Policy boomerang in technical education: a system dynamics perspective

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Abstract

Purpose – The Indian technical education has experienced an exponential growth since 1995. However, the technical education system was not able to sustain it and the enrollments, particularly in engineering, fell down considerably. The purpose of this paper is to analyze the growth of Indian technical education from system dynamics (SD) perspective.

Design/methodology/approach – Technical education is a complex system in which the outcome of a decision comes with a third order delay. SD is an appropriate tool to analyze the causal structure and behavior of complex systems. This study developed an analogy from the physics of a boomerang to do the comparative assessment of "sudden overshoot and collapse" phase in the growth of Indian technical education. Further, it compared the technical education growth with the Gartner hype cycle. The growth model of Indian technical education was developed using SD software STELLA (version 10.0).

Findings – The model was simulated for five different policy scenarios. The outcome of the SD analysis shows that the "goal-seeking behaviour," which produces stable growth without hampering quality, is the best proposition amongst all scenarios considered in the study. It identifies policies which will enable long-term stability in the Indian technical education system as well as policies which will lead to perpetual instability in the system.

Research limitations/implications – The study conducted will encourage researchers to use SD in analyzing complex systems for sustainability and in the selection of appropriate policies.

Originality/value – The paper uses boomerang analogy for analyzing the growth in engineering enrollments and highlights the presence of "the boomerang effect," a term coined by the authors for sudden overshoot and collapse behavior, in the causal structure which is injurious to the education system.

Keywords System dynamics, Policy, Boomerang effect, Hype cycle, Technical education

Paper type Research paper

Introduction

The uncontrolled surge in the engineering enrollments in the Indian technical education system during past decades caused enormous scarcity of good quality faculty and inadequate academic infrastructure. The policy makers of the Indian technical education, perhaps overwhelmed by the market demand, focused on increasing enrollments in engineering and allowed mushrooming of private technical institutions in an uncontrolled manner. Furthermore, a majority of private technical institutions also compromised on quality of student intake. All these factors have led to poor quality of engineering graduates. As a result, the supply of engineering graduates exceeded the employee demand from the industry. Furthermore, the private engineering institutions, which cater to 85 percent of engineering education, produced graduates with employability level as low as 20 percent. Too much focus on drastically increasing quantity has adversely affected the quality of technical education in India (Reddy, 2012; Gambhir *et al.*, 2016). This has caused enormous unemployment among engineering graduates. Paradoxically, the industry is unable to meet its talent requirements because a majority of engineering graduates have poor level of employability and do not match the industry needs. Around 40 percent of engineering seats remained vacant in year 2015.

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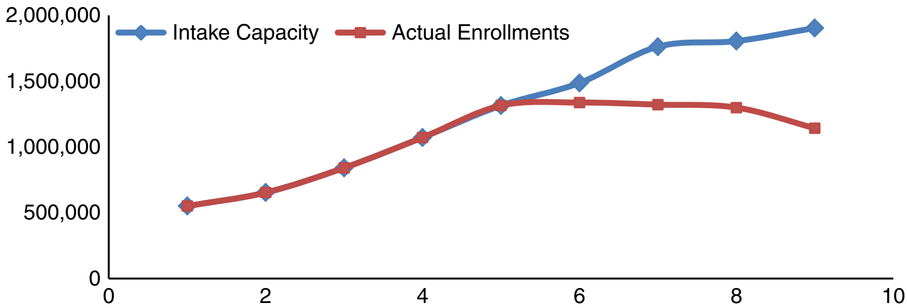
Figure 1 shows the enrollments and intake capacity in engineering since year 2006. The intake capacity rose by 200 percent in a span of four years (year 2006-2010). The actual enrollments were close to the intake capacity till year 2010 and were driven by lucrative job prospects available for good quality industry ready engineers. Private players saw this as a good business opportunity and invested in technical education in large numbers. Out of 3,364 engineering institutions, 3,029 engineering institutions in India are in private hands (AICTE Approval Process Handbook, 2015-2016). However, the poor quality graduates supplied by such private institutions have been struggling to subsist in the immensely dynamic and challenging market. Around 20-30 percent of 1.5 million engineering graduates passing out every year remain unemployed in India (Mahajan, 2014). As a result, engineering is no more perceived as a lucrative career option by masses. The number of enrollments dipped since 2011 when private institutions were not able to place their graduates due to their poor employability level. Many private engineering institutions have shut down and many others have filed for closure to the All India Council of Technical Education (AICTE). Perhaps, the expansion policy adopted by the Indian technical education appears to have boomeranged as the engineering enrollments have fallen down. Technical education is a complex system in which the outcome of a decision variable comes in a long time and may cause unanticipated side effects. These unexpected dynamics often lead to policy failures (Meadows, 1982). System dynamics (SD) is a powerful tool to get useful insight into situations of dynamic complexity and policy resistance (Sterman, 2010). It is an approach to understand the non-linear behavior of complex systems.

Methodology

This paper analyzes the sudden surge and collapse in the growth of technical education in India through SD approach. The authors have coined this phenomenon of sudden overshoot and collapse in technical education as "the boomerang effect." In next section, an analogy from the physics of boomerang has been developed and compared with the growth of Indian technical education. Subsequent section describes the growth of Indian technical education over time using Gartner hype cycle. Thereafter, a SD model has been developed to analyze the growth of Indian technical education. A SD software, Stella (version 10.0) was used to construct the model and perform simulations. The model was then tested for robustness for different policy scenarios. Simulations were performed using data of past engineering enrollments in India. Concluding section, gives the managerial implications of various policy scenarios analyzed through computer simulations. Figure 2 outlines the steps of this research framework.



Sources: AICTE Approval Process Handbook (2015/2016), Thomas (2015)

Figure 1. Enrollment scenario in Indian technical education

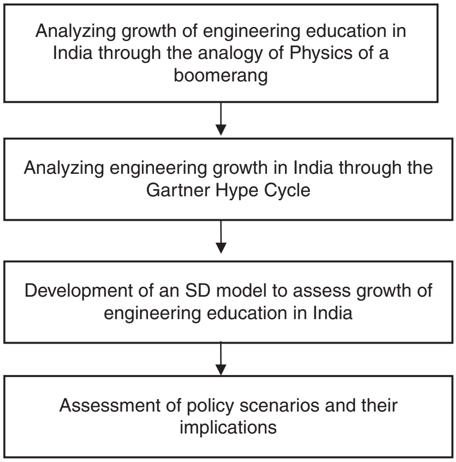
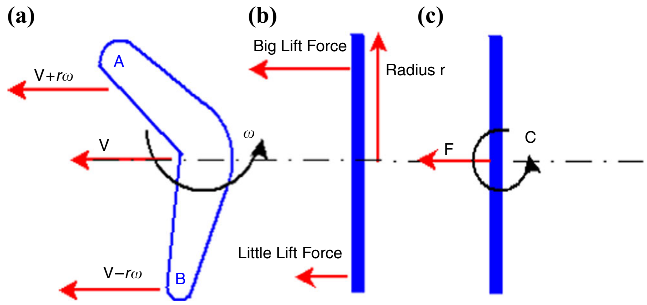


Figure 2. Research framework

Theory of boomerang

The oldest known boomerangs are 11,000-15,000 years old (Mauro, 1989). The primitive hunting societies in Australia used boomerang to hit a target they wanted to eat. They surprisingly noticed that some boomerangs if flattened into asymmetric wings shape, were capable to fly in a circular path and then return back to the thrower. But this would happen only when the boomerang misses the target completely. The flight behavior of a boomerang is governed by two scientific principles; principle of aerodynamic lift and principle of gyroscopic precession. Precession is a term used for the rotation of axis direction of a gyroscope (Tapley, 1990).

A boomerang must be thrown vertically in order to travel a circular path. An analysis of forces acting on a boomerang of radius r is shown in Figure 3. The center of the boomerang moves with a velocity V. The spinning angular velocity of the boomerang is ω. The top end A of the boomerang has velocity V+$r\omega$ whereas the bottom end B has velocity V−$r\omega$. Therefore, the top arm A moves faster than the center by $r\omega$ and bottom arm moves slower than the center by $r\omega$. As a result, there is an imbalance in forces acting at the two extreme ends (point A and point B) of the boomerang (Figure 3(b)). The lift generated by the forward moving and spinning arms acts horizontally from the flat sides of the arms. The two forces acting at point A and B can be represented by F_A and F_B. These two forces can be replaced by an equivalent force F and a couple C. If vertical component of the lift force balances the



Source: Adapted from Hunt (2001)

Figure 3. Forces acting on a boomerang

force due to gravity, then we are left with a net force parallel to the ground and it can be represented as the centripetal force. Force F (centripetal force) in Figure 3 is responsible for producing circular motion whereas the constant couple (C) causes steady precession at rate Ω. The force exerted by the aerodynamic lift on the spinning boomerang actually takes place 90° forward and therefore, the angular direction of a boomerang changes from right to left. The centripetal force F is caused by the aerodynamic lift and the constant couple C causes the gyroscopic precession.

Figure 4 demonstrates the path of a boomerang flight. The spin angular velocity of the rotating boomerang points in the direction of the spin axis. The precession torque, which is generated due to the imbalance in the lift forces, tries to change the angular momentum vector toward its direction.

All returning boomerangs have unsymmetrical shapes like aerofoil and therefore produce unbalanced aerodynamic forces. Whereas, a non-returning throwing stick has a symmetrical shape causing it to travel as straight as possible. Thus, it is imbalance of forces that boomerangs. This analogy is apt in technical education which has boomeranged due to imbalances between demand and supply; quantity and quality.

Hype cycle

The hype cycle is a graphical representation developed by a US-based research firm Gartner, Inc. in year 1995 (Adamuthe *et al.*, 2015). Gartner's hype cycle provides an overview of how a technology or application will evolve over time (Gartner, 2015). The hype cycle is used to assess the technology maturity. It delineates the advancement of innovation, from over enthusiasm to the final understanding of innovation and its relevance through a period of disillusionment (Fenn and Raskino, 2011). It helps decision makers in making investment decisions. A hype cycle consists of five key phases; technology trigger, peak of inflated expectations, trough of disillusionment, slope of enlightenment and plateau of productivity. Figure 5 shows the five key phases of the Gartner hype cycle.

Technology trigger

This phase is brought in by a potential breakthrough in technology which acts as a trigger for the spontaneous growth in adoption of technology.

Peak of inflated expectations

A wave of expectations develops and rises above the reality of capabilities in this phase.

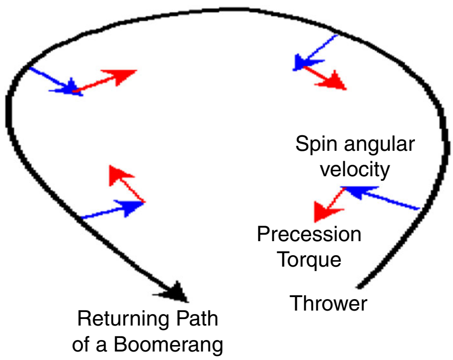


Figure 4.
Flight path of a returning boomerang

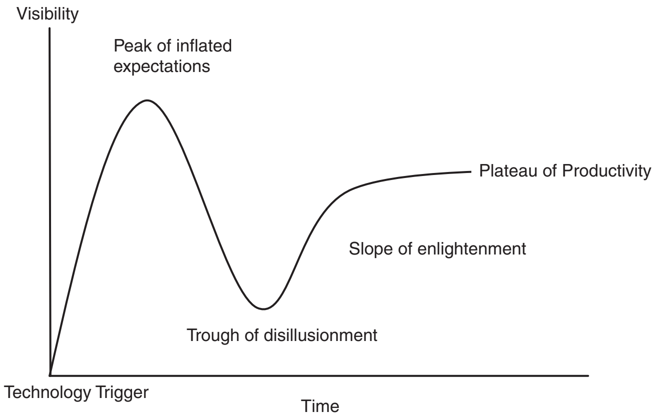


Figure 5.
Gartner hype cycle

Trough of disillusionment

In this phase, impatience for expected results begins to replace the original excitement. Problems with performance, delayed returns and poor financial results lead to disillusionment.

Plateau of productivity

A corrective and a controlled approach in growth delivers the expected results and performance and hence a goal-seeking approach in technology adoption is observed in this phase with no signs of inflated or underrated expectations in technology adoption.

Analogy of boomerang in Indian technical education

The Gartner hype cycle is used by organizations to track the evolution of technology over time. This section illustrates, through hype cycle, how technical education in India has progressed over time (Figure 6).

Engineering institutions in India grew gradually from 50 in the year 1950 to 139 in the year 1970. Engineering as a career was not pursued by masses before 1990s and industry always felt shortage of qualified engineers. The Indian economy had undergone significant policy shifts in 1990s. The private Universities Act was introduced in the parliament in year 1995 which gave gigantic boost to opening of private institutions in India. This triggered the enrollments in engineering and by year 2001, there were 1,400 engineering institutions in India out of which 1,200 were from private sector (Singh and Singh, 2014). The enrollments rose from about 100,000 in year 2001 to 15,00,000 by year 2013. The admission seekers started looking engineering as a better career option with lucrative packages. As a result, a positive hype was created which spread across students and their parents very quickly. This compounding effect of enrollments led the technical education to grow at a pace of 125 percent (year 2007-2012) which even surpassed the nation's economic growth of about 50 percent (GDP) during the same period (Choudaha, 2012). This resulted in a situation of overcapacity. Sudden spurt in engineering institutions created acute shortage of good quality faculty and adequate infrastructure. As a consequence, the quality of engineering graduates fell down to as low as 20 percent in terms of employability (Aspiring Minds, 2014). Thus, a large number of technical institutions virtually became factories producing spurious products (students) which were not of quality standards acceptable to the end customer (industry). For this reason, by the end of year 2012, engineering was no more seen as an attractive career option which led to the creation of negative hype. This negative hype spread exponentially causing significant fall in engineering enrollments. After year 2013,

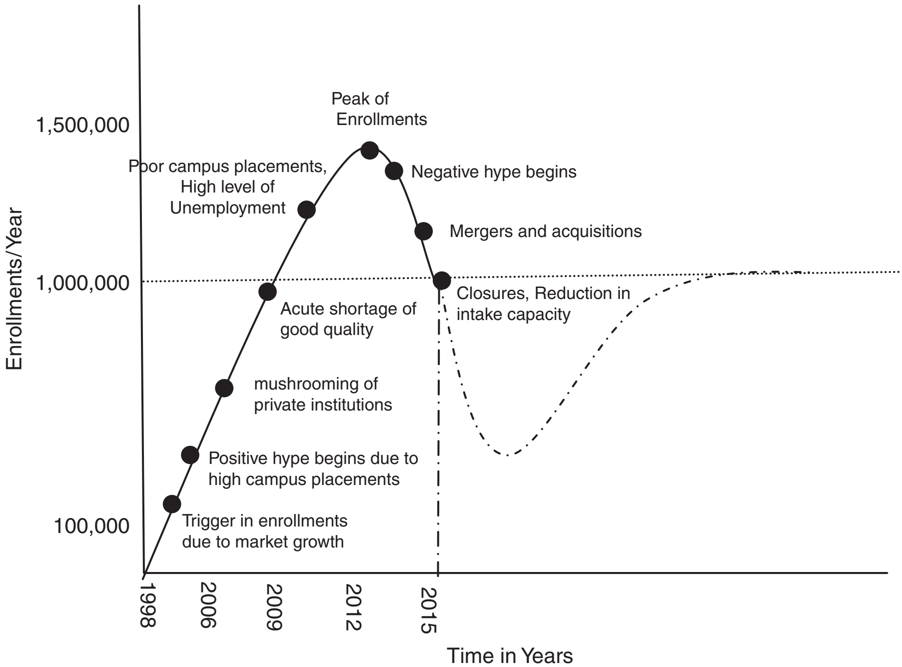


Figure 6.
Progress of engineering enrollments over time

many institutions across India started reporting drastic fall in engineering enrollments. AICTE decided to cut down 600,000 engineering seats in India in year 2015 (*Hindustan Times*, 2015). Thus, many engineering colleges were either merged or closed down due to poor intake of students. Hence the policy for vast scale expansion of technical education in India has actually boomeranged causing huge level of unemployment on one side and shortage of good quality graduates on the other. Table I illustrates the analogy of a boomerang with the technical education.

The SD model

This section analyzes the growth of Indian technical education through SD approach which appears to be following the Gartner hype cycle. The SD approach is used to study the inter-relationships among various factors of any system (such as technical education) and analyzes the system behavior against policy options. SD is a cogent approach to understand dynamic complexity of social systems (Sterman, 2010). Many researchers have used SD for policy analysis of systems in their study. Ardila and Franco (2013) analyzed fiscal and communication policies which could boost the adoption of alternative fuel vehicles in the Colombian market. Cai and Liu (2013) studied the waste disposal policies in China by performing policy mix simulations. Zhang *et al.* (2013) used SD concept to assess the sustainable manufacturing through a conceptual model. Analyzed policies for improving road safety using SD. Zhang *et al.* (2013) developed a SD model for sustainable manufacturing. Fateh Rad *et al.* (2015) investigated the relationship between university and industry as two major infrastructures of national innovations system using SD approach. A plethora of research papers pertaining to policy analysis of various social systems through SD approach is available in the literature which confirm that SD can be an appropriate tool for analyzing the growth of technical education.

S.No.	Boomerang	Technical education in India
1	Boomerang is thrown to capture or hit the target to encash the opportunity it presents	The policy for expansion in engineering was enforced on mass scale to meet growing industry demand of good quality graduates(target)
2	Precess in a boomerang is caused by difference in forces; Imbalanced forces exists because of variation in shape and weight	Hype (precess) is created by difference in actual demand and perceived demand (imbalanced forces); imbalanced forces exist because of gaps in demand and supply; quality and quantity, in technical education
3	Positive precess and a forward force take boomerang forward but away from the target	Positive hype (inflated expectations) generates more enrollments in engineering than required. In the process, the policy gets deviated from the target (producing good quality talent or high level of employability) causing rise in the unemployment level
4	Negative precess brings the boomerang back to its original position	Negative hype (disillusionment) creates fear of being unemployed and thus it brings down enrollments to a level much lower than required
5	If forces were balanced then due to absence of precess; the boomerang would hit the target in the direction toward which it is thrown	If forces were balanced (absence of imbalances in technical education; demand supply imbalance, Imbalance in quality imparted by technical institutions, imbalance in engineering disciplines, financial imbalance) then due to absence of hype, the growth would show a goal-seeking behavior with desired level of employability in graduates
6	If a boomerang hits its target, it will never return to the thrower	If this policy had achieved its target (high level of employability and balanced growth), enrollment would have never reversed to a level from where it started

Table I. Analogy of boomerang in technical education

In this paper, an SD model of technical education system was developed which involved following phases: problem articulation, formulation of dynamic hypotheses, formulation of simulation model, testing and policy design and evaluation. Problem articulation was the first step of modeling and it involved selection of key policy variables and system boundary. The key problem was to analyze the growth of technical education over a period of time. The time horizon chosen for the analysis was 50 years. Enrollments in engineering was taken as reference mode. Dynamic hypothesis is a working theory of how the problem was evolved. Formulation of dynamic hypothesis involved construction of the causal loop diagram (CLD) and stock and flow diagram (SFD) of the problem. In this study, a CLD was drawn to understand the feedback structure and inter-relationships of variables in the system. CLD was converted to SFD. The SD model was tested for robustness before performing final simulations. In the last step, different policy scenarios were generated to evaluate the model.

CLD

A CLD is made to represent the feedback structure of a system. It helps in capturing the mental models of the system by explaining the important feedbacks present in the system. It consists of variables which are connected by arrows explaining the causal relationships among the variables. Each causal link is allocated a polarity, either positive or negative. A polarity specifies how a dependent variables is affected by the change in independent variable. The loops which are formed by connecting variables with arrows can be reinforcing (positive loop) or balancing in nature. In a closed loop, if the feedback effect reinforces the original change, then the loop is positive or reinforcing. If the feedback effect opposes the original change, then the loop is negative or balancing (Sterman, 2010).

The CLD gives structural explanation to the hype cycle from SD angle. The CLD of the growth model (Figure 7) consists of three balancing (B1, B2 and B3) and one reinforcing loops (R1).

Balancing Loops B1 and B2

When enrollment rate increases, the graduation rate increases. Employee requirement (ER) is the annual demand of engineering graduates from the industry. The gap ratio is the ratio of ER and graduation rate. It is a measure of imbalance in demand and supply of engineering graduates in technical education. This variable is responsible for generating hype (positive or negative) in the system. When ER increases, the gap ratio increases. At significantly higher gap ratio, a plenty of jobs are available in the market. Also, the salaries offered to the graduates are higher. As a result, a positive wave is created in the market for engineering as a bright career option. This positive hype attracts a large number of enrollments in to the technical education system. The enrolled students get graduated after a delay of four years.

Balancing loop B3

This loop consists of a capacity constraint (ER) which has been considered as an exogenous variable in the SD model. The hype cycle is a combination of two modes of behavior; "overshoot and collapse" and "goal-seeking behaviour." The overshoot and collapse is observed when there are two balancing and one reinforcing loops. Whereas, the goal-seeking behavior is generated through a balancing loop with a capacity constraint. In Figure 7, loop B3 and a capacity constraint (ER) together generate the goal-seeking behavior.

Reinforcing loop R1

Reinforcing loop R1,balancing loops B1 and B2 generate the overshoot and collapse behavior in the hype cycle. The variable "enrollments" continually feeds back upon itself to reinforce its own growth or collapse. The admission seekers in India generally decide to pursue programs which offer promising career with high salary packages. For this, they get

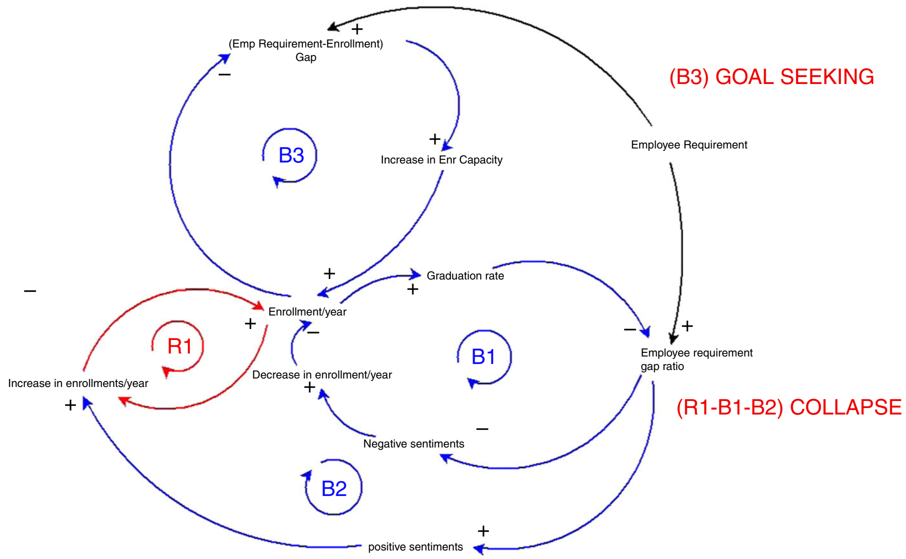


Figure 7.
CLD of the growth model

inclined toward programs which are followed by masses. Therefore, engineering with large enrollments reinforces its growth which is a characteristic of a positive loop.

The "overshoot and collapse" and "goal-seeking behaviour" do not occur simultaneously. The loop B3, which causes the goal-seeking behavior, follows the overshoot and collapse behavior generated by loops B1, B2 and R1. But, the loop B3 runs only when the system learns from the past, i.e., engineering enrollments are increased gradually ensuring equitable development of resources (faculty, physical and computational infrastructure, financial aids, alumni relations, industry interaction, etc.) necessary to impart high level of employability to the enrolled quantum of students. However, the development of these resources is not proportionate in time to the increase in intake capacity. Some of these resources like good quality faculty may take years to develop in sufficient numbers. For this reason, the Indian technical education failed to develop adequate resources for large number of enrollments which increased exponentially every year. Therefore, the loop depicting goal-seeking behavior ensures gradual growth of technical education system in quantity as well as quality.

To generate the dynamics of the growth model, the CLD was converted to the SFD (Figure 8) using SD software Stella version 10.0.

SFD

A SFD generates dynamics of a system using stocks, inflows and outflows. Stocks are accumulations and are represented by rectangles. The net flow into the stock is the rate of change of stock. The mathematical expression for the stock at time t is given as:

$$\text{Stock}(t) = \int_{t0}^{t} [\text{Inflow}(s) - \text{Outflow}(s)] + \text{Stock}(t_0) \quad (1)$$

Inflows represent additions to the stocks and outflows represent extraction from the stocks (Sterman, 2010). Clouds represent the sources and sinks for the flows. A source represents the stock outside the boundary of the system from which the flow originates. Likewise, a sink represents the stock outside the system into which the flow enters. In the SFD given in Figure 8, enrollments in engineering, undergraduate students, hype level and employee demand are stocks. The auxiliary variables are represented by circles and the rate of change of stocks are represented by valves.

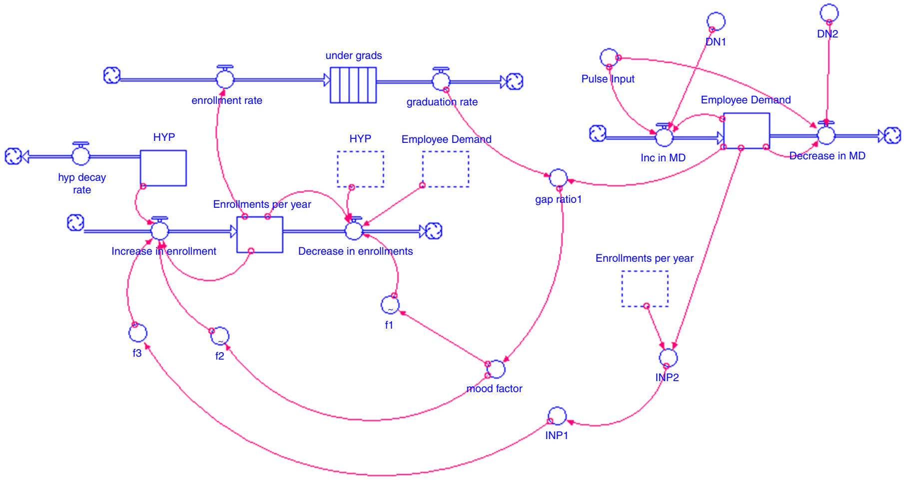


Figure 8.
SFD of the growth model

The reference mode “enrollments in engineering” is expressed mathematically as a stock in the following equation:

$$\text{Enrollments\_per\_year}(t) = \text{Enrollments\_per\_year}(t-dt) + (\text{Increase\_in\_enrollment} - \text{Decrease\_in\_enrollments}) \times dt \quad (2)$$

Likewise, the SFD incorporates mathematical expressions for all stocks considered in the growth model.

Model validation and testing

In the model proposed, five policy scenarios were considered. The model was run for 50 years in length to generate the growth behavior. Scenarios 1, 2 and 3 represent a hype cycle which consist of “boomerang effect” and a “goal-seeking behaviour.” ER was kept as constant, increasing and decreasing during simulation for scenarios 1, 2 and 3, respectively. Scenario 4 depicts a goal-seeking behavior whereas scenario 5, a perpetual state of chaos persistent in the system due to no learning from the past. Table II displays the aforementioned five policy scenarios considered in this investigation.

Apart from developing structure of the model, validation is essential for providing credible projection system behaviour for all policy interventions. It determines adequacy of the underlying fundamental rules and causal relationships in capturing the emergent behavior of the model (Ahmad and Bin Mat Tahar, 2014). The growth model was tested for boundary adequacy to assess the appropriateness of its boundary in context to the model proposed. A clear differentiation between endogenous and exogenous variables was done to ascertain a clear system boundary. The model was also checked for dimensional consistency which is one of the most basic test in modeling (Sterman, 2010). All equations in the model were checked and were found to be dimensionally consistent. Extreme condition test was performed on the proposed model to assess the robustness of the model by assigning large values to the variable “employee requirement.” The model behaved realistically under extreme inputs of ER and initial stock. All extreme simulation behaviors were found to be consistent.

S.No	Policy scenario	Factors	Varying parameter	Reference mode
1	Scenario 1: learning from mistakes (LFM) “Boomerang effect” and “goal-seeking behaviour”	Constant ER Initial enrollments = 300,000	Initial ER: 500,000; 10,00,000; 20,00,000	Enrollments/year
2	Scenario 2: learning from mistakes (LFM) Overshoot, collapse and goal-seeking behavior	Increasing ER Initial enrollments = 300,000	Initial ER 500,000; 10,00,000; 20,00,000	Enrollments/year
3	Scenario 3: learning from mistakes (LFM) Overshoot, collapse and goal-seeking behavior	Decreasing ER Initial enrollments = 300,000	Initial ER 500,000; 10,00,000; 20,00,000	Enrollments/year
4	Scenario 4: holistic growth Goal-seeking behavior, absence of hype	Constant ER; Initial enrollments = 300,000	Initial ER 10,00,000 Investment level in engineering education: very low (1), low (2), medium (3), high (4), very high (5)	Enrollments/year
5	Scenario 5: perpetual state of chaos or instability Repetitive overshoot and collapse; no learning from the past	Constant ER; Initial enrollments = 300,000	Initial ER: 10,00,000	Enrollments/year

Table II. Scheme of experimentation

A statistical test was performed to assess the quality of fit of the model proposed. Sterman *et al.* (1988) used root mean square error (RMSE) test to validate their SD model. RMSE is the square root of variance of residuals. The root mean square percentage error can be calculated by the following relationship:

$$\mathrm{RMSE}(\%) = A = 100 \times \left(\frac{\sum \left(\frac{\text{Predicted value} - \text{Actual value}}{\text{Actualvalue}} \right)^2}{\text{Number of observations}} \right)^{0.5} \quad (3)$$

It explains how close the observed data points are to the model's predicted values. It can be interpreted as a standard deviation of the unexplained variance and its lower value indicates a better fit (Karen, 2013). The root mean square percentage error for simulation results and actual enrollment data (Figure 9) was found to be 13.8 percent which can be considered on the lower side on a scale of 0 to 1. Mean absolute percentage error (MAPE) was also calculated to assess the goodness of fit of simulation results with actual data. MAPE can be calculated as:

$$\mathrm{MAPE} = \frac{1}{N} \sum \frac{|\text{Predicted value} - \text{Actual value}|}{\text{Actual value}} \quad (4)$$

The prediction accuracy of simulation results calculated through MAPE was found to be 12.8 percent. Both RMSE and MAPE confirm that the trend produced by the simulation results represent the system behavior fairly well with an accuracy of around 87 percent.

Results and discussion

This section presents simulation results from the enrollment growth model as per the scheme of experimentation presented in Table II. Simulations were performed for 50 years in length. The model was simulated by going 13 years back in the past (Year 2003), the time when technical institutions started mushrooming all over India. The enrollment data for this period was available in the literature (AICTE-Annual Reports, 2011/2012) and was used in conducting quantitative assessment of the model's historical fit. Therefore, it was appropriate to include this time frame in the analysis. Simulations were carried out using Euler's integration method with "year" as the unit of time.

The results obtained for all scenarios are discussed as follows.

Figure 10(a) represents simulation curves obtained for three different ER levels kept at 500,000, 1,000,000 and 2,000,000, respectively. Figure 10(b) shows a plot of ER and enrollments in engineering. In scenario 1, the ER was kept constant during the simulation run. The curves obtained resemble a typical Gartner hype cycle which consists of a "boomerang effect" and a "goal-seeking behaviour." A slight shift toward the right can be observed in the curves

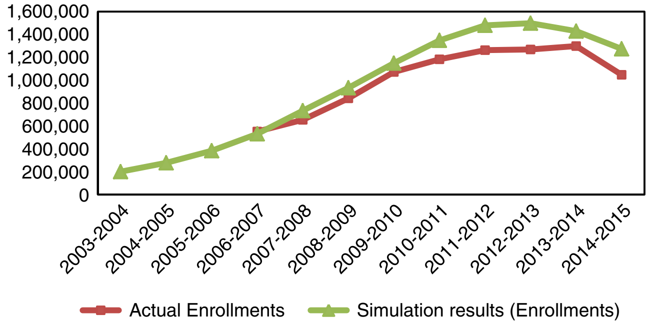


Figure 9. Comparison of simulation result with actual data

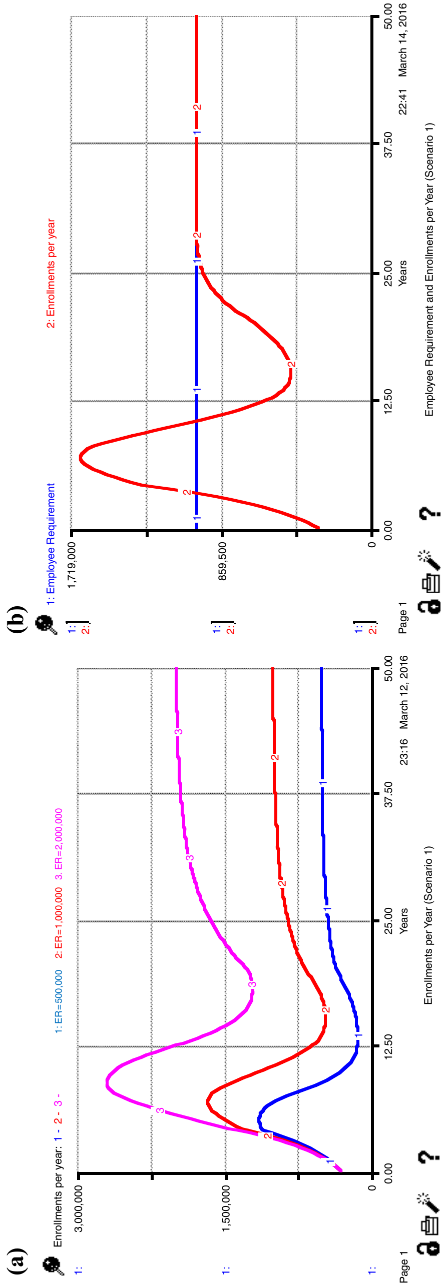


Figure 10.
Scenario 1, learning from mistakes, ER = constant

obtained, with an increase in the annual ER. This perhaps could be because of the increase in amplification effect in enrollments due to creation of a stronger hype with an increase in ER. In scenario 1, the system initially overshoots and collapses and then gradually stabilizes and attains a goal-seeking behavior. The latter part is exhibited only when the system learns from the mistakes of the past. The technical education in India, which also experienced the boomerang effect, appears to be lying closer to the trough of disillusionment (Figure 7) at current state. This policy boomerang took around 12 years time frame (Figures 7 and 10) during which a large number of engineering graduates became unemployed. Due to sudden spurt in its growth, the Indian technical education system was not able to generate good quality faculty in adequate numbers and infrastructural resources necessary for producing employable graduates. The poor employability level attained by the graduates in due course rendered them jobless and on the contrary, industry remained talent deprived. The technical education in India may follow goal-seeking behavior in future, as explained by the simulation results (Figure 10), provided the policy makers learn from the mistakes of the past and implement corrective measures to ensure sustainable growth in quality as well as quantity.

Scenario 2 and scenario 3 are extensions of scenario 1 where ERs are not constant but varying. The scenario 2 (Figures 11 (a and b)) shows the growth pattern of enrollments in engineering with an assumption that the ER increases non-linearly every year. This behavior was simulated by supposing that the growth in industry may go bullish and may require engineering talent from the education system at an increasing rate every year. The simulations runs produced the hype cycle expected which exhibited a continually increasing (goal chasing) enrollments in the last phase.

Analogous to scenario 2, the model was tested for a non-linearly decreasing ER. The graph generated through the simulation runs chased continually decreasing ER (Figure 12). The simulation curves, generated under the two extreme conditions (scenario 2 and 3) of ER, could be considered as plausible as they exhibit the behavior expected.

Scenario 4 is represented by the curves shown in Figure 13 which represents a holistic and sustainable growth in engineering education. The boomerang effect is absent in this scenario. Under this scenario, the system grows in a controlled manner when the intake capacity is increased gradually after assessing the market requirement and building the adequate physical and intellectual resources necessary for imparting good quality education. This quality check acts as a deterrent to the creation of hype and thus facilitates the system to reach the target and stabilize in a shorter span of time. The curves 1,2,3,4 and 5 represent the level of investment in engineering education from low level (curve 1) to very high level(curve 5), respectively. A higher level of investment is required to develop good quality research laboratories, equipments, instruments, library, computational resources and highly qualified faculty and staff. Therefore, curve 5 will approach target at a faster pace than slower rate investments. The comparison of different levels of investment shows that the proactive involvement and investment in education is effective in meeting market demand faster and also ensuring sustainable growth. The simulation results in Figure 13 show that a high level of investment (curve 5) in education can help enrollments meet the target in about six years. On the contrary, a very low rate of investment in education could take the system to similar position in as long as 35 years. Since the factors responsible for imparting good quality in technical education (such as qualified faculty, research facilities, etc.) do not develop at the same rate as the rated increase in the enrollments, therefore it is important for the stake holders to proactively involve and invest in education to maintain the right balance between quality and quantity in the system.

Scenario 5 (Figure 14) resembles the perpetual state of chaos and instability where the system does not learn from the mistakes of past and oscillates repetitively. The goal-seeking behavior is absent in this scenario which causes the "boomerang effect" to repeat after a certain interval of time. This repetitive overshoot and collapse causes massive opportunity loss to all the stakeholders of technical education. There is an opportunity loss to the

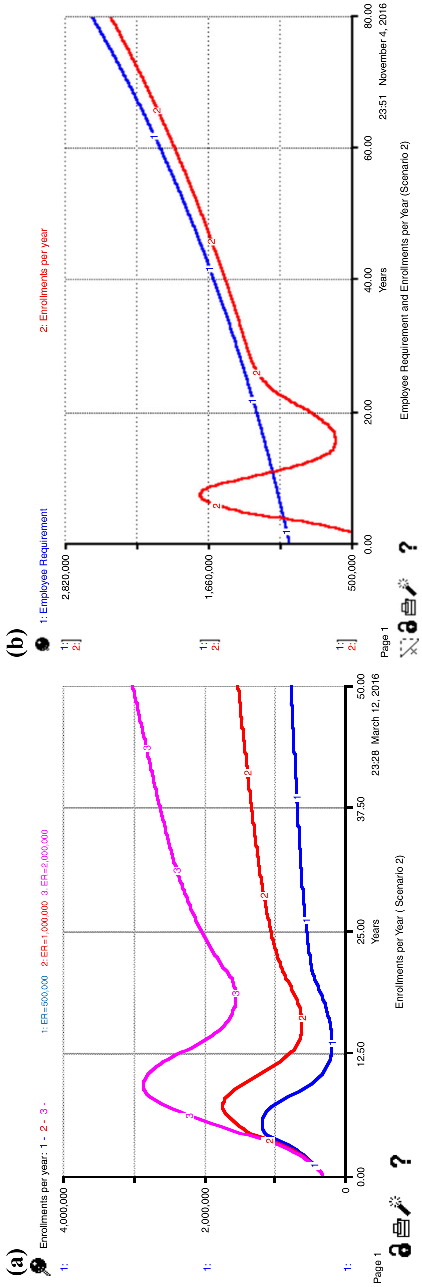


Figure 11.
Scenario 2, learning from mistakes, ER = non-linearly increasing

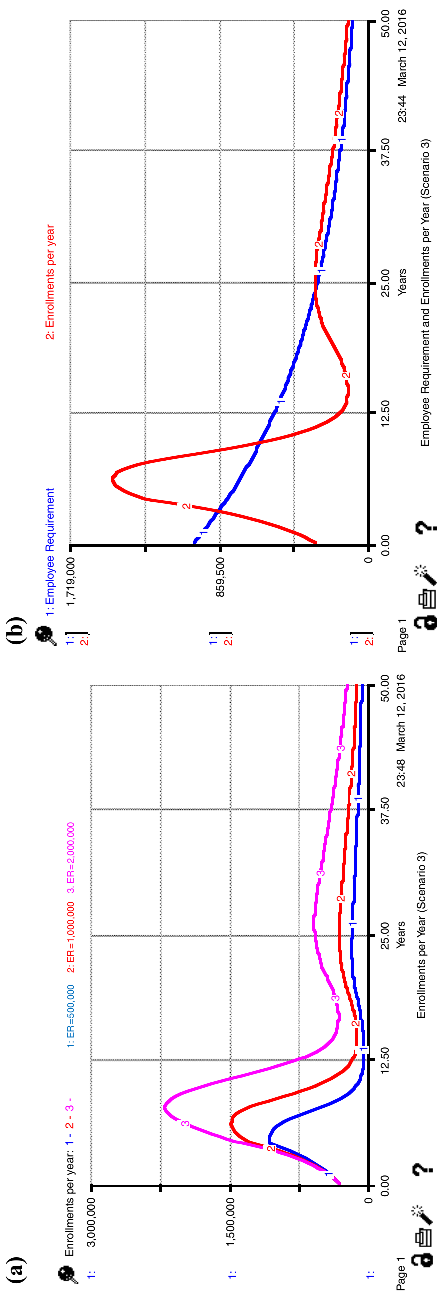


Figure 12.
Scenario 3, learning from mistakes, ER = non-linearly decreasing

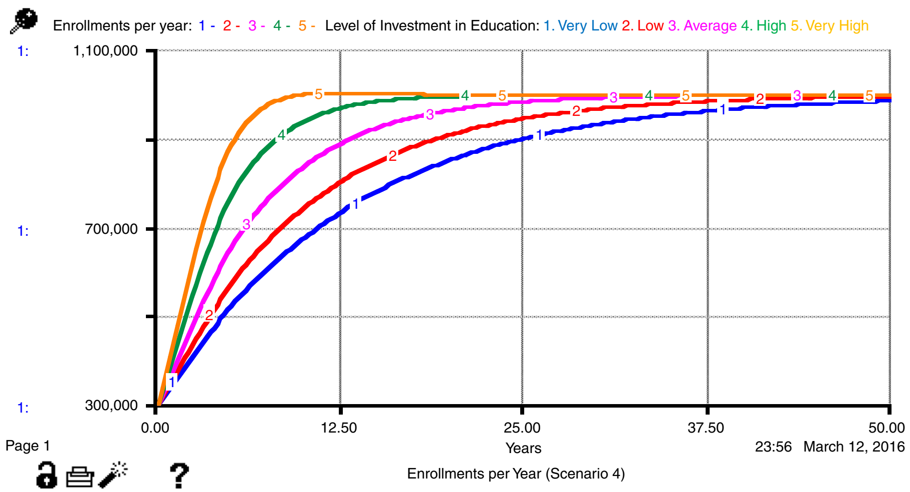


Figure 13.
Scenario 4, goal-seeking behavior

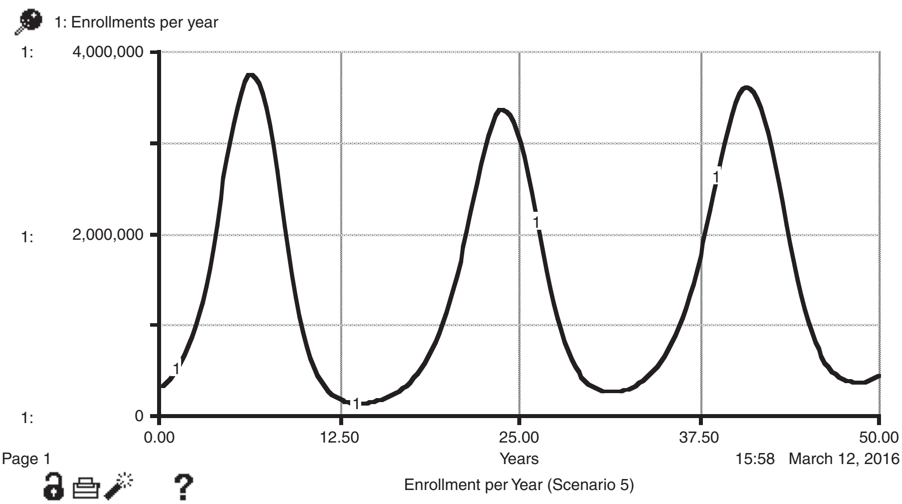


Figure 14.
Scenario 5, perpetual state of instability

industry due to shortage of talent as well as to the academia due to alarmingly high level of unemployment. Market forces will create opportunities and there will always be players who would like to encash this limited opportunity for mere profiteering. If the system does not learn from past, opportunists would rush in, mint money and would lead the system to a state of distress. Indian technical education system had seen such a rush in the past. If the policy makers do not learn from the past, then the Indian technical education is likely to follow the scenario 5 which is the most catastrophic among all other scenarios.

Conclusion

This paper has analyzed the growth of technical education in India on the pattern of Gartner hype cycle. A SD study was conducted to examine the causal structure of the growth model, based on hype cycle, which was divided into two parts; “overshoot and collapse” and "goal-seeking behaviour." An analogy from the physics of a boomerang was developed to study the sudden overshoot and collapse in engineering enrollments in India. In this study, the phenomenon of overshoot and collapse has been christened by the authors as the "boomerang effect." Five different scenarios were generated to study their impact on technical education system. Scenario 4 (holistic growth) was found to be the most favorable causing minimal opportunity loss to the society. The absence of boomerang effect in scenario 4 causes the system to grow gradually by maintaining high quality in imparting education. Since under scenario 4, the education system does not produce unemployed graduates and the industry gets employable graduates in required numbers, the overall opportunity loss caused is minimum. On the contrary, scenario 5 causes maximum opportunity loss to the education system because of continuous repetition of the boomerang effect in the growth pattern. Therefore, under such a state, neither the industry gets the right talent nor the graduates, who pass out in large numbers every year, and do not get jobs. As a result, there is a considerable loss to industry as well as academia. This study explains that the boomerang effect is an undesirable phenomenon and is caused primarily due to the imbalances in demand supply of engineering graduates. To address this issue, policy makers need to make strategies to lower the demand supply gap. This could be attained by bridging the communication gap across the supply chain, i.e., from schools to engineering institutions to industry. Proactive involvement and investment in education by industry as well as government are necessary to maintain the high standards of quality resources required for producing employable graduates.

Limitations and future scope

In this study, the ER was considered as an exogenous variable in the SD model. The policy scenarios were generated by considering ER to be increasing, constant and decreasing during the simulation time frame. A detailed study could be carried out for studying the ER pattern for engineering graduates in India. SD studies could also be conducted to identify "boomerang effect" in other social systems. A comparative study could be conducted to analyze the systems which had sustainable growth and systems which had disruptions using concept of SD and boomerang effect.

References

Adamuthe, A.C., Tomke, J.V. and Thampi, G.T. (2015), "An empirical analysis of hype-cycle: a case study of cloud computing technologies", *International Journal of Advanced Research in Computer and Communication Engineering*, Vol. 4 No. 10, pp. 316-323.

Ahmad, S. and Bin Mat Tahar, R. (2014), "Using system dynamics to evaluate renewable electricity development in Malaysia", *Kybernetes*, Vol. 43 No. 1, pp. 24-39.

AICTE-Annual Reports (2011/2012), "All India Council of Technical Education, 2005-2015", available at: www.aicte-india.org/misannual.php (accessed March 5, 2016).

AICTE, Approval Process Handbook (2015/2016), available at: www.aicte-india.org/downloads/Approval_Process_Handbook_2015_16.pdf (accessed March 8, 2016).

Ardila, L. and Franco, C. (2013), "Policy analysis to boost the adoption of alternative fuel vehicles in the Colombian market", *31st International Conference of System Dynamics Society, July*, pp. 1-4.

Aspiring Minds (2014), "National employability report-engineers", available at: www.aspiringminds.in/docs/national_employabilityReport_engineers_annual_report_2014.pdf (accessed January 23, 2016).

Cai, L. and Liu, Y. (2013), "Application of system dynamics for municipal waste management in china: a case study of Beijing", *Conference Proceedings of the 31st International Conference of the System Dynamics Society, Masachussets, MA, July 21-25*, available at: www.nswaienvis.nic.in/Waste_Portal/Case_Studies_31.10.14/Application%20of%20System%20Dynamics%20for%20Municipal%20Waste%20Management%20in%20China-A%20case%20study%20of%20Beijing.PDF (accessed July 27, 2016).

Choudaha, R. (2012), "Growth statistics on engineering and management institutions in India", available at: www.dreducation.com/2012/03/data-engineering-management.html (accessed January 16, 2016).

Fateh Rad, M., Seyedesfahani, M.M. and Jalilvand, M.R. (2015), "An effective collaboration model between industry and university based on the theory of self organization: a system dynamics model", *Journal of Science & Technology Policy Management*, Vol. 6 No. 1, pp. 2-24.

Fenn, J. and Raskino, M. (2011), "Understanding Gartner's Hype Cycles, 2011", Gartner, Inc., Stamford, available at: http://isites.harvard.edu/fs/docs/icb.topic1360759.files/understanding_gartners_hype__214001.pdf (accessed January 12, 2016).

Gartner (2015), "Gartner research methodologies: technology related insights for your critical business decisions", Gartner Inc., Stamford, available at: www.gartner.com/imagesrv/research/methodologies/methodologies_brochure_14.pdf (accessed January 6, 2016).

Gambhir, V., Wadhwa, N.C. and Grover, S. (2016), "Quality concerns in technical education in India: a quantifiable quality enabled model", *Quality Assurance in Education*, Vol. 24 No. 1, pp. 2-25.

Hindustan Times (2015), "AICTE plans to cut 600,000 engineering seats", Hindustan Times, September 22, p. 5, available at: www.hindustantimes.com/education/aicte-plans-to-cut-600-000-engineering-college-seats/story-TVbO64dWyv1Pum1fCWHpWP.html (accessed January 5, 2016).

Hunt, H. (2001), "Boomerang theory", Cambridge, available at: www2.eng.cam.ac.uk/~hemh/boomerang_theory.pdf (accessed January 5, 2015).

Karen, C.A. (2013), "Assessing the fit of regression model", The analysis factor, available at: www.theanalysisfactor.com/ assessing-the-fit-of-regression-models/ (accessed March 10, 2016).

Mahajan, C.A. (2014), "1.5 million engineering pass outs in India every year, fewer getting hired", Dazeinfo.com, available at: http://dazeinfo.com/2014/10/28/1-5-million-engineering-pass-outs-india-every-year-fewer-getting-hired-trends/ (accessed January 5, 2016).

Mauro, J.B. (1989), *An Introduction to Boomerangs*, 3rd ed., Smith & Flannery Inc., Richmond, VA, pp. 8-9, available at: www.flight-toys.com/ boomerang/downloads/mauro_book.pdf

Meadows, D.H. (1982), "Whole earth models and systems", CoEvolution Quarterly, pp. 98-108.

Reddy, R. (2012), "Just three per cent engineers are job-ready", *The Hindu*, March 12, p. 9, available at: www.thehindu.com/features/education/careers/just-three-per-cent-engineers-are-jobready/article2987626.ece (accessed September 10, 2015).

Singh, A. and Singh, S. (2014), "Private engineering education in India: past, present and future", *International Journal of Management and Social Science Research*, Vol. 3 No. 11, pp. 39-46.

Sterman, J.D. (2010), "Business dynamics: systems thinking and modeling for a complex world", Tata McGraw Hill Education Private Limited, Delhi.

Sterman, J.D., Richardson, G.P. and Davidsen, P. (1988), "Modelling and estimation of petroleum resources in the United States", *Technological Forecasting and Social Change*, Vol. 33 No. 3, pp. 219-249.

Tapley, B.D. (1990), *Eschbachs's Handbook of Engineering Fundamentals*, 4th ed., John Wiley & Sons, Inc., New York, NY, pp. 41-42.

Thomas, S. (2015), "Engineering a quality dip", Deccan Chronicle, June 10, available at: www.deccanchronicle.com/150610/nation-education/article/engineering-quality-dip (accessed March 27, 2016).

Zhang, H., Calvo-Amodio, J. and Haapala, K.R. (2013), "A conceptual model for assisting sustainable manufacturing through system dynamics", *Journal of Manufacturing Systems*, Vol. 32 No. 4, pp. 543-549.

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