



ESI 5315 - Optimization and Simulation

Course Syllabus

Course Information

- **Course Number and Title:** ESI 5315 - Optimization and Simulation
- **Credit Hours:** 3 credits
- **Current Academic Term:** Spring 2023

Instructor Information

- **Instructor:** Shahram Taj, Ph.D.
- **Office:** ARC 2232
- **Office Hours:** Monday 12PM - 2PM
Tuesday, Thursday 1PM-3PM
- **Office Phone:** (863) 874 – 8521
- **E-mail:** stj@floridapoly.edu
- **Class Meeting:** Thursday 4:00PM-6:45PM IST 1017

Course Details

- **Class Delivery Mode:** The class will be delivered in a face-to-face format where the students are expected to attend all their scheduled university classes to satisfy all academic objectives as defined by the instructor.
- **Course Website:** <https://floridapolytechnic.instructure.com/courses/6948>
- **Official Catalog Course Description:**
This course familiarizes the student with frequently used models in Operations Research. Such models include decision analysis; optimization techniques, and Discrete-Event Simulation. Course is supplemented with real world examples and cases.
- **Communication/Computation Skills Requirement (6A-10.030):** No
- **Required Texts:**
Cliff T. Ragsdale, Spreadsheet Modeling & Decision Analysis: A Practical Introduction to Business Analytics, 9th edition, 2022, ISBN 978-0-357-13209-8, published 2022 by Cengage Learning US

Supplementary readings:

1. Shahram Taj, Galia Novakova Nedeltcheva, George Pfeil, and Michael Roumaya, "A Spreadsheet Model for Efficient Production and Scheduling of a Manufacturing Line/Cell", International Journal of Production Research, 2012, Vol. 50, No. 4, pp. 1141-1154.

2. Shahram Taj and Elham Mousavidin, "Using Discrete Event Visual Simulation to Teach Process Modelling in MBA Operations Management" International Journal of Simulation and Process Modeling, Vol. 10, No. 1, pp. 45-64, 2015
 3. Shahram Taj, Hassan Shirvani and Bahman Mirshab A New Approach to Data Envelopment Analysis with an Application to Bank Efficiency in Turkey, Banks and Bank Systems Journal, Vol. 6, No. 1, pp. 42-47, 2011.
 4. Shahram Taj, "Data Envelopment Analysis for Lean Manufacturing," AT. Business Management Review, Vol.5, No. 3, pp.79-86, 2009.
 5. Shahram Taj, David Cochran, James Duda and Jochen Linck, "Simulation and Production Planning for Manufacturing Cells," Proceedings of the Winter Simulation Conference, Washington, DC, Dec. 13-16, 1998
 6. George Pfeil, Ron Holcomb, Charles Muir, and Shahram Taj, "Visteon's Sterling Plant Uses Simulation-Based Decision Support in Training, Operations, and Planning," Interfaces, Vol 30, Jan.-Feb. 2000.
 7. Shahram Taj, "A Mathematical Model for Planning Policies for Food Stamps," Applications Of Management Science, Vol. 7, 1993.
- **Software:** MS Excel -Solver, Simul8
 - **Equipment and Materials:**
The format of the course will include lectures by the instructor, class discussions, directed readings, homework, project, and students' presentations.
 - **Course Objectives:**
Understand what optimization and simulation are how different models can be applied to complex challenges in engineering and business. Students will learn to apply the concepts and techniques of optimization and simulation in the real world—through a strong emphasis on model building, problem solving skills to arrive at the best possible solution regarding different types of managerial and engineering problems.
 - **Course Learning Outcomes:**
Upon successfully completing this course, learners will be able to:
 1. Ability to apply math models to operations research scenarios
 2. Demonstrate ability to analyze a scenario, process or product within economic constraints
 3. Ability to solve engineering and business problems related to operations research scenarios

MS in Engineering Management Program Learning Outcomes	Course Learning Outcome and Learning Level*		
	1	2	3
(1) Apply business fundamentals and develop strategies to address complex challenges in engineering, applied science, and related industries.	Apply	Apply	Apply
(2) Identify, formulate, and solve engineering problems of single or multidisciplinary nature by applying principles of engineering, science, mathematics, and analytics.	Apply	Analysis	Apply
(3) Apply data science concepts, tools, and develop analytical insights to solve business and engineering problems.		Apply	Evaluate
(4) Communicate complex business and engineering problems to diverse audiences.		Analysis	Analysis

*: learning level as described in Bloom's taxonomy and Anderson and Krathwohl's taxonomy.

MS in Data Science Program Learning Outcomes	Course Learning Outcome and Learning Level*		
	1	2	3
(1) Demonstrate mastery in analyzing complex problems and applying knowledge of data science to formulate solutions.	Application	Analysis	Evaluation
(2) Communicate data science information clearly and effectively through presentations and technical writings to both expert and non-expert audiences.			Comprehension
(3) Demonstrate critical evaluation of recent research literature.	Knowledge		Analysis
(4) Identify a novel relevant research problem in a chosen data science research field, perform the literature survey for the problem, create a plan to solve the problem, carry on the plan, and defend the research.		Analysis	Evaluation
(5) Recognize appropriate practices in the field of data science and their ethical implications.			Comprehension

*: learning level as described in Bloom's taxonomy and Anderson and Krathwohl's taxonomy.

Academic Support Resources

- **Library:** Students can access the Florida Polytechnic University Library through the University website and [Canvas](#), on and off campus. Students may direct questions to Academic Success Center success@floridapoly.edu or by email, library@floridapoly.edu.
- **Peer Learning Strategists:** These are specially trained student leaders who help their peers strategize approaches to course content and work through solution methods. PLS students work in collaboration with the courses they support so the content and methods are aligned with your instructors' expectations. The PLS room is located on the first floor of the IST in the center hallway.
- **Writing Center:** Located on the second floor of the IST (2059/2061), the Writing Center helps students to develop their writing and presentation skills. Consultations are available in person and virtually. For more detail, visit <https://floridapolytechnic.libguides.com/writingservices>.

Course Policies

Attendance (see also [University Policy](#))

Students in face-to-face (this includes labs and C-courses) courses are expected "to attend all of their scheduled University classes and to satisfy all academic objectives as defined by the instructor" (University Policy, FPU-5.0010AP).

If you know that you will miss a class for any reason discuss the situation with your instructor in a timely manner. Exceptions to any attendance requirements may be made on a case-by-case basis.

Students Feeling Sick

Students should not come to class if they are feeling ill, particularly if experiencing symptoms of COVID-19, or if you have been directed by a health professional to quarantine. Students who are experiencing an emergency situation that aligns with an academic exercise of consequence (e.g., a Common Exam) should work with CARE Services at care@floridapoly.edu

Late Work/Make-up work

Each student must keep current on assignments. *Late assignments are not graded, unless permission has been obtained from the instructor.* In case of a medical emergency, please notify your instructor as soon as possible who will evaluate any exceptions on a case-by-case basis.

- **Grading Scale:** (See also [University Grading Policy](#)).

Grades will be determined according to the following scale:

A	93% – 100%	B	83% – 85%	C	73% – 75%	D	63% – 65%
A–	90% – 92%	B–	80% – 82%	C–	70% – 72%	D–	60% – 62%
B+	86% – 89%	C+	76% – 79%	D+	66% – 69%	F	0% – 59%

Grading Information Specifically for Graduate Students

The grades of "A" through "C," and "SR" are passing grades. The grades of "B-," "C+," and "C" are considered passing for graduate students but indicate weak performance for a graduate student and may not be accepted for some programs.

Note: The grades of "C-," "D+," "D," "D-," "F," and "UR" are failing grades.

- **Assignment/Evaluation Methods:**

<i>Assignment</i>	<i>Percentage</i>
Attendance & Participation	5%
Simulation Project	15%
Assignments	20%
Midterm Exam	30%
Final Exam	30%
Total	100%

Participation in all course activities is a very important element of this course and is a basic expectation. Course participation consists of active and respectful involvement in class discussions, presentations, peer feedback, postings, replies, projects, and other interactions.

- **Late Work/Make-up work:**

Each student must keep current on assignments. *Late assignments are not graded, unless permission has been obtained from the instructor in advance.* Medical emergencies with valid documentation would be about the only exception. Any other documentation will be evaluated on a case-by-case basis.

University Policies

Reasonable Accommodations

The University is committed to ensuring equal access to all educational opportunities. The University, through the Office of Disability Services (ODS), facilitates reasonable accommodations for students with disabilities and documented eligibility. It is the student's responsibility to self-identify as a student with disabilities and register with ODS to request accommodations.

If you have already registered with ODS, please ensure that you have requested an accommodation letter for this course through the [ODS student portal](#) and communicate with your instructor about your approved accommodations as soon as possible. Arrangements for testing accommodations must be made in advance. Accommodations are not retroactive.

If you are not registered with ODS but believe you have a temporary health condition or permanent disability requiring an accommodation, please contact ODS as soon as possible.

The Office of Disability Services (ODS):

DisabilityServices@floridapoly.edu

(863)874-8770

The Access Point

[ODS website: www.floridapoly.edu](#) > Student Affairs > Health Wellness > Disability Services

Accommodations for Religious Observances, Practices and Beliefs

The University will reasonably accommodate the religious observances, practices, and beliefs of individuals in regard to admissions, class attendance, and the scheduling of examinations and work assignments. (See [University Policy](#).)

Title IX

Florida Polytechnic University is committed to ensuring a safe, productive learning environment on our campus that prohibits sex discrimination and sexual misconduct, including sexual harassment, sexual

assault, dating violence, domestic violence and stalking. It is important for you to know that there are resources available if you or someone you know needs assistance. You may speak to your professor, but your professors have an obligation to report the incident to the Title IX Coordinator. It is an educational goal that you feel able to share information related to your life experiences in classroom discussions and in one-on-one meetings. However, it is requirement for university employees to share information with the Title IX Coordinator regarding disclosure. However, please know that your information will be kept private to the greatest extent possible. You will not be required to share your experience. If you want to speak to someone who is permitted to keep your disclosure confidential, please seek assistance from the Florida Polytechnic University [Ombuds Office](#), BayCare's Student Assistance Program, 1-800-878-5470 and locally within the community at [Peace River Center](#), 863-413-2707 (24-hour hotline) or 863-413-2708 to schedule an appointment.

Academic Integrity

All students are expected to adhere to the highest standards of academic integrity. Violations of academic integrity include actions such as cheating, plagiarism, use of unauthorized resources, illegal use of intellectual property, and inappropriately aiding other students. Such actions undermine the central mission of the university and negatively impact the value of your Florida Poly degree. It is critical that students take a professional approach to their academic work. The faculty and administration take academic integrity very seriously. Suspected violations will be fully investigated, possibly resulting in an academic integrity hearing and sanctions against the accused student if found in violation. Sanctions range from receiving a zero on the exam or assignment, to expulsion from the university. Repeat offenders are subject to more severe sanctions and penalties. Do not compromise your integrity for a perceived short-term gain. More information about Florida Poly's academic integrity policies and procedures can be found here: <https://floridapoly.edu/wp-content/uploads/2017/07/FPU-5.005-Academic-Integrity-7.29.14.pdf#search=academic%20integrity>

Recording Lectures

Students may, without prior notice, record video or audio of a class lecture for a class in which the student is enrolled for their own personal educational use.

Recordings may not be used as a substitute for class participation or class attendance. Recordings may not be published or shared in any way, either intentionally or accidentally, without the written consent of the faculty member. Failure to adhere to these requirements is a violation of state law (subject to civil penalty) and the student code of conduct (subject to disciplinary action).

*Recording class activities other than class lectures, including but not limited to lab sessions, student presentations (whether individually or part of a group), class discussion (except when incidental to and incorporated within a class lecture), and invited guest speakers **is prohibited**.*

Course Schedule

A tentative course calendar is included below.

Dates	Topic Schedule	Sample Out of Class Student Work
Jan. 12	In Introduction to Modeling and Decision Analysis. Introduction to Optimization and Linear Programming. Using Solver	
Jan. 19	Introduction to Optimization and Linear Programming. Using Solver Continued Linear Programming – Application Application <ul style="list-style-type: none">• Marketing Applications• Manufacturing Applications Employee Scheduling Applications• Financial Applications• Transportation Applications• Ingredient Blending Applications• Production & Inventory Planning Applications Data Envelopment Analysis	Assign #1 Ch. 2: 8,11,15,19 Case 2.1 – For the Lines They are A-Changin’
Jan. 26	Linear Programming – Application Continued Application <ul style="list-style-type: none">• Marketing Applications• Manufacturing Applications• Employee Scheduling Applications• Financial Applications• Transportation Applications• Ingredient Blending Applications• Production & Inventory Planning Applications• Data Envelopment Analysis	Assign #2 Ch. 3: 13,16,19,21
Feb. 2	Sensitivity Analysis and the Simplex Method <ul style="list-style-type: none">• The Answer Report• The Sensitivity Report• The Limit Report• The Simplex Method	Assign #3 Ch 3: 25,27,30,32,35,37,49 Case 3.2 – Foreign Exchange Trading at Baldwin Enterprises Case 3.4 – Saving the Manatees
Feb. 9	Network Modeling: Transportation Models, Assignment, Transshipment Models, Network Models: Maximal-Flow, Shortest-Route, and Minimal-Spanning Tree Models	Assign #4 Ch. 4: 4,6 Case - Sytech
Feb. 16	Network Models: Maximal-Flow, Shortest-Route, and Minimal-Spanning Tree Models	Assign #5 Ch. 5: 11,12,17,18,23,28,29,32

		Case 5.2 – Old Dominion Energy
Feb 23	Midterm Exam	
March 2	Integer Programming and applications <ul style="list-style-type: none"> • Employee Scheduling Problem • Capital Budgeting Problem • Fixed-Charge Problem • The Branch & Bound Algorithm 	Assign #6 Ch. 6: 8,9,12,15,20,27
March 9	Spring Break – No Class	
March 16	Goal Programming and Multiple Objective Optimization <ul style="list-style-type: none"> • Defining Decision Variables • Defining the Goals • Hard Constraints • GP Objective Function • Applications 	Assign #7 Ch. 7: 15,19 Case: Planning Diets for the Food Stamp Program
March 23	Nonlinear Programming and & Evolutionary Optimization <ul style="list-style-type: none"> • Solution Strategies for NLP • Local vs. Global Optimal Solutions • Applications 	Assign #8 Ch. 8: 8,21,28,33 Case: Electing the Next President
March 30	Nonlinear Programming and & Evolutionary Optimization - continued	
April 6,13	Simulation Modeling - Using Simul8	
April 20	Simulation Presentation	Simulation Project Due
April 27	Reading Day – No Class	
TBD	Final Exam	

I reserve the right to modify this schedule as required by the progression of the class.

Important Dates

January 9 – 13	Mon-Fri	Drop/Add Week
January 16	Mon	Martin Luther King Jr. Holiday - No Classes
March 4 – 12	Sat-Sun	Spring Break - No Classes
March 6	Mon	Midterm Grades due
April 14	Fri	Withdrawal Without Academic Penalty Deadline (W assigned)
April 26	Wed	Last Day of Classes
April 27, 28	Th-Fri	Reading Days - No Classes
April 29, May 1-4	Sat, Mon-Th	Final Exams
May 7	Sun	Commencement
May 10	Wed	Final Grades Available Online

Rubric for Report and Presentations

Report Rubric

Objective	Category	Below Expectations	Weak	Average	Good	Excellent
	Score	1	2	3	4	5
Students can write professional quality documents	Introduction	Opening is off-topic and inappropriate to the purpose, not concise and no clarity	Opening is somewhat related to the topic and appropriate to the purpose but is not concise and clear	Opening is related to the topic and appropriate to the purpose. Somewhat clear and concise	Opening is related to the topic and appropriate to the purpose. Clear and concise	Strong opening that is clear and concise
	Organization	Disorganized; incorrect format; unclear direction	Somewhat organized; incorrect format; unclear direction	Organized; correct format; unclear direction	Organized; correct format; clear direction	Correct formatting, strong clarity and organization in the development of main points
	Literature Review	Does not present information from any source	Presents information from irrelevant sources representing limited points of view/approaches	Presents information from relevant sources representing limited points of view/approaches	Presents in-depth information from relevant sources representing limited points of view/approaches	Synthesizes in-depth information from relevant sources representing limited points of view/approaches
	Research Design (weighted twice)	Does not provide information on research design	Inquiry design demonstrates misunderstanding of the methodology or theoretical framework	Critical elements of the methodology or theoretical framework are missing, incorrectly developed or unfocused	Critical elements of the methodology or theoretical framework are appropriately developed however, more subtle elements are ignored or unaccounted for	All elements of the methodology or theoretical framework are skillfully developed and may be synthesized from across disciplines or relevant subdisciplines
	Analysis (weighted twice)	Incorrect, Irrelevant, no supporting evidence	Correct, irrelevant, no supporting evidence	Correct, relevant, no supporting evidence	Relevant and correct with supporting evidence	Relevant, correct, complete, incorporates innovative insights
	Next Steps	Missing or content does not support conclusion	Conclusion irrelevant to the findings	Conclusion somewhat relevant to the findings	Conclusion relevant to the findings	Strong conclusion that is clear, complete and compelling
	Grammar & Spelling	Uses language that often impedes meaning due to errors	Uses language that often sometimes meaning due to errors	Uses language that generally conveys meaning to readers with clarity, although writing includes some errors	Uses straightforward language that conveys meaning to readers. Language has few errors	Uses graceful language that communicates meaning to readers with clarity and fluency and is virtually error free
	Reference Style (APA)	Did not follow APA style	Numerous errors in APA style, did not cite sources correctly, formatting issues	Some errors in APA style, cited correctly but formatting issues persist	Minimum errors in style and formatting but does not detract from readability	No errors in APA style
Total points for Report = 50						

Presentation Rubric

Objective	Category	Below Expectations	Weak	Average	Good	Excellent
	Score	1	2	3	4	5
Students can demonstrate mastery of communication technology	Use of Media	Lack of media detracts from the presentation objective	Misuse of media that detracts from the presentation objective	Use of media barely supports and contributes to the presentation objective	Use of media supports and contributes to the presentation objective	Use of media supports, clarifies and reinforces the presentation objective
	Quality of Slides	Very poor quality. Not enough or too much colors, fonts and animations that detract from project objective	Poor quality. Not enough or too much colors, fonts and animations that detract from project objective	Fonts, colors and animations barely support the presentation objective	Fonts, colors and animations support the presentation objective	Fonts, colors and animations support, clarify and reinforce the presentation objective
Students can develop and deliver a compelling oral talk with relevant facts and information	Opening statement	Opening is off-topic and inappropriate to the purpose, not concise and no clarity	Opening is somewhat related to the topic and appropriate to the purpose but is not concise and clear	Opening is related to the topic and appropriate to the purpose. Somewhat clear and concise	Opening is related to the topic and appropriate to the purpose. Clear and concise	Strong opening that is clear and concise
	Organization	Disorganized; incorrect format; unclear direction	Somewhat organized; incorrect format; unclear direction	Organized; correct format; unclear direction	Organized; correct format; clear direction	Correct formatting, strong clarity and organization in the development of main points
	Literature Review	Does not present information from any source	Presents information from irrelevant sources representing limited points of view/approaches	Presents information from relevant sources representing limited points of view/approaches	Presents in-depth information from relevant sources representing limited points of view/approaches	Synthesizes in-depth information from relevant sources representing limited points of view/approaches
	Analysis	Incorrect, Irrelevant, no supporting evidence	Correct, irrelevant, no supporting evidence	Correct, relevant, no supporting evidence	Relevant and correct with supporting evidence	Relevant, correct, complete, incorporates innovative insights
	Next Steps	Missing or content does not support conclusion	Conclusion irrelevant to the findings	Conclusion somewhat relevant to the findings	Conclusion relevant to the findings	Strong conclusion that is clear, complete and compelling
	Timing	Presentation is too short, insufficient coverage of material	Presentation is too long. Unable to cover all the material	Able to cover all the material within five extra minutes	Utilizes allotted time to provide sufficient coverage of material	Well-paced coverage of material within the allotted time
Students can deliver an oral talk with clarity and appropriate poise	Delivery Techniques	Does not participate in the oral presentation	Delivery techniques (posture, gesture, eye contact, and vocal expressiveness) detract from the understandability of the presentation, and speaker appears uncomfortable.	Delivery techniques (posture, gesture, eye contact, and vocal expressiveness) make the presentation understandable, and speaker appears tentative.	Delivery techniques (posture, gesture, eye contact, and vocal expressiveness) make the presentation interesting, and speaker appears comfortable.	Delivery techniques (posture, gesture, eye contact, and vocal expressiveness) make the presentation compelling, and speaker appears polished and confident.
	Peer Evaluation	5 points				
Total Points = 50						



ESI 5315 – Optimization and Simulation Simulation Project Spring 2023

Medical Clinic Simulation 2023*ⁱ

To both manage costs and provide an improved patient experience, an outpatient clinic sets out to evaluate its basic processes. As their process improvement consultant, you have evaluated the situation and come to the conclusion that a simulation model will help the management team better understand current problems and identify potential improvements. Management has cited underutilization of key resources and long patient wait times as their most pressing problems.

Your first step is to model the current process. In the first round, your primary concern is getting down the correct routing and overall flow. After you are comfortable that you have correctly captured the overall process, you will go back and add detail to the model.

As patients enter the clinic, they must register with the patient registrar. Returning patients are sent directly to the exam waiting area. New patients are given a clipboard and additional paperwork to fill out, which they must drop off before proceeding to the exam waiting area. New patients do not need to reenter the registrar queue to drop off the paperwork.

When a nurse is free, the nurse will take the patient to an exam room. There are 4 exam rooms in the clinic. The nurse gathers preliminary information and leaves the patient until an MD is available to conduct the exam. Upon completion of the exam, some patients may need EKG/Lab (done by the nurse). Finally, the patient will stop by the finance desk to make any new appointments and take care of any necessary payment. The clinic currently staffs 1 receptionist (registration), 1 bookkeeper (finance), 1 nurse, and 1 MD on a typical day.

Use the parameters provided to help you draft the SIMUL8 model.
Start by mapping the clinic process. When you are comfortable that you have established the correct general framework, return to your model to reflect the following facts.

Data Element	Process Time	Probability/Distribution
Patient Interarrival Time	5 minutes	Exponential (5)
Registration	6 minutes	Lognormal (6, 1.25)
New Patient Percentage	--	32%
New Patient Paperwork	5 minutes	Lognormal (5, 2.5)
Nurse Interview	7 minutes	Lognormal (10, 3.75)
MD Exam	17 minutes	Triangular (10, 17, 35)
EKG/Lab Percentage		25%
EKG/Lab	20 minutes	Triangular (10, 20, 35)
Check out	2 minutes	Lognormal (2, 0.5)

Assume that the clinic is open from 8:00 am to 6:00 pm and run the model for one day.

Phase I:

- Q1.1 What is the expected time a patient must wait before the examination begins?
Q1.2 What is the average time a patient will spend in the clinic?
Q1.3 What percentages of patients complete their visit in 1 hour or less?
Q1.4 Is the clinic's staffing sufficient? How do you define "sufficient"? Justify your answer.

Phase II:

Because staffing is such an important part of the process, you decide to return to the model and add staffing levels as a more specific constraint. Add resources to the model as follows:

Position	Daily Cost	Revenue
Registrar	\$250	
Nurse	\$600	
MD	\$2000	
Bookkeeper(check-out)	\$175	
Doctor Charge		\$300
XRAY/EKG/Lab Charge		\$500

Run the simulation for a trial run of 100 times and by using the means in the results tables (for the confidence interval of 95%) of your multiple runs calculate the following:

- Q2.1 What is the average time a patient will spend in the clinic (Shot, Doctor, Xray)?
Q2.2 Financial data including revenue, cost, and profit.
Q 2.1 What is the best allocation of resources that optimizes the daily profit?
Q 2.2 The clinic has four additional rooms that are currently used for storage and they could easily be converted to exam rooms. Assume the cost to convert a storage room to an exam room is negligible. What is the effect of adding extra rooms?

Phase III (Bonus)

Because staffing is such an important part of the process, you decide to return to the

model and add staffing levels as a more specific constraint. Add resources to the model as follows:

Position	Staff
Registrar	2
Nurses	2
MDs	4
Bookkeeper	1

The MDs do not all work at the same time. Instead, they work on two shifts. Two of the MDs are staffed from 8 to 2 p.m. and another 2 are staffed from 12 p.m. to 6 p.m.

In observing the model, you notice that the registrars and bookkeeper are often available when the others have a queue. Investigate what would happen if the registrars and bookkeeper were to cover for each other by creating a pooled ‘administrative’ resource.

Finally, you want to be able to evaluate how different appointment schemes would impact patient wait times. To start with, consider booking 3 appointments every 20 minutes between 8:00 and 5:20. Assume that patients will arrive for their appointments following a normal distribution with an average of 0 minutes (arrive exactly on time) and a standard deviation of 5 minutes (early or late).

Run the simulation for a trial run of 100 times and by using the means in the results tables (for the confidence interval of 95%) of your multiple runs calculate the following:

- Q3.1 Does the administrative pool help the clinic reduce customer service?
- Q3.2 How might you change the appointments to provide a better experience for the clinic’s patients?
- Q3.2 How many patients could the clinic possibly manage in one day?
- Q3.4 What is the best allocation of resources that optimizes the daily profit?

ⁱ Reference: Taj, S. and Mousavidin, E. (2015) ‘Using discrete event visual simulation to teach process modelling in MBA operations management courses’, Int. J. Simulation and Process Modelling, Vol. 10, No. 1