Investments in Operational Attributes and Impact on Outcomes in Training Services

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Abstract
The service industry has grown considerably in the last century and investments in operational improvements have increased. Operational investments decisions have a huge impact on the profitability of the organization not only at present but also in the future affecting the sustainability of the organization. The service-profit chain is a framework that brings together several components in the service delivery process. Evaluations of service operations based on the service-profit chain and others have taken a static approach without any consideration to the feedback structure. We develop a system dynamics model to evaluate the impact of number of courses offered on profitability of training services. This is accomplished by incorporating an optimization structure using the hill-climbing algorithm. The results from the simulation are then discussed along with validation of the model.

Introduction
The service industry has grown considerably in the last century. Services can be as varied as those provided in the area of banking, health care, education and training, management consulting, communications, human services, and e-commerce, to name a few. Each of these has unique characteristics. Many of them are slowly migrating to the use of technologies, mainly the internet, as an additional option offered to their customers instead of traditional face-to-face service delivery (Curran et al., 2003). This increases the service delivery outreach to geographically distant and previously remote parts of the world. Thus creating global competition and setting organizations at the verge of constant drive for more accurate, timely and relevant decisions.

Managers in organizations make investment decisions all the time. These investment decisions have an impact on the bottom-line profits and the market penetration of the organization. Not all such decisions are evaluated for their impact. Some have more impact than others do. The Service-Profit Chain (SPC) (Heskett et al., 1994) is a theoretical approach that brings together several components of the service delivery system to evaluate investments. These components are,

- operational attributes like number of tellers in a bank, number of flight schedule options to a particular city available to customers;
- customer perceptions like service quality, value, satisfaction;
- customer behavioral intentions[1] to refer/recommend and/or return;

[1] Customer behavioral intentions are the intentions that the customer forms about his/her future behavior based on the perceptions of the service received.

- customer loyalty[2] including referrals/recommendations that were fruitful and actual behavior (e.g. returns) that indicate loyalty and finally,
- financial component including expenses, revenue, surplus/profits.

The idea of 'profit' that has been introduced seeks to ascertain that the revenue generated is greater than the expenses incurred by the organization as of today. It does not talk about the future. Profitability, taking into consideration today's constraints, does not guarantee tomorrow's profits. Further, profitability is not the only outcome that today's managers need to be concerned about. Other outcomes such as the extent to which the market is penetrated and marginal return on the investment made are also important. And any investments being made at present not only has an impact on tomorrow's profits but also on tomorrow's market penetration with varying marginal rates of return. So, how can today's manager know or decide when and how much to invest in operational attributes and whether such investments will sustain the operation? To be able to answer this question, we will look at the following questions:

1. How do investments in operational attributes affect the long-term sustainability[3] of the organization?
2. For any given investment problem in services, how much can one invest in operational attributes over a period of time and expect to get an adequate financial return (bang for the buck)?
3. Similarly, can the model identify the point in time beyond which the marginal rate of return decreases over time?

This paper describes a model for the business component of Health & Safety Services department for First Aid CPR training at a three billion dollar organization. The model is simulated to answer the above questions. This is accomplished using the hill-climbing algorithm (Sterman, 2000) to identify the steady state of the system. This is done through a search pattern by sensing whether there is too much or too little of the components of the system structure. The Susceptible-Infectious (SI) epidemic model in Sterman (2000) is modified in this research to depict the relationships between potential customers and actual customers. The model developed in this research can handle multiple operational attributes. By using this model, a decision-maker will be able to evaluate the impact of simultaneous investments with respect to multiple attributes.

Service-Profit Chain

Heskett et al. (1994) establish relationships between profitability, customer loyalty, employee satisfaction, employee loyalty, and productivity. The authors call this the Service-Profit Chain and propose several links. They say that profit and growth are simulated primarily by customer loyalty. Loyalty is a direct result of customer satisfaction, which in turn is largely influenced by the value of services provided to customers. This value is created by satisfied, loyal and productive employees. Employee satisfaction results primarily from high quality support services and policies that enable employees to deliver results to customers.

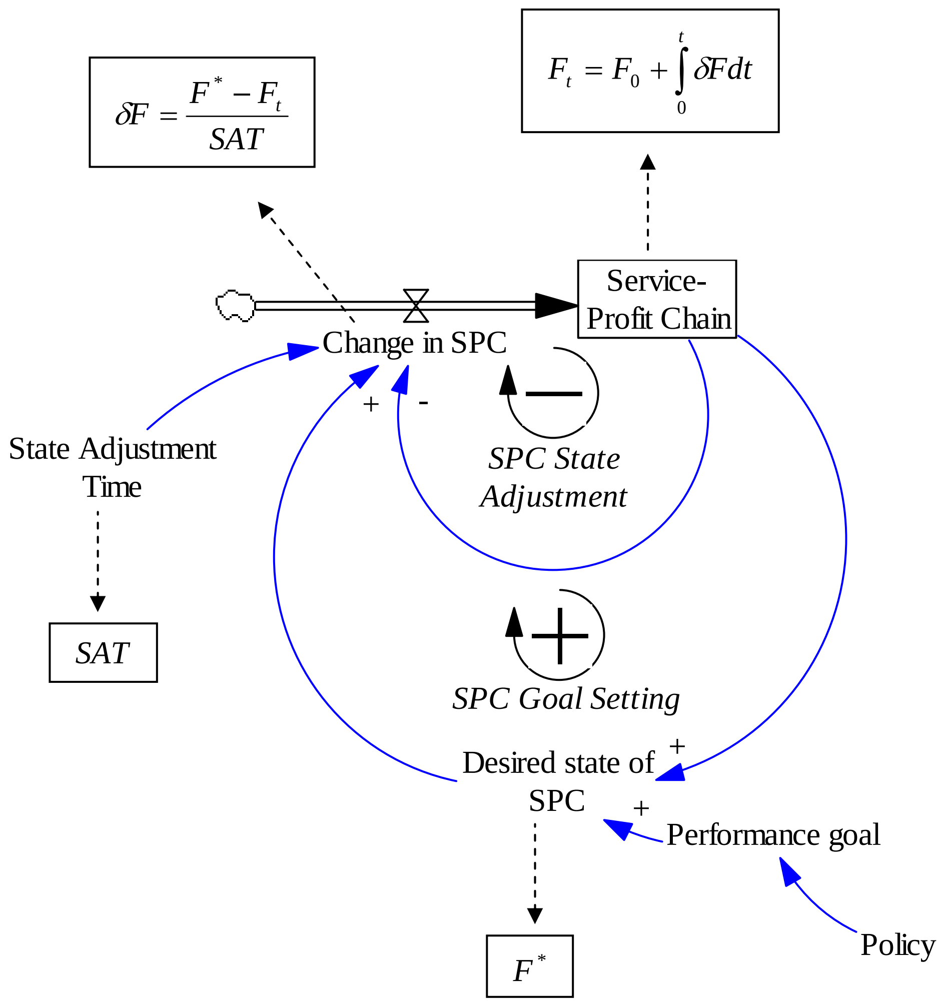
[2] Customer loyalty is the dependability or faithfulness of the customer to act in a manner that is beneficial to the organization.
[3] Sustainability is the ability of an organization to uphold its state in the market place.

Evaluation of the Service-Profit Chain

Let F represent the transformation function formed because of the interactions between all the components of the SPC. Hence, F_t will represent the state of the SPC at any point in time t. Based on Sterman (2000), the system dynamics model for identifying the steady state of the transformation function F_t (here the SPC) is shown in Figure 1. The model consists of two loops, one balancing *SPC State Adjustment* loop and one reinforcing *SPC Goal Setting* loop. The balancing loop tries to correct for the discrepancy by closing the gap to get to the desired state. The reinforcing loop sets the desired state for the system. The desired state of the system is determined by performance goal that is affected by external factors like policy decisions.

Simulating this model will determine the *Change in SPC* required to alter the current state of the *Service-Profit Chain* to attain the *Desired state of SPC* and thus determining the steady state for the SPC. The *Change in SPC* includes all interventions that will be made by the decision maker to the operational attributes and price.

Figure 1. Evaluation of the transformation function



This generalized model can evaluate the overall impact on market penetration/revenue/surplus when simultaneous investments are made in multiple operational attributes (1, 2, … n). This is done through the search algorithm built around the multiple operational attributes. Price is another attribute that has a search algorithm and helps setting the price at the optimal level. The higher the price per customer, the more will be the overall revenue. But on the down side, higher priced services will tend customers to perceive lower value for money (all else being equal).

All optimizations which are heuristic search algorithms have similar structures. The outcome from the current state of the SPC is compared against the performance goal to set a target for the operational attribute (or price). This target which is part of the reinforcing loop sets the desired amount of operational attribute (or price). The balancing loop searches for the appropriate amount of the operational attribute (or price) by trying to close the gap (or discrepancy). Thus, the balancing loop acts together with the reinforcing loop to determine the optimal level, while simultaneously, determining the behavior of the system.

Evaluating Training Services using SPC

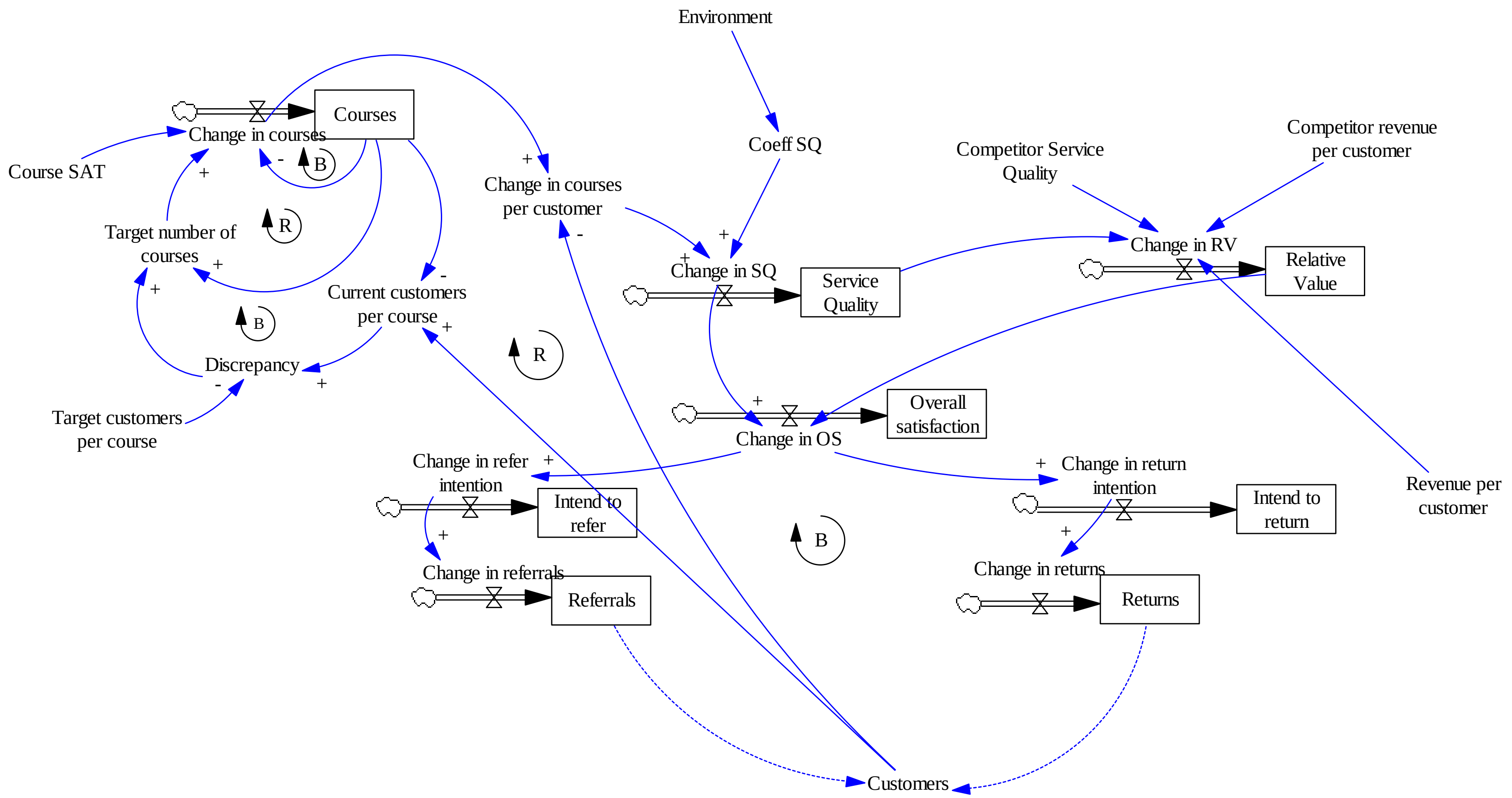
The Merriam-Webster dictionary gives the definition of *training* as ‘to teach so as to make fit, qualified or proficient’. Training is a service that focuses on a specific topic and aims at making the student proficient. Educational institutions offer training services to students. Due to the students’ intimate involvement with the educational process, students have traditionally been viewed as a product of an educational institution, Gold (2001). However, Wallace (1999) suggests that, although using the term ‘customers’ can arouse many emotions and misconceptions in academia, referring to students as customers does not mean that administration cannot or should not drive the educational agenda. Now, there is consensus that the student is the primary customer of educational services, Banwet and Dutta (2003). Ham and Hayduk (2003) claim that service quality improvement is important for educational services and university’s administrators and business leaders should make investments for the same. Service quality, customer satisfaction and behavioral intentions are global issues that affect all organizations, and educational institutions are no exception to this, Ham and Hayduk (2003). The current research considers students as customers and evaluates such investments made in operational attributes to improve service quality, satisfaction, loyalty and eventually market penetration/surplus, etc.

This section builds a system dynamics model to evaluate the sustainability of investments in operational attribute improvements in the SPC as it relates to training services. The model is developed in modules.

Dynamic Service-Profit Chain

The module is shown in Figure 2 and includes one operational attribute – number of *Courses* offered. *Target customers per course* is a performance goal based on policy decisions made by the organization. Customers perceive this operational attribute based on the course to customer ratio. For any *Change in courses per customer* there is a change in service quality (*Change in SQ*). Change in the *Environment* affects a change in service quality through the coefficient of service quality (*Coeff SQ*). *Revenue per customer* (shown as Price in the operational model) and *Competitor revenue per customer* (shown as competitor price) both affect the *Relative value*. By offering more number of *Courses*, the organization presents more locations and schedule options for the customer. Because of this, the customer is expected to have an increase in the perceived *Service Quality*, *Overall satisfaction*, intentions and loyalty in terms of *Referrals* and *Returns*, thus increasing the number of *Customers*. Dashed arrows between *Referrals*/*Returns* and *Customers* show existence of other variables that affect the relationship and are explained in detail in the Customer Base Growth module. *Course SAT* stands for Course State Adjustment Time and determines how often the state variable *Courses* is adjusted. Or, how long it takes to make changes to number of *Courses*. The actual time depends on the type of operational attribute (e.g. changing number of courses offered is easier and can be done more often than changing the number of locations, hence the former will have a lower SAT than the latter), application and industry.

Figure 2. Dynamic SPC Module



The *Current customers per course* is compared against the *Target customers per course*. Based on the comparison and the current number of *Courses*, the *Target number of courses* is set which alters the *Change in courses*. For a given *Target number of courses*, the closer the number of *Courses* to the target, the lower the *Change in courses* that is required. Thus the structure determines the steady state for the system. Such a state is known to have reached when the system is in dynamic equilibrium. In other words, quantity that enters the system (inflow rate) is equal to the quantity that leaves the system (outflow rate) and the state variables have a constant amount. The system will continue to exhibit this steady state behavior until another intervention or a change in one of the exogenous factors is effected. Next, the Customer Base Growth module is discussed.

Customer Base Growth

This module of the system dynamics model is built around the number of *Customers* the organization is serving at any given time period. *Customers* is a stock variable and the units of measurement will be the number of people. *Potential Customers* is another stock variable indicating the number of people in the market that could become potential customers. *Customers* are replenished by the people from the *Potential Customers* by adoption. There are two types of adoption, *Normal Adoption* and *Referred Adoption*. *Normal Adoption* will be discussed later. *Referred Adoption* accumulates *Customers* with the number of people that had the need and decided to take the service based on a positive referral made for the organization under study. What percentage of the *Potential Customers* actually adopts the service is determined by *Referrals,* which is measured as a percentage. *Market size* is an exogenous factor that also affects the *Referred Adoption* rate.

The concept of customer referrals is analogous to the SI-model for infectious diseases (Kermack and McKendrick, 1927; Sterman, 2000). The SI-model captures the structure of spread of diseases where the infection is contagious. The disease spreads from one person (from the Infectious Population) to another (from the Susceptible Population) when they come in physical contact with one another. In the SI-model, *Contact Rate* (c measured as the number of people contacted per person per time period) is the rate at which people in the community interact. The *Susceptible Population* (S measured as the number of people) brings about Sc contacts. The probability that a randomly selected encounter is an encounter with an infectious person is I/N (I is the total of *Infectious Population* and N is the *Total Population*). The model assumes that infected people are not confined to bed or quarantined. This assumption is irrelevant to the Customer Referrals model, since except for the duration of the training/course, which is a very negligible amount of time compared to the duration the infected people will be confined to bed or quarantined, *Customers* will interact with other people at the same rate as *Potential Customers*. Among the encounters in the SI-model, not every encounter with an infectious person leads to infection. Infectivity (i) of the disease is the probability that a person gets infected after contact with an infectious person. Thus, Sterman (2000) gives the *Infection Rate* (IR) as the total number of encounters, Sc multiplied by the probability that the encounter is with an infectious person, I/N multiplied by the probability i that an encounter with an infectious person results in infection:

$$IR = (ciS)(I/N)$$

Further, assuming that the *Total Population* remains constant,

S + I = N
Hence, the *Infection Rate* is
IR = (c)(i)I(1-I/N)
As we can see, the product c*i is the probability that any contact results in infection. The equivalent of this product for the Customer Referrals model would be the percentage of the people that were referred and ended up coming to the organization. The reason why it is inappropriate to explicitly model the *Contact Rate* for the Customer Referrals model is because, unlike the SI-model, people do not need to come in physical contact with one another to refer. The population density or spread of the community does not affect the contact rate, since one can refer another even over the phone or internet. In other words, the Customer Referrals model aims to capture the proportion of people that got referred and ended up taking the course, which is a percentage, *Referrals*. The state variable *Referrals* is the link between the Customer Base Growth and the Dynamic SPC modules. The percentage of *Referrals* determined by the Dynamic SPC module for any given year feeds the Customer Base Growth module. Table 1 shows the analogy between the two models by listing out the corresponding variables.

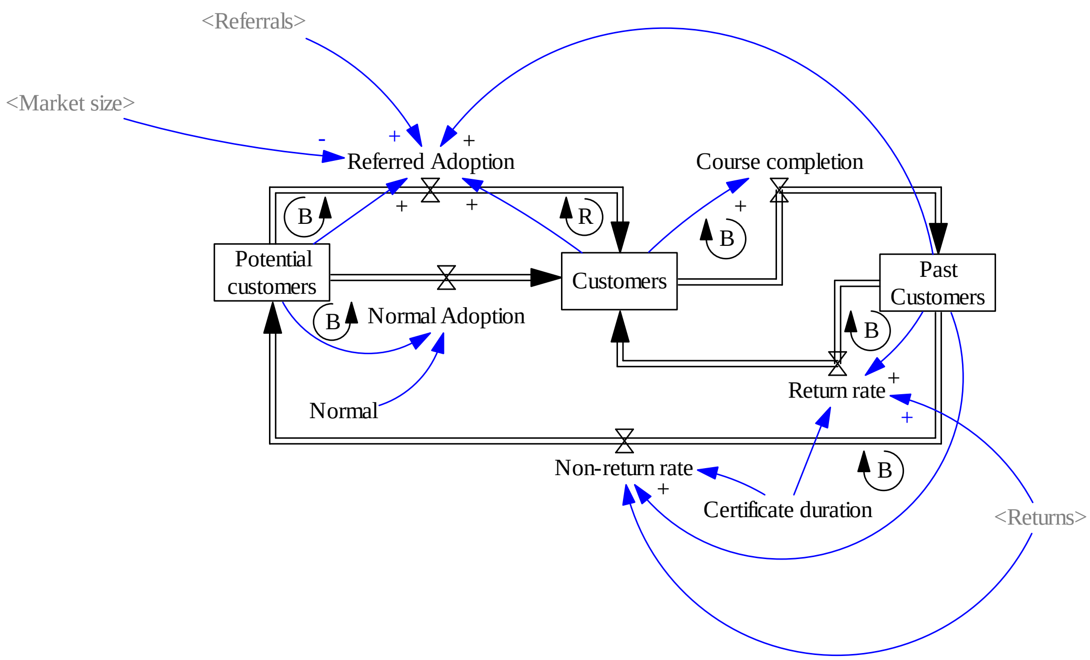
Table 1. Analogy of Customer Referrals to SI-model

Customer Referrals	SI-model
Potential Customers	Susceptible Population
Referred Adoption	Infection Rate
Market Size	Total Population
Referrals	Contact Rate * Infectivity
Customers	Infectious Population

Customer referrals is one part of the overall “Customer Base Growth” module. There are other parts in the module, normal adoption and returns, which will be discussed now. *Normal Adoption* encompasses people that choose to take the training service because they have a need to do so but were not referred by former customers. *Normal* is the percentage of potential customers that take the course without referrals. The greater the *Potential Customers* are, the greater will be the *Normal Adoption* rate.
Past Customers is another stock variable that tracks the number of people from the moment they complete the course/training to when their training certification expires. *Certificate Duration* is the amount of time for which the certification is valid. The *Course Completion* rate depletes the current *Customers* and accumulates *Past Customers* as the people taking the training complete the requirements for the certification. As the number of people cannot exceed the market size, at any point in time, the sum of *Potential Customers*, *Customers* and *Past Customers* is always equal to the *Market Size*. Both *Customers* and *Past Customers* can refer people and hence, both affect the *Referred Adoption* rate.
Referrals is one type of customer loyalty and the other type is retention or the return of a prior customer for repeat business. *Past Customers*, based on their experience with the service, decide either to return back or not for more service once their certification expires. The ones that return replenish the *Customers stock* through *Return Rate* and the

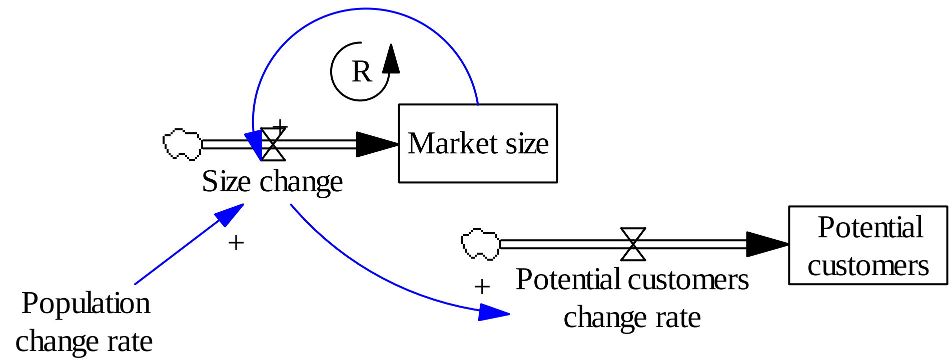
ones that do not come back after the expiration of their certification feed in back to *Potential Customers* through *Non-return Rate*. *Return Rate* and *Non-return Rate* are determined by *Returns* (measured as a percentage of people that come back) and *Certificate Duration* (measured as the number of time periods for which the certification is valid). *Returns* is a link between the Dynamic SPC module and the Customer Base Growth module. The percentage of *Returns* determined by the Dynamic SPC module feeds the Customer Base Growth module.
Market Size, *Referrals* and *Returns* are shown here as shadow variables because they are exogenous to the Customer Base Growth module. The module is shown in Figure 3. Change in Market module (which *Market Size* is a part of) will be discussed next.

Figure 3. Customer Base Growth Module



Change in Market
Market Size, and hence the *Potential customers* can change because of several reasons like birth/death/immigration/emigration. There is a reinforcing loop, as *Market size* increases, the *Size change* also increases, further increasing the *Market size*. *Population change rate* affects the *Size change* rate which in turn alters the *Potential customers change rate*; eventually altering the *Potential customers* in the Customer Base Growth module. This is shown in Figure 4.

Figure 4. Change in Market



Putting together all the above modules, Figure 5 shows the full-blown system dynamics model and Table 2 lists the state and control variables modeled in the SSC.

Figure 5. Full-blown System Dynamics Model

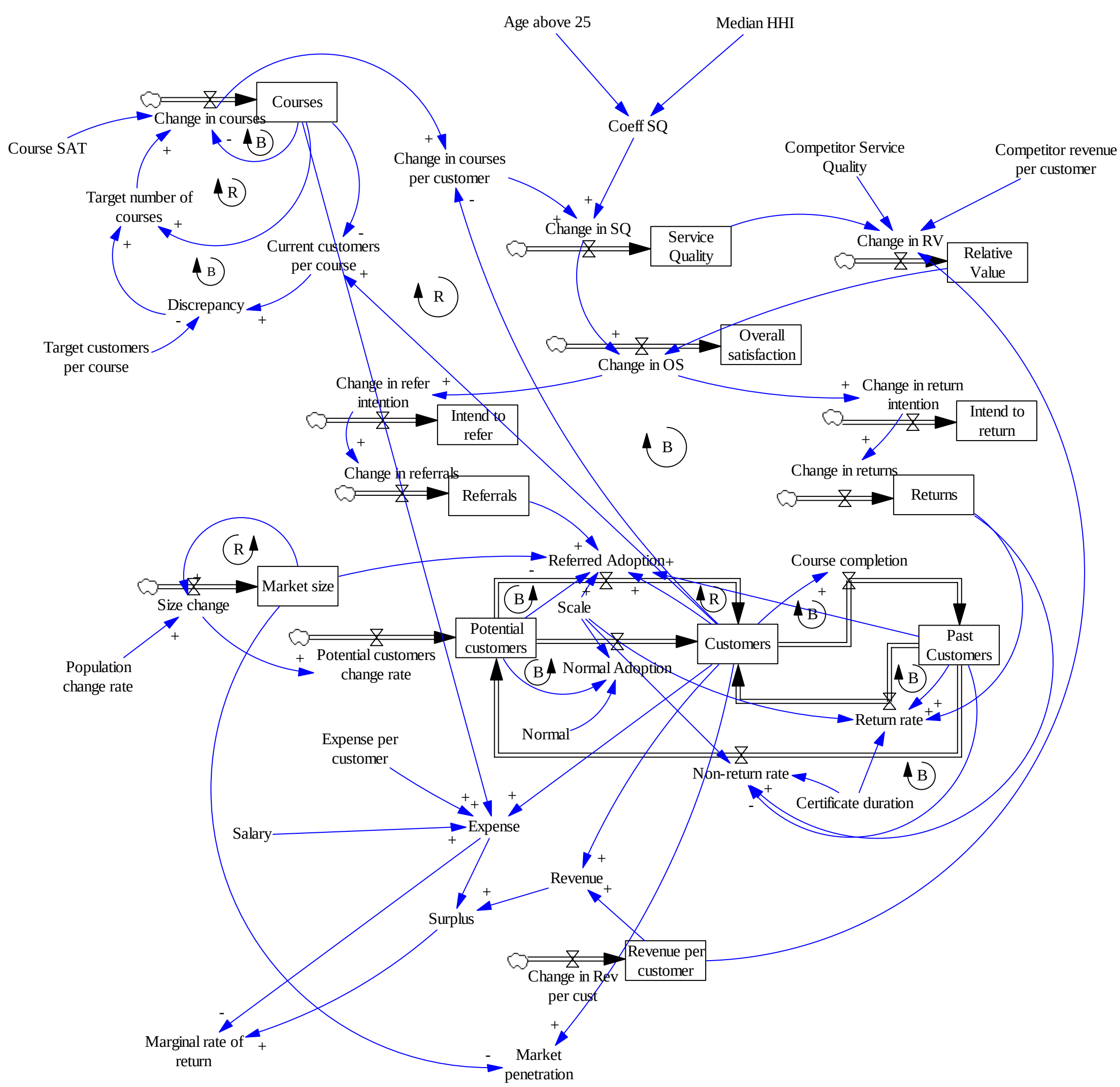


Table 2. State and Control variables in the SSC

Component of SSC	Dimension	State variables modeled as stocks	Control variables modeled as flows
Operational attribute	Improvement effort	Courses	Change in courses
Customer perceptions	Service quality	Service quality	Change in SQ
	Value	Relative value	Change in RV
	Overall satisfaction	Overall satisfaction	Change in OS
Customer behavioral intentions	Referral/Recommendation intentions	Intend to refer	Change in refer intention
	Retention intentions	Intend to return	Change in return intention
Customer loyalty	Referrals/Recommendations	Referrals	Change in referrals
	Retention	Returns	Change in returns
Customer Base Growth		Potential customers Customers Past customers	Referred Adoption Normal Adoption Course completion Return rate Non-return rate
Uncontrollable factors		Market size	Size change

The Problem

Field unit A of the organization has a policy establishing that they should register no more than ten customers in each course offering. This field unit is interested in knowing whether it is a sustainable policy. Is their customer base poised to increase? How do they need to phase in their investments in increasing course offerings over time? What is the exact impact on service quality, satisfaction and on customer loyalty which in turn affects the number of customer walk-ins? To what extent can the field unit increase the number of courses and expect an increase in market penetration? Is there a point in time beyond which the marginal rate of return decreases with investments?

All of these questions can be answered by applying the methodology and the model developed in this research. Field unit A of this organization is large and complex, with many departments and functions interacting. A problem of this sort involves various aspects like financial, capacity, service delivery, market research, etc. Knowledge of the entire operation is much diluted in several departments and no one person has a holistic view to address the questions identified previously. However, large amounts of data are being collected year after year. These large amounts of data can be used along with the model and the proposed methodology to answer the questions in the case study.

The field unit knows that the main competitor in the market provides a similar course for $60 (lower when compared with the field unit’s course fee of $65) but they believe the contents are of lower quality. The relative value[4] of the course offered, based on a previous study, was rated at 78.7%. Since service quality[5] itself was not a measured item in that study, it will be set arbitrarily at some percent and the changes will be modeled and analyzed. Service quality of the filed unit is set at 50% (meaning 50% of the customers rated the service as ‘Excellent’) and that of the competitor at 40% (lower since past study shows a lower service quality) based on input from experts.

Unit of Analysis

The unit of analysis will be a field unit. Field units have Health & Safety instructors employed to teach the courses and train the people. They use books, videos and other materials for providing these courses. Typical settings for teaching are the field unit office, schools and other office buildings. A lot of data is collected around this operation. Customers are surveyed about their perceptions. Responses to surveys were aggregated at the field unit level.

Two delays are used as part of the model, both as state adjustment times[6]. One is the *course state adjustment time* and equal to one year. This means that the number of courses can be changed once every year. This can be changed when using the model for another field unit, if need be. For instance, another field unit might be capable of making such an intervention more often, say every six months. In that case, the course state adjustment time will be six months. Further, the state adjustment time will vary for different operational attributes.

The other state adjustment is *certificate duration* which is set at 2 years. *Certificate duration* affects three state variables – *customers*, *potential customers* and *past customers*. *Certificate duration* affects *customers* through *return rate*, affects *potential customers* through *non-return rate* and affects *past customers* through both *return rate* and *non-return rate*. *Certificate duration* determines how long it takes to deplete the state variable *past customers* by the amount of customers whose certificate expired, through *return rate* and through *non-return rate*. Simultaneously, the amount of customers depleted by *return rate* replenishes *customers* and the amount of customers depleted by *non-return rate* replenishes *potential customers*. Both *return rate* and *non-return rate* are affected by both, *past customers* and *certificate duration*. Thus the time delay (certification validity time) of the customers is captured using the *certification adjustment* state adjustment time.

The time step of simulation in this case was originally set at one year. Later, the time step had to be reduced to 0.5 year (six months) based on the findings in model validation. The results shown are with a time step of six months. The time horizon was set at 20 years to illustrate the achievement of steady state in the long term. Data was available only on a yearly basis. However, if more frequent data were available, more realistic and accurate predictions of behavior can be made.

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[4] Relative value is defined as the value perceived by the customer based on the quality of the service received for the price paid in comparison to the quality of similar service offered by competitors for their price (McDougall and Levesque, 2000).

[5] Service quality is the quality of the service provided by the organization to the customer and constitutes a set of items. Service quality is measured as it is perceived by the customer using these items on a survey instrument shown in Appendix C.

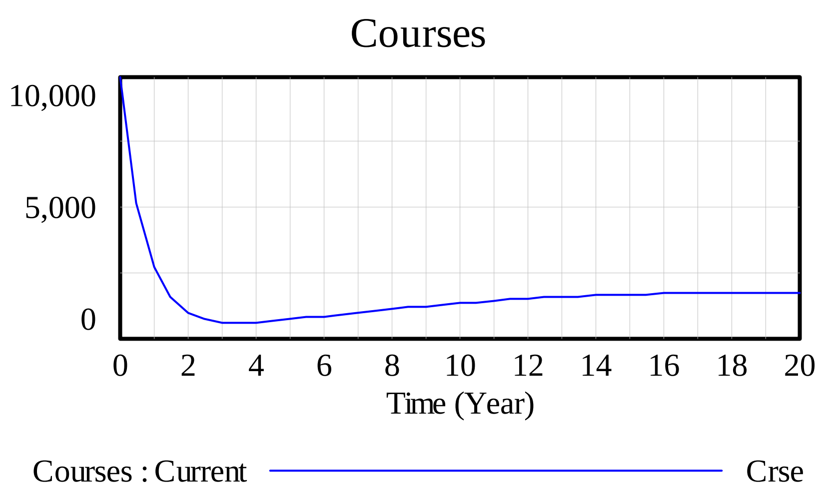
[6] State adjustment time is the time taken to make changes or adjustments to the state of the system.

Validation

Validation includes tests around developed computer programs and simulation runs. Validation is also referred to as model verification (Law and Kelton, 1991). Typically, tests for extreme conditions, integration errors, surprise behavior and sensitivity analysis are part of results validation (Sterman, 2000).

The model was tested for robustness under extreme conditions by altering several variables over a large range. For instance, initial number of *Courses* was varied over a range from 1 to 10,000. Of course, for the size of the field unit under study, 10,000 courses is a very extreme case. The model handled changes at either extreme well and this is evident from the behavior. The initial value is important in determining the starting point but does not interfere with the hill-climbing algorithm (as expected) to seek the optimal path and the equilibrium. The model corrects drastic changes of the initial values in the beginning time periods and exhibits similar smooth behavior patterns to attain the same steady state or equilibrium over time. One such extreme behavior pattern with the initial value of *Courses* = 10,000 is shown in Figure 6 below. A different behavior from the base case is obtained because of the change in the initial value.

Figure 6. Extreme condition behavior



Similar trends were noted with other variables in the model. This validates the robustness of the model under extreme conditions.

The model was then tested for integration errors using the time step method (Sterman, 2000). For this, the time step for the simulation was reduced to 0.5 years (six months) from the original one year. This gave similar behavior patterns but the sharp peaks and troughs were replaced by smooth curves. This is because, with a smaller time step, more accurate integrations and calculations were possible, with additional computing time and power. When the time step was further reduced to 0.25 years (three months), the behavior was more or less the same as those for a time step of 0.5 years. Hence, the appropriate time step for the simulation of the case study is 0.5 years (six months), since expending additional computing time and power for no additional benefit is meaningless.

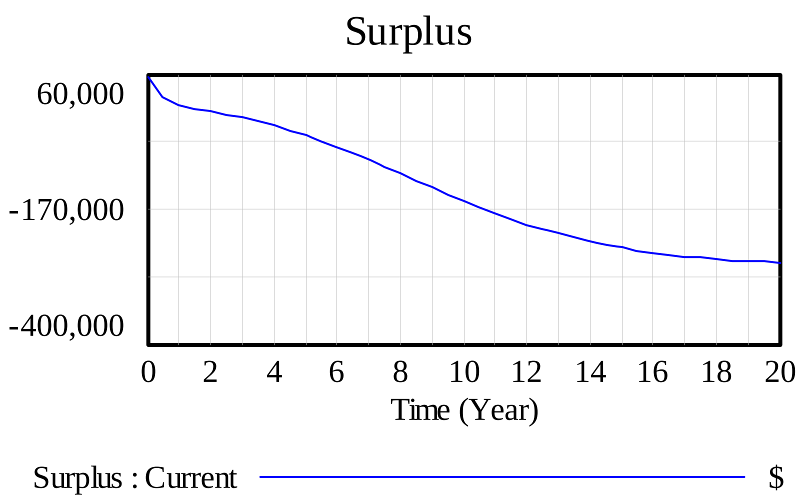
One surprise behavior was identified during the simulation of the case study. Overall satisfaction increases only 0.15%. The original expectation was to observe a much higher increase. On further investigation of the structure and studies of several simulation runs, it was determined that number of *Course* offerings as an operational attribute, though significant, does not have a huge impact on service quality and subsequently value and overall satisfaction perceptions. Further, the impact is also diluted by the effect of the environment on service quality perceptions. These are important findings for the research per se and thus, reinforce the importance of model validation. For the decision maker, this means that the number of courses for sure is an operational attribute that has a significant impact on the perceptions of customers, but not necessarily one with a huge impact. The decision maker should consider other operational attributes to have a bigger impact on service quality and overall satisfaction.

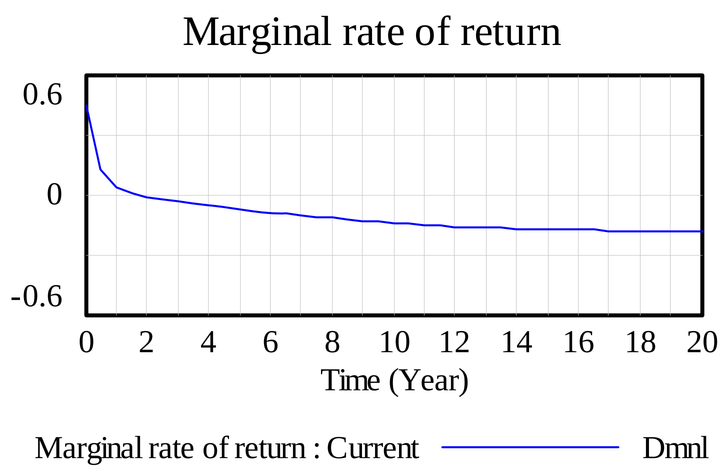
Sensitivity analysis is another important step in results validation. It is related to robustness under extreme conditions in a sense that, extreme conditions test behavior at extreme points (such points are set very extreme such that there are no possible outer points) but sensitivity analysis tests behavior within the range. This is used to determine if the model behavior changes significantly when the input parameters are changed (Law and Kelton, 1991). According to Sterman (2000), sensitivity analysis is more than just changing the input values and there are three types of sensitivity analyses – policy, behavior mode and numerical. Policy sensitivity exists when a change in assumption reverses the impact or desirability of a policy. Behavior mode sensitivity exists when changes in assumptions in the model change the behavior pattern and finally, numerical sensitivity exists when changes in assumptions changes the numerical results of the model. As Sterman (2000) points out, all models exhibit numerical sensitivity, and the model developed in this research is no exception to this.

Policy sensitivity analysis was conducted over several components of the model. One policy sensitivity that the model (to be precise, this is a sensitivity of the methodology due to insufficient data) possesses is around relative value. The model can be simulated as long as the service quality of the field unit is greater than the competitor and the price (revenue per customer) of the competitor is lower than the field unit. Under other conditions, the relationships/equations between the environmental variables and service quality identified in this research are still valid. However, those between the components in the SPC (customer perceptions, customer behavioral intentions, customer loyalty) cannot be used. Of course, this sensitivity can be relaxed by incorporating into the structure, additional relationships between these variables (service quality, price, competitor's service quality and competitor's price) and the impact on relative value under different conditions.

Dropping the policy of no more than ten customers per course to five, there was a reversal from a surplus to a deficit and a continuously dropping marginal rate of return to below zero, see Figure 7. The reason for such a behavior is under-utilization of the resources (here, ability of the instructor to train a certain number of customers in one course offering). Lesser customers are trained for each course offering who perceive the service provided to be of better quality and hence an increase in overall satisfaction by almost 0.5% (number of additional people that rated the service as 'Excellent' on the survey instrument) compared to the 0.15% in the base case scenario. On checking the results with experts and field unit managers, it was validated that even such slight increases in service quality and overall satisfaction are very hard to come by and are necessary for the field unit to flourish in the market. However, expenses are higher and hence the surplus plummets.

Figure 7. Policy sensitivity: No more than five customers per course



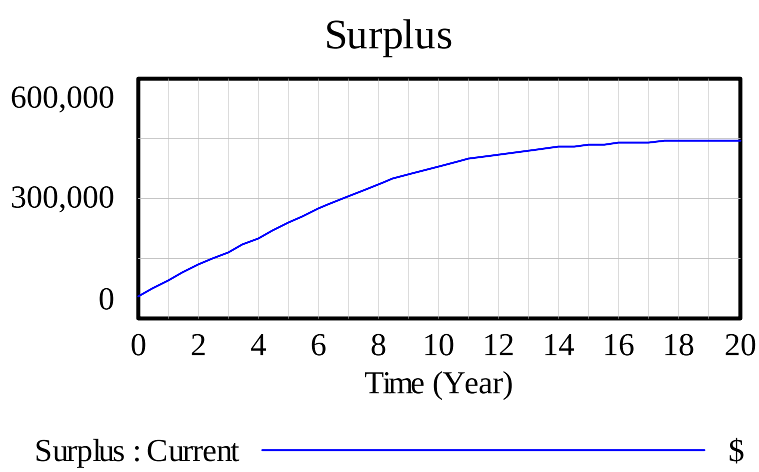


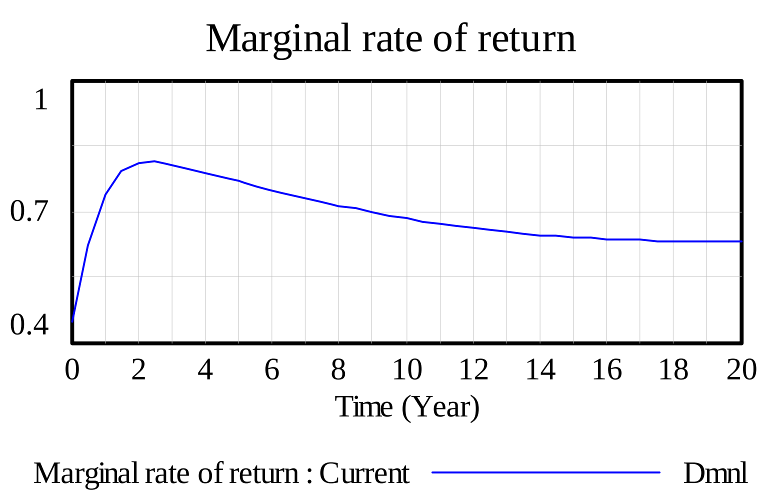
When the policy was increased to no more than 15 customers per course, both surplus and marginal rate of return shot up, see Figure 8. Such small changes in the policy in either direction make a very large displacement from a deficit of $261,000 (and marginal rate of return of -0.185) at steady state to a surplus of $445,000 (and a marginal rate of return of 0.63) at steady state. Here, although there is a huge surplus and a good marginal rate of return, overall satisfaction almost did not have any change from the initial 53%. Such reversal effects happened because changes in assumptions in policy are analogous to changes to a 'hand holding a bull-whip' exhibiting a bull-whip effect. When a hand holding a bull-whip is moved back and forth rapidly, even for small movements of the hand, the tip of the bull-whip has very large displacements.

What does this mean for the field unit? Is it good to have a deficit with an increase of 0.5% overall satisfaction or to have a surplus and no impact on overall satisfaction. Of course, there is a trade-off and the effects in this case study are enlarged to illustrate the point. Having immediate surplus, without improvements in overall satisfaction can be good during the short term, but is a recipe for the operation to fade away slowly. On the other hand, having deficits cannot sustain the operation. Hence the manager is forced to find a suitable compromise between either extreme; to have surplus and also have positive effects on overall satisfaction. With such a compromise, the model would suggest the optimal path to the steady state. This optimal path will determine necessary interventions at every point in time during the entire time horizon. As identified earlier, changing the policy to no more than 11 customers per course keeps surplus, marginal rate of return and also penetration at realistically (as validated by experts) high levels with an increase in overall satisfaction.

Change in other variables did not exhibit such large and dramatic displacements. This reinforces the importance of different variables in the model for the decision making process.

Figure 8. Policy sensitivity: No more than 15 customers per course





The model has slight behavior mode sensitivity as determined under changes in assumptions to the population change rate. When population was assumed to decrease at 10% per year, the behavior of surplus changed form the original goal-seeking behavior to an overshoot and collapse behavior, see Figure 9. On the other hand, when the assumption was changed to an increase of 10% per year, the behavior was exponential, see Figure 10. But all other variables had same behavior patterns under both scenarios. Such behavior was expected as 10% increase or decrease is a significant change to the assumption. However, there were no major reversals (for example from surplus to deficit or vice-versa) such as those discussed in policy sensitivity. This also illustrates that some parameters and assumptions have greater impact on the results and behavior than others. For instance, changes in policy were significant enough to decide a surplus vs. deficit. On the other hand, changes in market result in changes only in behavior pattern. Such parameters and assumptions are points of leverage where slight changes can make significant differences. More than just validations, these are also findings as part of the case study that can be used in decision-making.

Figure 9. Behavior mode sensitivity: Population decreasing at 10% per year

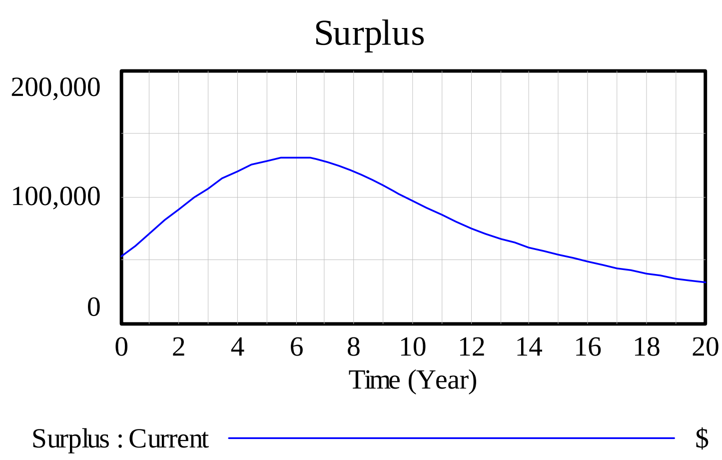
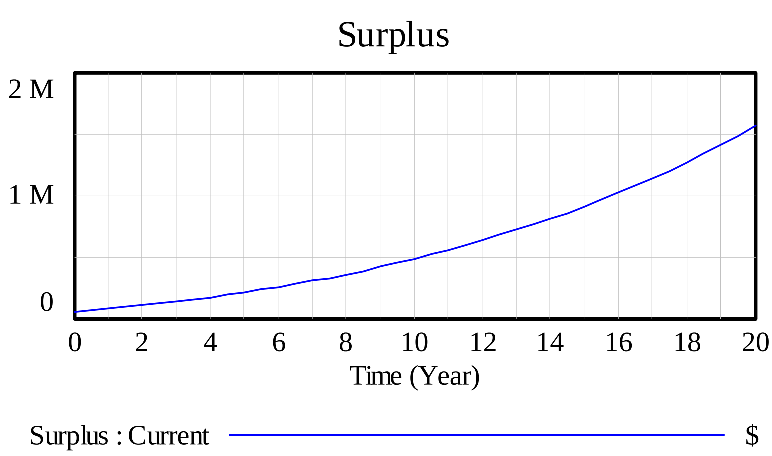


Figure 10. Behavior mode sensitivity: Population increasing at 10% per year

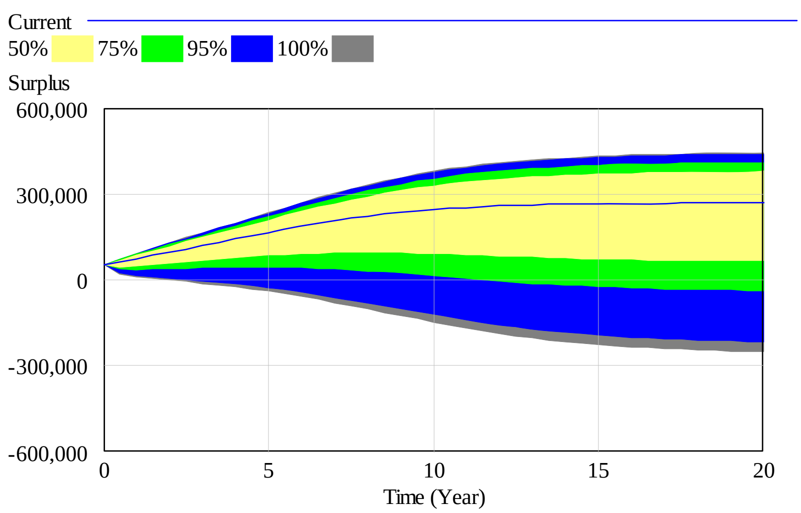


Numerical sensitivity analysis is typically done where the input values are altered based on random numbers generated by some distribution (Law and Kelton, 1991). Monte Carlo simulations, also known as multivariate sensitivity simulations change the parameters based on such random distributions to determine best, worst and most likely outcomes of the simulations (Sterman, 2000).

For this case study, such Monte Carlo simulations were used to perform sensitivity analysis and determine the confidence bounds for key variables – *Overall satisfaction*, *Surplus*, *Market penetration* and *Marginal rate of return*. Each scenario was simulated with 200 iterations. The graphs show the variability associated with the behaviors with changes in the parameters. The four bands have corresponding confidence bounds (as percentages). For instance, for a confidence bound of 95%, there is 95% likelihood (or probability) that the variable will have a behavior pattern within those boundaries (Vensim, 1998). Three scenarios were analyzed.

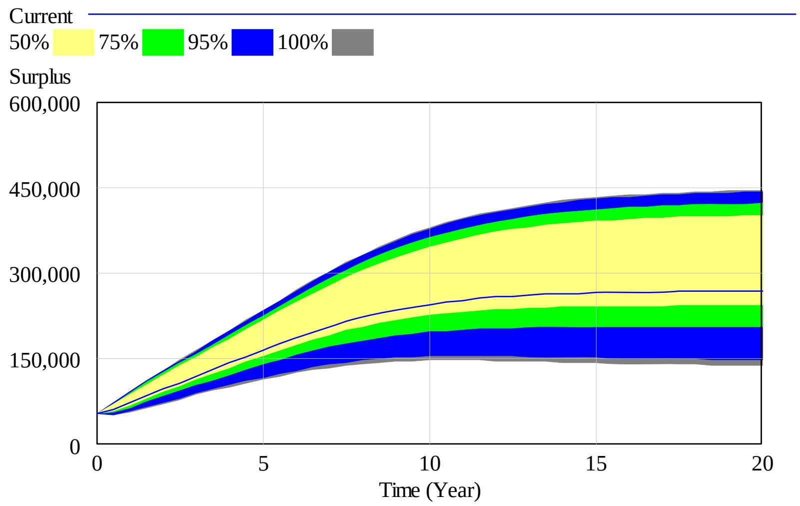
For scenario 1, the environment was held constant to better comprehend the effect of policy-making on the outcome. The policy was allowed to vary between no more than 5 customers per course and no more than 15 customers per course. For this, *Target customers per course* was allowed to vary uniformly with a minimum of 5 and a maximum of 15. The confidence bounds from the sensitivity analysis are shown in Figure 11 below. It can be seen that there is only 50% likelihood that there will be a surplus over the time horizon. Even moving to a slightly higher confidence bound of 75% has a chance of deficit. The behavior with 10 customers per course is also shown by the blue line corresponding to 'Current' discussed under the base scenario.

Figure 11. Confidence bounds: Major variation in policy



When a more realistic range of 8 to 15 was used for the *Target customers per course*, the confidence bounds changed drastically showing definite surplus with 100% confidence, see Figure 12. This gives valuable information to the decision-maker in terms of confidence in the profitability of the operation.

Figure 12. Confidence bounds: Realistic variation in policy



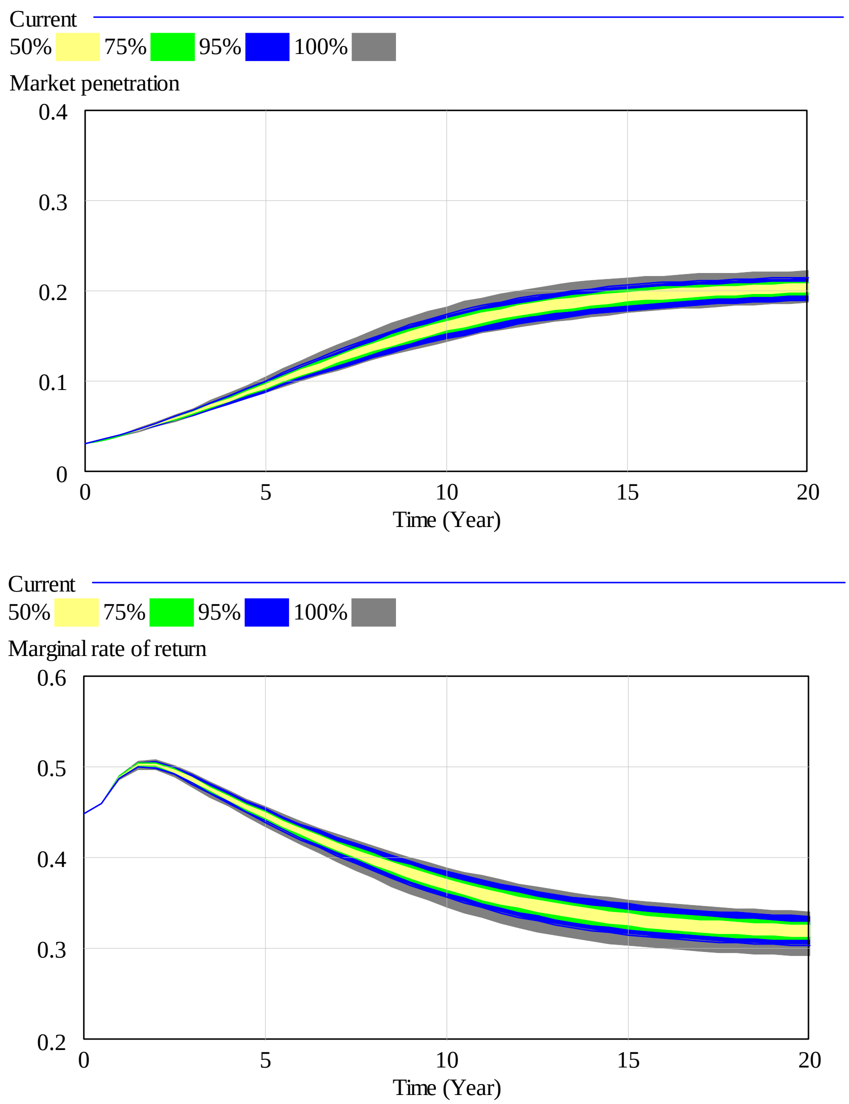
In scenario 2, policy (*Target customers per course*) was held constant and the environment was allowed to change. All three environmental variables – age, wealth and population change were allowed to vary normally based on the data available. The minimums, maximums, means and standard deviations used are given in Table 3.

Table 3. Parameter distributions

Parameter	Minimum	Maximum	Mean	Standard Deviation
Age above 25	42%	68%	57%	7%
Median Household Income	$35,312	$50,025	$43,150	$985
Population change rate	-2%	7%	2%	1%

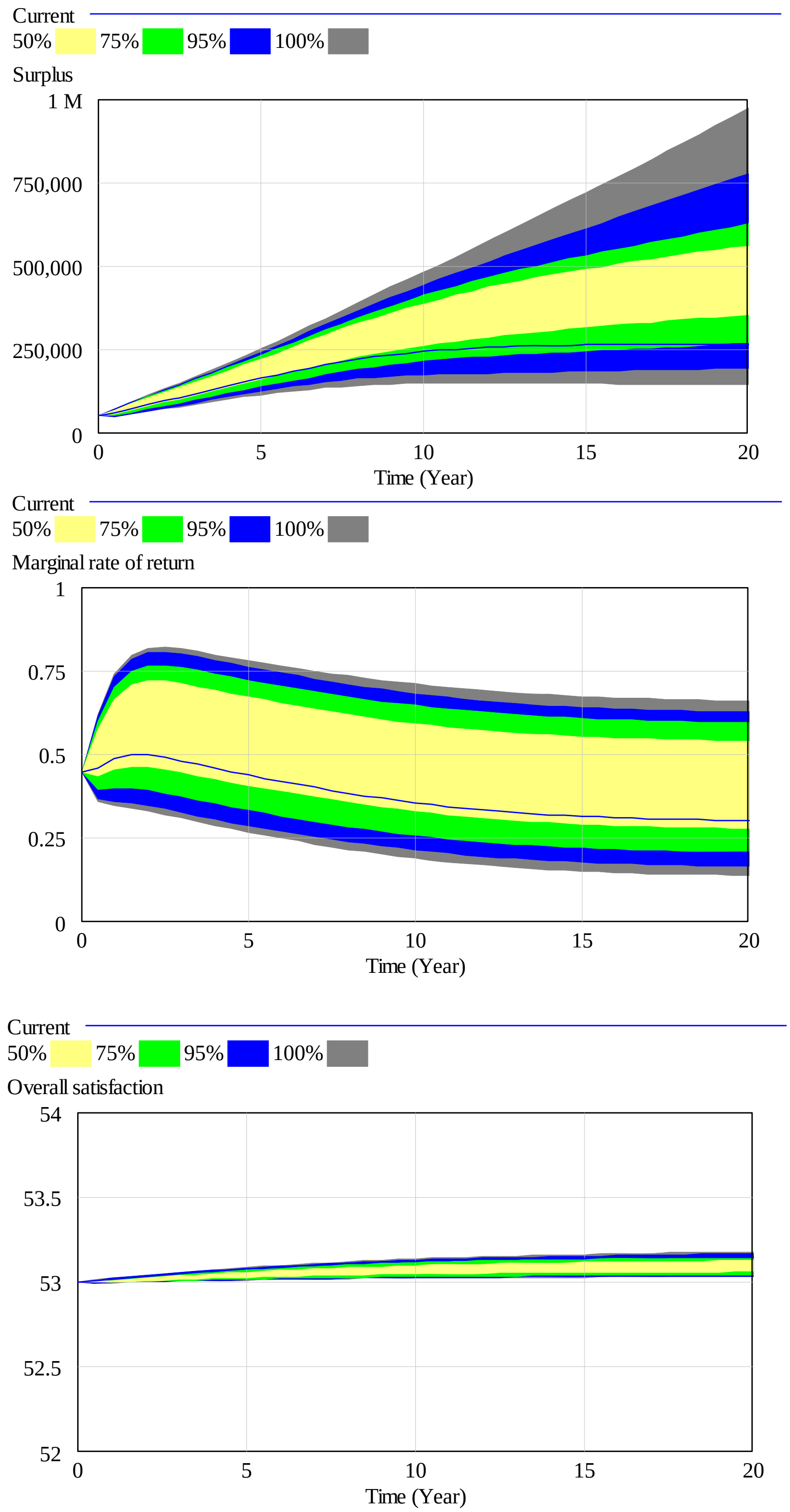
The dynamic confidence bounds obtained for *Market penetration* and *Marginal rate of return* are shown in Figure 13. It is evident that the bounds are thin. Thinner bounds give greater confidence in the behavior. Here, it is very likely that *market penetration* will be around 0.2 and *marginal rate of return* little over 0.3.

Figure 13. Confidence bounds: Variation in environment



Finally in scenario 3, both policy (*Target number of customers per course* – realistic) and environment were allowed to vary. The distributions used for each of the individual parameters were same as those used in scenarios 1 and 2 above. The resulting confidence bounds are shown in Figure 14. Bounds on *surplus* have widened to a great extent and this is due to too many variations. The bounds on *marginal rate of return* are wider than those in scenario 2, which tells us that policy changes impact *marginal rate of return* way more than environment changes. *Market penetration* under scenario 3 exhibited bounds similar to those in scenario 2 that were narrow. *Overall satisfaction* showed similar confidence bounds in all three scenarios. From all of these results, it is clear that there are some parameters that impact more than others, and have striking outcomes. And, there are some components that are least impacted. *Marginal rate of return* is sensitive to policy changes, *market penetration* is sensitive to environmental changes, *overall satisfaction* is sensitive to neither and *surplus* is sensitive to both.

Figure 14. Confidence bounds: Variation in policy and environment



Results of the simulation

The behavior patterns obtained for certain key variables in the model follow. Figure 15 shows the behavior for *number of courses*, *change in number of courses* and *overall satisfaction*. The *number of courses* to be offered (measured in Courses, shown as Crse in the chart) follows almost an S-shaped curve with the lower leg rising more abruptly and attaining a steady state. The *change in number of courses* (measured in Courses/Year, shown as Crse/Year in the chart) follows a skewed bell-shaped curve and is positive for the entire time horizon indicating the need to increase course offerings (i.e. intervention by adding courses) every year for the next 20 years. The behavior starts to gradually rise from the initial value of approximately 50 courses per year to reach a maximum at the sixth year. For the first six years, courses are added at an increasing rate (every subsequent year more courses are added than the previous year). After the sixth year, the behavior drop to reach a steady state by the 20^{th} year. Thus from the sixth year onward, courses are added at a decreasing rate (every subsequent year lesser courses are added than the previous year). *Overall satisfaction* (measured in percentage, shown as Per in the chart) rises only by a little amount to attain a steady state.

Figure 16 shows the behavior patterns for *surplus*, *market penetration* and *marginal rate of return*. *Surplus* (measured in $) and *market penetration* (measured as dimensionless, shown as Dmnl in the graph) follow similar S-shaped behaviors, although *surplus* is more of a goal-seeking behavior. *Marginal rate of return* (measured as dimensionless, shown as Dmnl in the graph) is defined as the return obtained for every additional dollar invested. *Marginal rate of return* peaks in the second year and starts to drop to attain a steady state.

Figure 15. Behavior of key attribute and perceptions

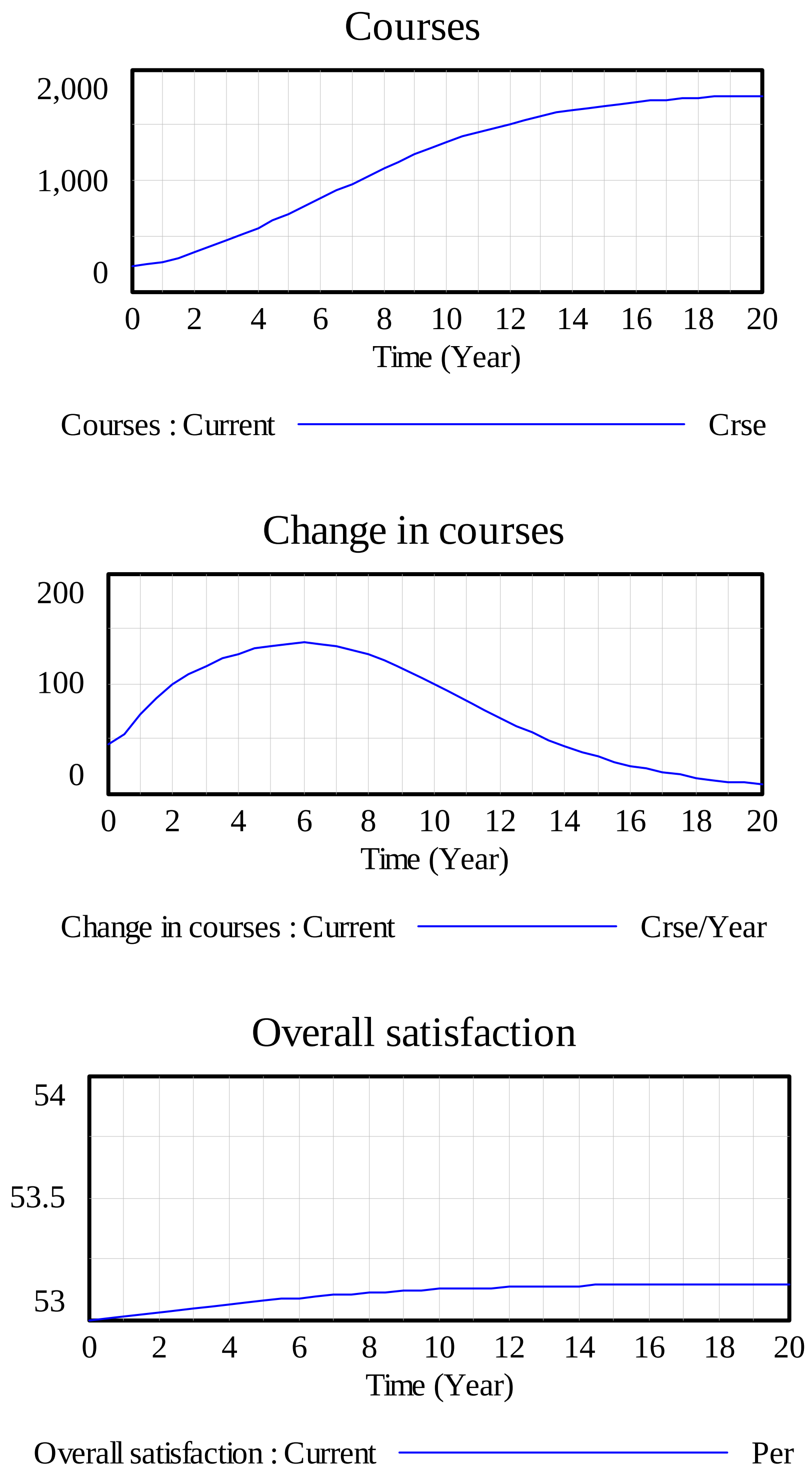
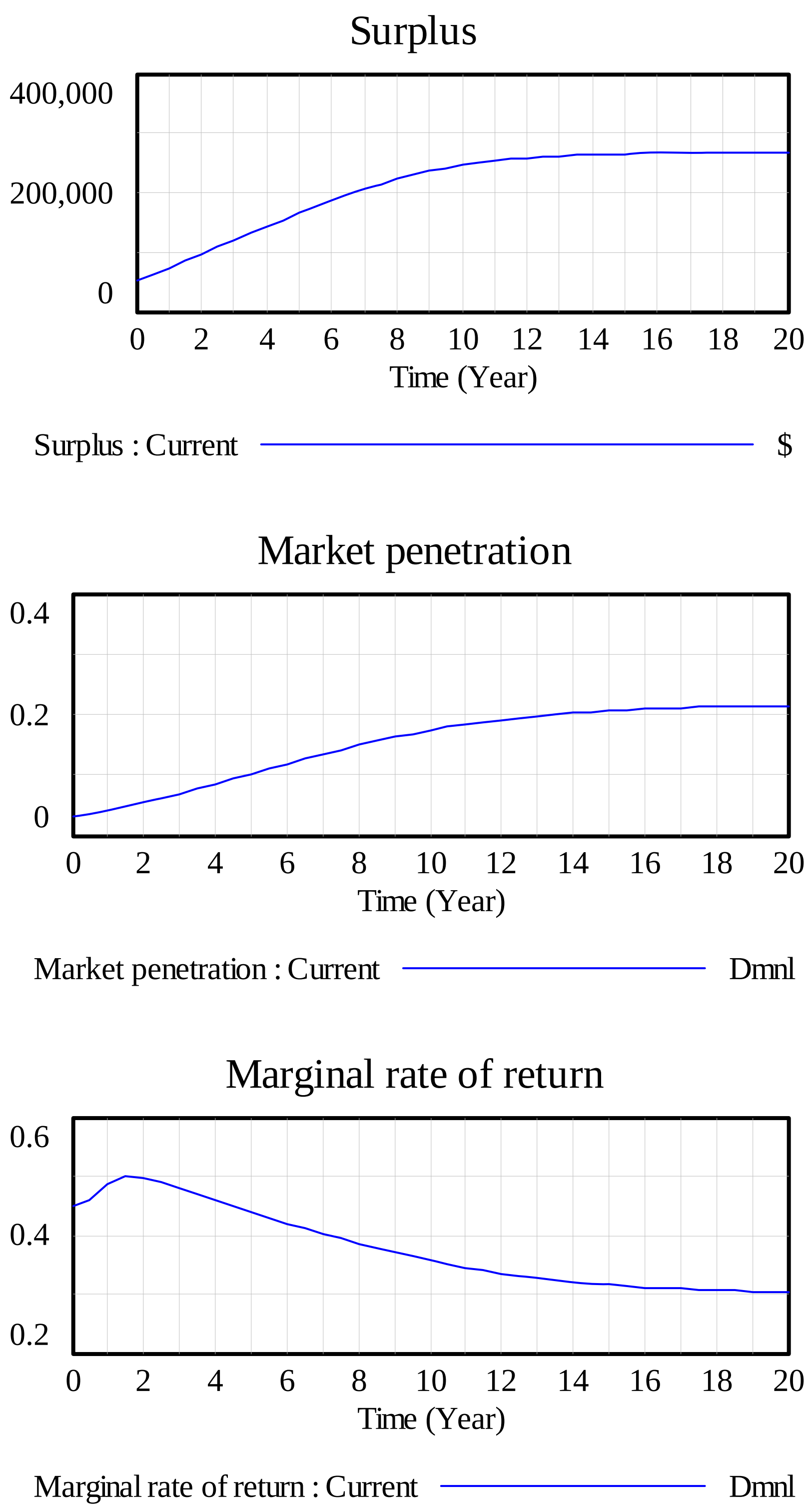


Figure 16. Behavior of surplus, market penetration and marginal rate of return



Steady state has been achieved. This was evident because, with no further interventions, the system continues to perform at the new equilibrium level. In other words the system is in

dynamic equilibrium. Under dynamic equilibrium, the inflow equals the outflow with respect to corresponding state variables. Because of such equality, the net flow is zero. Hence, the state variable remains at the same level. This does not necessarily mean that the system is stationary (static equilibrium), however, static equilibrium is a special case of dynamic equilibrium. But, there is constant movement in the system but the values of all state variables remain constant.
To understand the state of dynamic equilibrium, consider a bath tub (state variable) containing a certain amount of water, and the faucet and drain are left open. Now, let us assume that the faucet fills up the tub with a certain amount of water, say per minute (inflow rate) and the drain empties the same amount of water per minute (outflow rate). Hence, the inflow and outflow rates are equal, which would mean that the tub would continue to have the same amount of water minute after minute. Such a bath tub system (combination of bath tub, faucet and drain) is said to be in a state of dynamic equilibrium.
The steady state values for key variables in the SSC are given below in Table 4.

Table 4. Steady state values for key variables

Variable	Initial value	Final/steady state value
Courses	220 courses	1,765 courses
Change in courses	45 courses	8 courses
Overall satisfaction	53%	53.15%
Customers	2,650 people	17,731 people
Surplus	$53,250	$268,374
Market penetration	0.032	0.215
Marginal rate of return	0.447	0.304

Answers to the Questions in the Case Study

Based on the behavior patterns and the results from the model, questions in the case study can be answered.

- The customer base does in fact increase from 2,650 people to 17,731 people over 20 years.
- The course offerings need to increase continuously from the current 220 courses to 1,765 courses in 20 years following a skewed bell-shaped curve shown in Figure 15.
- How the increase in customer base (market penetration captures increase in customer base) and course offerings (surplus and marginal rate of return account for expenses incurred due to additional courses offerings) above compare against changes in population and the environment in general are interesting questions that are discussed in detail as part of the sensitivity analysis under model validation. Behavior mode sensitivity discusses effect of changes in market size (population) on surplus. Numerical sensitivity explains the impact of realistic changes (inputs from experts) in environment (market size, age and wealth) on market penetration and marginal rate of return. Further, there is also discussion on the combined effect of policy and environment changes on these variables.
- The overall satisfaction behavior pattern in Figure 15. The effect size of these investments (i.e. increase in course offerings) is small but significant on service quality, satisfaction and other components in the SPC as can be seen from the overall satisfaction behavior which increases by less than 0.15% and attains a steady state. This increase is minimal but is highly significant (p-value < 0.0005). To the decision maker, this means

that service quality is a key variable to make an impact on overall satisfaction. Intervening with the number of course offerings (as an operational attribute), for sure will cause an impact on overall satisfaction but will be minimal. If overall satisfaction is a main outcome variable that is of concern, the decision maker should turn to other operational attributes that might bring about greater impact.

- The field unit can increase the course offerings to 1,770 courses over 20 years and expect to increase the market penetration from 0.032 to a steady state of 0.215.
- Surplus will increase from $53,250 in the current time period to $268,374 after 20 years. Considering 20 years is a long period of time, the future surplus was adjusted to account for time value of money[7] to get a better sense of the comparison. The present value of $268,374 came out to be $134,876, which is still almost three times over the initial surplus. This conversion was done to illustrate the comparison. Other dollar amounts in this case study are shown without adjustments. Similar, adjustments can be made as deemed necessary for actual decision making.
- Additional investments do not always give increasing rate of returns. This is evident from the marginal rate of return behavior in Figure 16. The marginal rate of return increases and peaks during the second year, but, then on starts to drop to reach a steady state by year 20.
- Is the policy of no more than ten customers for each course offering sustainable? The answer to this question depends on how the field unit weighs its options. The field unit can currently cover all its expenses by the revenues generated. Investing in more course offerings, increases market penetration and surplus but at the same time brings in decreasing marginal rates of return. The model also identified that the steady state marginal rate of return can be increased to 0.379 by changing the policy to no more than eleven customers per course offering. This will keep the market penetration at the same level but increase the surplus at the end of 20 years to $316,502 (a gain of $48,128) with an increase of only 0.12% in overall satisfaction (a drop of 0.03%).

Conclusion

Evaluation of services operations is very necessary and relevant. Services are different from manufacturing and this should be considered during the modeling process. Abundant research has been done to identify relationships in service operations using statistics. Due to the nature and complexity of the structure of these operations, there is a need for a dynamic approach. We developed a dynamic model to evaluate training service operations from a systems perspective.

Investments in operational attributes positively affect customer perceptions (service quality, value and satisfaction) which in turn positively affect customer behavioral intentions and customer loyalty. Customer loyalty is vital for both retaining (return) existing customers and attracting new customers through referrals. The corresponding hypotheses were tested for training services in a large organization. The increased loyalty increases the customer base for the future and enables the organization to further penetrate the market. In the case study, the organization was able to meet all its expense obligations. Will the operation generate surplus? Yes, as can be seen from the results. But this relates exclusively to the financial aspect. Does that mean the operation is sustainable? Behaviors of other variables need to be considered as well to

[7] Considering an inflation rate of 3.5% compounded annually over the next 20 years.

answer this question. There was a decrease (after an initial slight increase) in marginal rate of return for every additional dollar invested. Strategically speaking, for a particular organization it might be sustainable to penetrate the market with decreasing marginal rate of return. But for another organization, the stakeholders might be content with current surplus and returns. A third organization might want to explore investments in other operational attributes with certain trade-offs. So, investments in operational attributes do affect the long-term sustainability of the organization. However, such impact varies from one type of operational attribute to another. Some attributes have more impact than others on certain outcomes (for instance, surplus, market penetration, marginal rate of return). The model and methodology developed in this research can be used to evaluate the extent of the impact. Such an exercise enables the decision maker to compare multiple scenarios, where interventions are made to varying magnitudes and on different attributes. Based on these results, the decision maker can decide on the appropriate course of action that is sustainable when looking at making investments in operational attributes.

Simulation of the system dynamics model along with model validation provided valuable insights into evaluation of the operation. Several scenarios and sensitivity analyses were simulated to study the financial return (surplus) behavior of investments in operational attributes. In addition, market penetration and marginal rate of return behaviors could also be obtained. The base case scenario provided results on the behavior of key variables linked to interventions in operational attributes (number of courses offered). Though, this could be useful information for the decision maker, this may not be sufficient. Decision makers need to know more about how the operation performs and gain further insights. These insights could emerge by conducting sensitivity analysis. As such, policy, behavior mode and numerical sensitivity were carried out. Findings of the sensitivity analysis illustrate that there was sensitivity of surplus and marginal rate of return, to policy changes. Surplus exhibited behavior mode sensitivity to changes in market size (uncontrollable factor). From numerical sensitivity analysis, it was found that marginal rate of return is sensitive to policy changes, market penetration to environment changes, overall satisfaction is sensitive to neither and surplus is sensitive to both. Confidence bounds were also identified for variables exhibiting certain kinds of behaviors. These bounds give the decision maker probabilities for certain kinds of outcomes (for example, generating surplus or achieving a certain market penetration). By modifying the model one can simulate investments in multiple operational attributes and also analyze their outcomes. Using the models developed during the course of this research, managers can better understand trade-offs, compromises and probabilities of success for making right investment decisions.

Surplus and market penetration are important variables that were tracked during the study. Another important variable, especially when additional investments are made, is marginal rate of return. Every additional dollar invested not necessarily gives the same return as the previous dollar invested. As expected, this rate of return climbed in the beginning and began to decline until attaining a steady state. This dynamic model is able to capture this behavior by identifying the point in time where the marginal rate of return peaks (or reaches a maximum) and starts to decrease. This finding is important for managers to explore alternate courses of action if one scenario ends up with huge decreasing returns. Of course, this finding is specific to the case study. But similar findings can be obtained for other cases in training services and operations in other service industries to answer the same question.

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