives three "**too late**" preconditions from the functions "**Pass Courses**", "**Write Scientific Papers**" and "**Write Thesis**". Consequently, the timely completion of the program is not possible. The output "**improve writing skills**" of the function "**Attend Preparatory Courses**" is conditional and will only be provided if the student attends such courses. Secondly, attending those courses would not remove the delay, since those courses require time and meanwhile the mandatory courses would have to wait. In both cases, it would not sufficiently dampen the variability of the functions "**Pass Courses**", "**Write Literature Review**", "**Write Thesis**" and "**Write Scientific Papers**". Language skills are essential for graduate programs and they form a true barrier for students, who lack such skills.

Tabelle 1:   *A list of the functions that consist the FRAM model*

No.	FUNCTION	No.	FUNCTION
1	Provide Procedures & Guidelines	12	Pass Courses
2	Evaluation	13	Compliance with Requirements
3	Supervision	14	Write Literature Review
4	Application for Admission	15	Collect Data
5	Preliminary Planning	16	Perform Experiments
6	Provide Resources	17	Analyze Data
7	Planning	18	Write Scientific Papers
8	Initiate Studies	19	Write Thesis
9	Attend Preparatory Courses	20	Submit & Defend Thesis
10	Collect Preliminary Data	21	Conclude Program
11	Provide Research Protocol & Methodology		
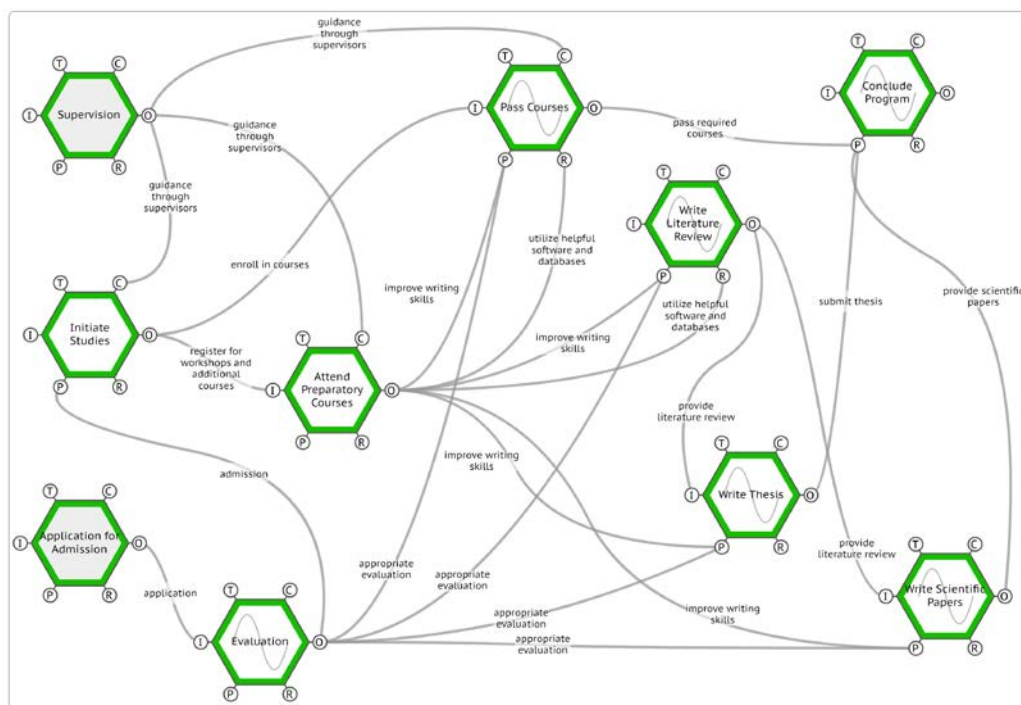
Figure 1: *A simplified graphical representation of the FRAM model constructed in the FRAM Model Visualizer (FMV), which was developed by Rees Hill (http://functionalresonance.com/ FMV/index.html)*

4. Discussion and Conclusions

Due to the many contextual differences among studies and the complexity of graduate programs, it is difficult to identify the primary influential factors causing attrition and graduation delays. The provision of generalizable conclusions across disciplines, universities and countries is not easily achievable and may not be possible. The performance of students is affected by various institutional and human factors and the decision to drop out of a graduate program cannot be always attributed to a singular event or a simple cause. To provide a new perspective for the understanding of the mechanisms that lead to attrition and delays, the application of the Functional Resonance Analysis Method (FRAM) was proposed. FRAM can provide insight on how functions, which represent tasks and different stages in the program, interact and how the variability of their outputs might resonate to produce adverse outcomes. The selected case study demonstrated how an imprecise evaluation of the student's language skills could affect his/her progress in a research-based program. The student might be complying with the conditions for admission and still not possess required skills to graduate. The model is not exclusive to the selected case and can be further used to run multiple instantiations and study other aspects and factors.

The main purpose of this exploratory study was to merely present a simple example and demonstrate how FRAM can be applied to locate sources of variability within a graduate program. The results might not be directly generalizable to other contexts, since the findings are limited to the selected case study. The number of experts consulted for this analysis is small and the findings are surely limited in that aspect as

well. For the purpose of this study, the amount of collected data and number of analysts were sufficient.

FRAM in its basic version lacks quantification (Hollnagel 2012). The linguistic descriptors are simplified representations, which do not specify precisely the magnitude of variability. Additionally, conducting a FRAM analysis on a complex system requires significant amounts of data and is very difficult without subject matter expertise. The introduction of advanced computing tools would certainly improve the efficiency, provide better results and allow for more extensive and easier application. Applications of FRAM took place in various fields and many improved versions of the method were introduced. To the best of our knowledge, FRAM was not applied before to analyze graduate programs. This provides possibilities for future studies to address the limitations of this study in a more elaborate and extensive fashion.

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