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Discrete Event Simulation of the Special Forces Qualification Course

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Author Note: Nicole Polhamus conducted this research as a First Class Cadet at the United States Military Academy (USMA) as part of an Independent Study in the Department of Systems Engineering. Major Christopher Fisher is an Assistant Professor in the USMA Department of Mathematics and is currently assigned as an analyst in the Operations Research Center.

Abstract: The purpose of this project is to evaluate effectiveness of the configuration of the Special Forces Qualification Course (SFQC) training pipeline using discrete event simulation. This study assesses the distribution of time for trainees to complete the course, distribution of SFQC graduation rates, and areas where trainees are spending the most time. This animated simulation also enables analysis which provides recommendations for how best to improve training and output of highly trained and proficient personnel by comparing phase capacity limitations and course cohorts.

Keywords: Discrete Event Simulation, Systems Simulation, Special Forces, Special Forces Qualification Course

1. Introduction

The Special Forces Qualification Course (SFQC) is the rigorous formal training required of each trainee selected for entry into the United States Army Special Forces (SF). Upon completion of the course, successful graduates enter into a coveted community of highly trained and specialized soldiers (USAJFKSWSC, 2013).

The SFQC consists of six training phases, plus a final graduation phase. The training phases are Orientation (OR); Small Unit Tactics (SU); Survival, Evasion, Resistance, and Escape (SERE); Military Occupational Specialty (MOS); Robin Sage; and Language. Phases are sequential; no trainee is able to move to the follow-on phase until successful completion of previous phase. If a trainee does not complete a phase successfully they may be allowed to reattempt the phase; this is referred to as a "recycle." Trainees are only able to recycle twice throughout their entire time in the course. For example, if a trainee had recycled once in Phase 1 and once in Phase 2, they would not be allowed any additional recycles for the remainder of the phases. The graduation phase is administrative, and no training or testing is conducted. Figure 1 outlines the flow in which trainees move through the training pipeline, beginning with Phase 1.

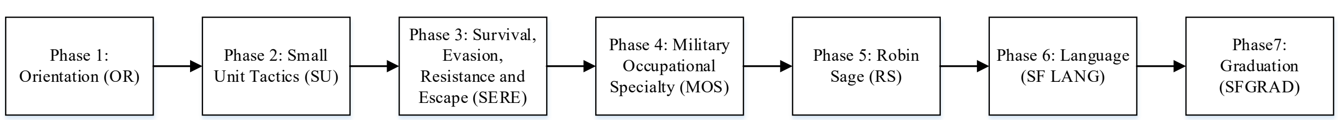

Figure 1. Phase Diagram

Since the training conducted in each phase is different, student pass rates and phase lengths are different as well. Table 1 provides a more detailed description of each of these phases, including each phase's length. New trainees arrive in "cohorts," and generally those who successfully pass each phase without recycling progress together and graduate the course at the same time. Currently, there are six cohorts per year, and classes are offered for each phase six times per year. Depending on the phase lengths and resource availability, it is possible to have two or more cohorts in the same phase at the same time.

The SFQC trains all SF Soldiers, including components such as Active Duty Officers (ADO), Active Duty Enlisted, and National Guard Soldiers. The only difference in training between components comes in Phase 4: MOS, which has five different versions. Success rates for all phases have historically varied based on component type.

Table 1. Special Forces Qualification Course Phase Descriptions (USAJFKSWSC, 2013)

Location	**Description**
Phase 1: Orientation (SFOR)	This phase is 33 days long and focuses on building a baseline of knowledge through training in Special Forces history, duties and responsibilities and mission overview. It establishes standards and competence in trainees and solidifies a uniform base of expertise moving forward through the course.
Phase 2: Small Unit Tactics (SU)	This phase is 44 days long and focuses on small unit operations. This style of tactics concentrates at the team and squad level. Trainees learn how to maneuver, execute tasks and gain high level proficiency.
Phase 3: Survival, Evasion, Resistance and Escape (SERE)	This phase is 19 days long and teaches trainees the basics of survival, how to evade the enemy, how to resist the enemy if captured and lastly methods to escape the enemy when able.
Phase 4: Military Occupational Specialty (MOS)	This phase is 113 days long and consists of five different specialties which all concentrate on training their differing occupational requirements and duties. These military occupational specialties include: Officer, Weapons, Engineer, Medical and Communications. This phase allows trainees to become proficient in their designated occupational field.
Phase 5: Robin Sage (RS)	This phase is 30 days long and is the culminating training exercise for the course. Trainees are tested on all the skills and tactics they have learned during their training and are required to expertly implement them.
Phase 6: Language (LANG)	This phase is 185 days long and consists of trainee's education on a specific language in culture. There are eighteen different languages that trainees can be assigned to but for simplicity these languages where considered as an individual data set and not divided into each language as entities move through the system for this simulation.
Phase 7 Graduation (SFGRAD)	This phase is 4 days long and acts a place holder to account for the time that trainees would be out processing from the course and preparing for graduation.

2. Problem Articulation

Over time, the SFQC has been modified in terms of number of cohorts per year, number of phases that make up the SFQC, sequencing of SFQC phases, and phase content. While these decisions have been made by subject matter experts with tremendous experience, they have lacked the ability to model these decisions before making them to understand how the changes will logistically impact the SFQC. These changes affect resource requirements such as manpower, materials, and throughput. They also have impacts on processes external to the SFQC, such as career progression, recruiting goals, and other external courses like Special Forces Assessment and Selection (SFAS) and the Special Operations Forces Captain's Career Course (SOFCCC). To keep the problem tractable given the available time, this analysis was scoped to only include ADO trainees. Additionally, only the seven phases of the SFQC were considered; external courses such as SFAS and SOFCCC were not included in the analysis.

Through phone interviews with Mr. Matthew Gorevin, an Operations Researcher for the United States Army Special Operations Center of Excellence, the following research questions were identified as key for the senior SF decision makers:

1. Given a number of initial trainees in a cohort, how many will complete each phase of the SFQC, and how many will ultimately graduate? In other words, what are the attrition rates for each phase and the SFQC as a whole?
2. For a given phase in the SFQC, how many of the students will be on their first, second, or third attempt?
3. How long will students remain in the SFQC, given that they either graduate or fail to graduate?
4. How would changing from six to four cohorts per year affect the SFQC logistically?

3. Methodology

3.1 Discrete Event Simulation

This study uses a discrete event simulation (DES) built in ProModel to model the SFQC to provide analysis of the course and propose differing methods to produce a more efficient and effective structure for the course. The purpose of the simulation is to evaluate how the SFQC can be improved by modifying elements of the simulation without having to incur the costs associated with actual implementation of changes. Elements that can be manipulated include class size, the number of classes offered in a year, the number of instructors at each phase and more.

DES is a modeling technique that models distinct events in sequence. DES can be identified as different from other simulation techniques because “the state variables change only at those discrete points in time at which events occur” (Banks 8). This allows the simulation to more accurately represent reality where entities act based on time constraints. DES is a common modeling technique for manufacturing systems and supply chain operations due to the ability to manipulate resources and time without affecting the live process (Bakrantz et al., 2017). As the SFQC has six main discrete events broken down into phases, this modeling technique is appropriate to identify potential problems with course restructuring, and ways to make improvements in the system.

Simulation techniques have many advantages including visualization, the ability to more easily diagnose problems, and low cost (Tako, 2011). Simulation modeling is unique in that you can see an animation of your project operating as it would in real time or expediated. This is beneficial to be able to identify issues within the system as well as to better understand how the data relates to the simulation. Another advantage is design implementation, which “allows you to test your designs without committing resources” (Banks, 1998) This is tremendously important because simulations can be easily analyzed by conducting modifications to explore many options. This otherwise could be expensive and time intensive.

3.2 Modeling Assumptions

Several modeling assumptions were required as the model was developed. Three of the key assumptions are listed here. First, the simulation assumes that historic success rates are accurate predictors of future success rates, and they will not vary if structural changes such as class size or time between classes are altered. Second, while Phase 6: Language actually consists of different courses in a number of different languages, historically language pass rates have been very high, so all languages are combined into one course for the simulation. Third, it is assumed that trainees flow through the system continuously based on course availability; delays due to injury or other external factors are not considered.

3.3 Development of the Entity Flow Diagram

Within the simulation, trainees are modeled as entities flowing through the SFQC. In order to move entities through the simulation effectively and track their progress effectively, this simulation utilizes three locations within each phase: a holding area, the actual course, and an exit. The holding area allows newly arrived entities at a given phase and entities that are recycled to queue at a single location. At this location their wait times can easily be tracked, which contributes to the analysis of how to best increase the efficiency the course. The holding areas also allows initial starts and recycles to be grouped in the same population and moved into a phase together rather than in separate populations. The holding areas also account for entities who, after recycling, voluntarily opt out of the course rather than re-attempting.

Figure 2 shows the entity flow diagram for Phase 6 of the course, and how the trainees moves through the phase given their input and output statuses. The trainee will arrive to the phase at the holding area. Once in the holding area trainees will either route into the phases training block or they will opt out and exit the system. Following the completion of the training, trainees can exit the location in one of three output statuses: a graduate, a recycle or a course failure. A graduate trainee exits this phase and moves into the next holding area to await the next phase of training. A recycle will return to the holding area where they will await another attempt of the non-successfully completed phase. Lastly, those who exit as a failure will exit the system through the phases individual exit. This includes entities who failed the phase or were recycled for a third cumulative time. This series of events is repeated at each phase through Phase 6. At the Phase 7 location there is no holding area because the probability of graduation following the successful completion of the first six phases is one hundred percent, making the holding area and exit locations irrelevant.

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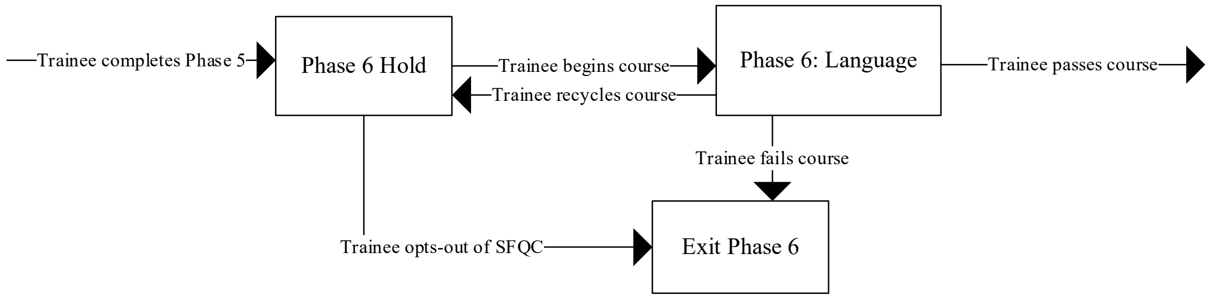

Figure 2. Entity Flow Diagram of Phase 6: Language

3.4 Data Collection and Manipulation

Once the flow of the trainees through the course had been modeled, the necessary data was collected from the past decade. The data provided came directly from the Army Training Requirements and Resource System (ATRRS), which is the main Army program of record for training records. The data includes the number of trainees who passed, recycled, or failed each class within each phase. It also includes the historic scheduling of the classes for each phase; and the number of arrivals into the SFQC. From this data, the probabilities for success, recycle, and failure were calculated trivially using division. The scheduling data were used to inform the simulation options for new entity arrivals, frequency of course starts, and course lengths.

4. Analysis and Results

4.1 Current SFQC Structure Results

First, the simulation was used to examine results with the current structure, with six cohorts arriving per year. Although the actual number of trainees per cohort can vary, this simulation assumed a constant arrival rate of 25 per cohort, for a total of 150 new arrivals annually. The simulation was run with one hundred iterations of a ten-year time span. Additionally, a two-year warm up period was used to ensure the simulation achieved steady state before data was collected and results were evaluated. Historic data was used for scheduling of courses, and new entity arrivals into the SFQC. This section examines the output of this simulation, including the distribution of graduation rates of the course and each phase, the ratio of recycles to first-time attempts for each phase of the course, and the distribution of time to complete each phase, addressing each of the research questions identified in Section 2. Section 4.2 compares these results with a scenario where four only four cohorts enter per year, which is a course of action being considered by SF leadership.

4.1.1 Graduation Rates

The first research question to answer using the simulation results is identifying the distribution of graduation rates. Table 3 describes how many entities completed each phase. Note that the number of total attempts includes both initial starts and recycles, not the number of unique entities which attempted the phase. Therefore, a phase may have more attempts than the number of graduates from the previous phase.

Also note that this table shows the overall probability of successful completion of each phase, including both first-time starts and recycle-starts. This means that the probability of successful completion only considers successes, and not recycles. The exception is the bottom row, depicting the SFQC total, since there is no way to recycle the course as a whole; a new trainee will either eventually pass, or fail.

There are a few observations from the graduation rates. First, the confidence interval for success probability is small, ranging only from 70%-74%. This is a somewhat surprising result, and if correct indicates that a deterministic model may be sufficient for high-level analysis of this system going forward.

4.1.2 Distribution of Recycles

One key question the SF leadership wanted answered was, on average, how many of the students in a given phase have zero, one, or two recycles. This can inform resourcing and potentially course structure. Figure 3 provides the total number of entities by number of recycles for each phase. From the figure, the first observation is that very few trainees will start a course as a two-time recycle. It is also clear that the phase with the most recycles is Phase 4: Military Occupational Specialty. This is congruent with the information in Table 2, because Phase 4 has one of the lowest probabilities of graduation at 73%. Likewise, Phase 3: Survival, Evasion, Resistance and Escape has a low recycle rate which is reflective of the high probability of graduating Phase 3 at 94%.

Table 2. Graduation Rates Distribution

Phase	Average Number of Total Attempts	Average Number of Successful Attempts	99% Confidence Interval for Number of Successful Attempts	Average Probability of Successful Phase Completion	99% Confidence Interval for Probability of Successful Phase Completion
Phase 1: Orientation (SFOR)	1719	1425	(1387, 1463)	83%	(81%, 85%)
Phase 2: Small Unit Tactics (SU)	1655	1297	(1263, 1332)	78%	(76%, 80%)
Phase 3: Survival, Evasion, Resistance and Escape (SERE)	1370	1284	(1250, 1318)	94%	(91%, 96%)
Phase 4: Military Occupational Specialty (MOS)	1588	1157	(1126, 1188)	73%	(71%, 75%)
Phase 5: Robin Sage (RS)	1298	1100	(1071, 1130)	85%	(83%, 87%)
Phase 6: Language (LANG)	1179	1074	(1045, 1103)	91%	(89%, 94%)
SFQC	1500	1074	(1045, 1103)	72%	(70%, 74%)

4.1.3 Time in the SFQC

Finally, the simulation provides the amount of time a trainee will spend in each phase, and the system. The simulation provides a breakdown of when trainees spend their time in operation and in waiting. Table 3 provides the average wait time and total time associated with each phase. As expected, the courses with the most recycles (SFOR, SU, and MOS) have the highest wait times. Intuitively, since trainees arrive in cohorts and the courses are aligned to move a cohort through the SFQC together, those who recycle essentially become “out of sync,” and have to wait for the next course to start.

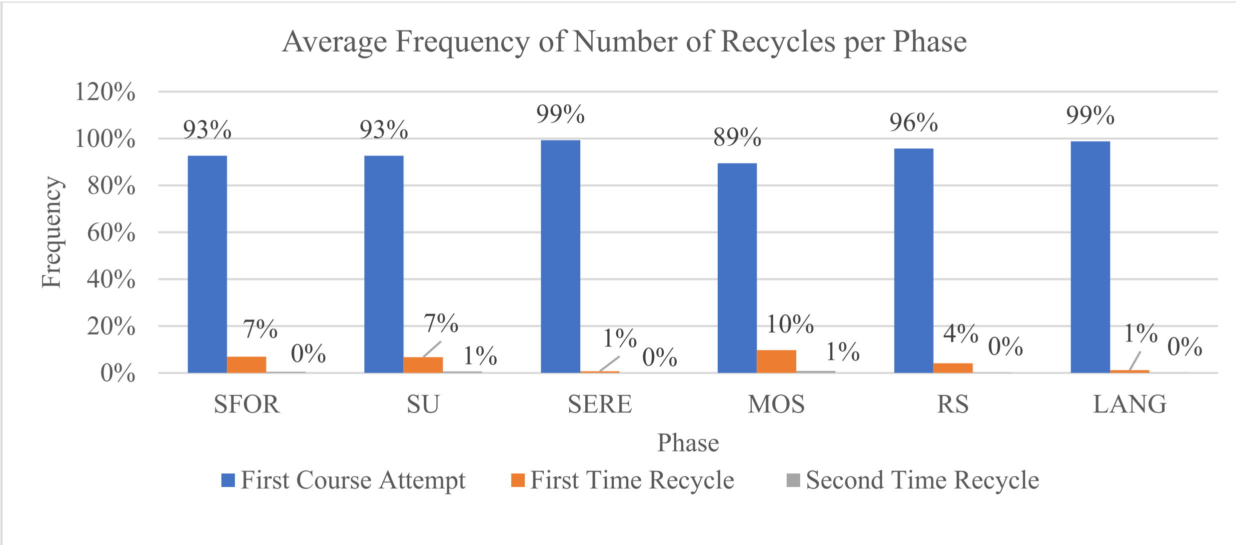

Figure 3. Distribution of Recycles per Phase

Another observation from Table 3 is that Phase 4 has a particularly long average wait time compared with the other phase. This is because not only does the course have a high recycle rate, but it is also longer than the 61 days between cohort arrivals. This means that trainees who recycles MOS will "miss" the cohort immediately following them, and have to wait for the next cohort. Possible ways to alleviate this are provided in Section 5.

Table 3. Cycle Times per Phase

Phase	Average Time in Waiting (Days)	Length of Course (Days)	Average Total Time in Phase (Days)
Phase 1: Orientation (SFOR)	8	33	41
Phase 2: Small Unit Tactics (SU)	9	44	53
Phase 3: Survival, Evasion, Resistance and Escape (SERE)	3	19	22
Phase 4: Military Occupational Specialty (MOS)	31	113	144
Phase 5: Robin Sage (RS)	6	30	36
Phase 6: Language (LANG)	6	185	191
SFQC (Total)	63	424	487

4.2 Comparison with Four Cohorts Per Year

With a baseline established for the current structure, the simulation was modified to see how changing to four cohorts per year would affect the system. Reducing the number of cohorts per year potentially reduces the resources required, assuming that the increase course sizes do not reduce quality of instruction. This scenario was also run 100 iterations, for 10 years. The course schedules were modified to assume a course was offered for each phase only four times per year. Similarly, new cohort arrivals were modified to occur four times per year. Also, the number of arrivals and course capacities were increased, to allow the same throughput despite the decrease in frequency of arrivals.

Since no changes were made to the probability of passing, recycling, or failing each phase, pass rates remained the same as the baseline scenario. The distribution of recycles per phase also saw no change in this scenario. The average waiting time and time in the system, however, did change; Table 4 provides the average waiting time and time in system for the new scenario.

Table 4. Cycle Times per Phase Using Four Cohorts

Phase	**Average Time in Waiting (days)**	**Length of Course (days)**	**Average Total Time in Phase (Days)**
Phase 1: Orientation (SFOR)	11	33	44
Phase 2: Small Unit Tactics (SU)	12	44	56
Phase 3: Survival, Evasion, Resistance and Escape (SERE)	3	19	22
Phase 4: Military Occupational Specialty (MOS)	41	113	154
Phase 5: Robin Sage (RS)	8	30	38
Phase 6: Language (LANG)	6	185	191
SFQC (Total)	81	424	505

Each phase sees an increase in wait time, making the overall wait time increase to 81 days, an 18 day increase over the baseline scenario. Over half of that increase is associated with the Phase 4, because of the course length issues raised in Section 4.1.3. However, Phase 4 contained the only major change from the baseline scenario. The other phases saw no more than a three-day increase, which is fairly insignificant considering the overall length of the SFQC. Overall the time SFQC only increases by eighteen days.

5. Recommendations

Based on the increased wait times in the four-cohort scenario, the SFQC should have six cohorts enter the system per year. This recommendation is based on the knowledge that the four-cohort scenario takes an additional eighteen days. If the goal is to produce as many highly trained professionals as possible this scenario would be more optimal. However, other factors like resources and costs heavily affect a change of this nature. It may be more cost effective to only offer four cohorts a year rather than six. In comparison the additional time may not be a significant enough factor to overcome the additional considerations.

Since the bulk of the increase in wait time occurred during Phase 4, a policy change targeting that wait time could alleviate the issue. Allowing trainees who recycle Phase 4 to "jump-in" with the following cohort after they had already begun the course would address the issue of trainees having to wait for the following course. This may not always be feasible, however, especially if the following course is at capacity. Further iterations of simulation can examine how this type of policy change would affect the results. Another possibility would be to try to have trainees recycle early in the phase, so they exit the course before the next course begins and can start with the immediately following cohort. Again, further simulation in conjunction with subject matter expert input can evaluate the appropriateness of this solution.

6. Future Work

Upon further research and simulation testing, the model of the SFQC can be expanded to include different components of the SFQC such as the enlisted population. The simulation built thus far has had this expansion in mind, and it will not be difficult to incorporate the other components. The only significant difference will be expanding the model to incorporate the different versions of Phase 4: Military Occupational Specialty. As it stands, officers only attend one of five MOS trainings. By adding the enlisted population to the simulation would more accurately reflect the larger community of SF soldiers. This process would require Phase 3: Survival, Evasion, Resistance and Escape, to route to seven separate locations: the five training blocks, the Phase 3 holding area, and the Phase 3 exit. Furthermore, Phase 6: Language could be expanded to include individual languages and their separate graduation rates.

Finally, the model could be expanded to include courses leading up to the SFQC, like SFAS and the SOFCCC, and it could also incorporate the stochastic nature of the number of annual recruits. These enhancements to the simulation would provide a more accurate representation of a broader SF population. Further analysis with this simulation could also include how to optimize arrival rates to mitigate wait times for trainees and maximizes resource efficiency. More resources could be added to the simulation which would provide greater data on how resources can be used and how they affect the training cycle time.

7. References

Bokrantz, J., Hanna, A., Lamkul, D., Perera, T., & Skoogh, A. *Data Quality Problems in Discrete Event Simulation of Manufacturing Operations.* Sage.

Banks, J. (1998), ed. *Handbook of Simulation: Principles, Methodology, Advances, Applications, and Practice*. New York: Wiley. Print.

Gorevin, M. (2019, February 11). Telephone Interview.

Promodel Advanced Simulation Training. 2015. Utah (UT): Promodel Corporations.

Promodel Simulation Essentials Training. 2016. Utah (UT): Promodel Corporations.

Training Development Division 1, DOTD, USAJFKSWSC. (2013). *Inside the SFQC.* Retrieved from the Special Forces Association website: www.specialforcesassociation.org

Tako, A. A. (2011, December). Model development in discrete-event simulation: Insights from six expert modelers. In *Proceedings of the Winter Simulation Conference* (pp. 3928-3939). Winter Simulation Conference.