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Analysis of impact of industry-academia interaction on quality of technical education: A system dynamics approach

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ABSTRACT

Indian technical education since the year 1995 experienced an exponential growth which adversely affected the quality of engineering graduates. Many research studies have strongly emphasized on improving the quality of technical education in India. The industry is proactively involved in improving the quality of its raw material suppliers, but it has overlooked academia despite it being an important supplier of human capital to the industry. This is perhaps because the industry adopted myopic approach towards academia considering it as a fruitless option. As a result, there is a visible disconnect between industry and academia in India which is a major cause for the poor quality of technical education. This research paper presents a novel approach to analyze the impact of industry interaction on the quality of technical education through system dynamics (SD) modeling. A computer based model was developed to explain the impact of Industry-Academia (IA) interaction in enhancing the quality of technical education as seen through the employability of graduates. The paper attempts to prove that the proactive involvement of industry in academia is a profitable proposition for both the stakeholders. The study also analyzes the impact of key policy variables on unemployment level, shortage of employees and total cost of involvement of industry in academia. The model was developed using SD simulation software STELLA (version 10.0) and four scenarios were generated to analyze the system behavior. The SD model was simulated for fifty years. The findings of the study reveal that proactive involvement of industry is essential for improving the quality of technical education and is profitable in the long run. The insights from the study would be helpful to policy makers and researchers from the industry and academia in analyzing the long-term implications of decisions using SD modeling.

1. Introduction

There is an ever-increasing pressure on industry to make superior quality products using high quality input resources and latest technology for sustenance in the globally competitive environment. The quality of human capital is vital for subsistence for any organization. Therefore, industry needs highly employable graduates who can contribute significantly towards the organizational growth. Academia, which is an important supplier to Industry (of human capital), gets minimal attention from it in comparison to the suppliers of other input resources. The industry has focused considerably on Tier-1, Tier-2 and Tier-3 suppliers for the improvement of their processes through proactive involvement. On the contrary, academia has been put on the flip side. As a consequence, there appears to be a significant gap in the interaction between industry and academia. It widens as we move downstream along the suppliers of Tier-I (under-graduate and post-graduate institutions), Tier-II (secondary and senior secondary schools) and Tier-III (primary schools) categories, respectively. Although the academia is important like any other supplier, the industry has not proactively involved itself in improving the quality of academia. This paradox can best be explained through the concept of SD. The outcome of any action of involvement in academia comes with a significant delay and has long-term implications. Whereas, profit-driven organizations look for short term gains which are not seen in academia in a shorter time frame. As a consequence, academia is given low priority by industry. This paper aims to illustrate, through SD approach, how proactive involvement of industry in academia is more profitable to it rather than remaining indifferent or reactive.

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2. Framework of the study

In Section 1, the research paper gives an overview of higher education in India and the challenges faced by it. Section 2 presents the literature review on the application of SD in different social systems including education. Section 3 gives the dynamic hypothesis of IA interaction model. In this section, the detailed causal loop diagram of the model is presented and discussed which is then converted to stock and flow diagram. Section 4 presents the model validation, results and analysis of behavior of different policy variables. Section 5 gives the managerial implications of the proposed policies (see Fig. 1).

3. Literature review

The literature review was conducted to understand the Indian higher education system, causes of poor quality in technical education in India, and to know the extent to which SD has been applied in understanding the behavior of complex systems. This section gives a review of the literature covering primarily three aspects: (1) Scenario of higher education in India; (2) Quality issues in technical education in India; and (3) Application of SD in education and other complex systems.

3.1. Higher education scenario in India

The Indian higher education system has 712 universities and university-level institutes and about 36,671 colleges. Amongst universities, 310 are state universities, 143 private universities, 43 central universities and 127 deemed universities (PWC Report, 2012). The technical education system in India covers courses in management, engineering, technology, architecture, pharmacy, hotel management and catering technology, and applied arts and crafts. The gross enrollment ratio (GER) in higher education is 18.8% which is still lower than the world average (24%) and much lower than that of the developed nations (58%) (PWC Report, 2012) (see Table 1).

Tables 2a and 2b give enrollment data for different programs in higher education in India for the year 2012–2013. Percentage enrollment for B.Tech in engineering is around 13.27% (For B.E. and B.Tech) making it the second highest enrolled programme after Bachelor of Arts. The percentage out-turn/pass-outs in the engineering and technology in the year 2012–2013 was around 10 (MHRD-Report, 2013). This seems rather alarming since the cur-

Table 1
Number of higher educational institutions in the year 2013–2014. *Source:* MHRD-Report (2013).

Higher education	**Universities**	Type	Number
		Central University	42
		State Public University	310
		Deemed University	127
		State Private University	143
		Central Open University	1
		State Open University	13
		Institution of National Importance	68
		Institutions under State Legislature Act	5
		Others	3
		Total	**712**
	Colleges		**36,671**
	Stand alone institution	Diploma Level Technical	3541
		PGDM	392
		Diploma Level Nursing	2674
		Diploma Level Teacher Training	4706
		Institutes under Ministries	132
		Total	**11,445**

Table 2a
Percentage enrollments in different undergraduate programs in higher education (year 2012–2013). *Source:* MHRD-Report (2013).

S.No.	Programme	Percentage enrollments
	B.A.-Bachelor of Arts	32.55
1	B.Com.-Bachelor of Commerce	11.42
2	B.Sc.-Bachelor of Science	11.17
3	B.Tech.-Bachelor of Technology	7.01
4	B.E.-Bachelor of Engineering	6.26
5	B.Ed.-Bachelor of Education	2.01
6	L.L.B.-Bachelor of Law or Laws	0.69

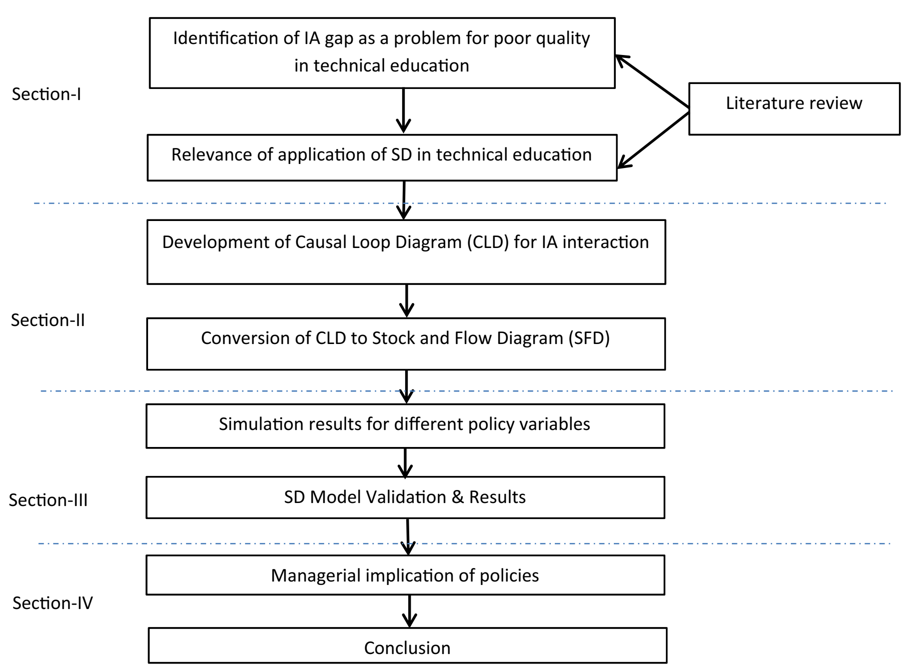

Fig. 1. Framework of the study.

Table 2b
Percentage enrollments in different post graduate programs in higher education (year 2012–2013). *Source:* MHRD-Report (2013).

S. No.	Programme	Percentage enrollments
7	M.A.-Master of Arts	4.34
8	M.Sc.-Master of Science	1.91
9	M.B.A.- Master of Business Administration	1.88
10	M.Com.-Master of Commerce	0.94
11	M.C.A. -Master of Computer Applications	0.84
12	M.B.B.S.-Bachelor of Medicine and Bachelor of Surgery	0.49
13	M.Tech. -Master of Technology	0.51
14	M.E.-Master of Engineering	0.24
15	Other	17.73

rent employability level in the technical education is very low. It is highly likely that the increase in enrollment rate will add more graduates to the unemployed pool which has already reached at an alarming position.

Quality in engineering education in India is highly imbalanced (Vrat, 2009). It has a pyramidal structure comprising of a few reputed institutions which are recognized in India and abroad. Industries require a larger number of engineering professionals to meet their requirements. They survive primarily on the engineering graduates of second and third level institutions in India (National Knowledge Commission, 2008). About 20% of the universities for higher education in India are state private universities. Additionally, there are a large number of private engineering colleges which are affiliated to the state public universities. Average employability of graduates coming out of private engineering institutions is as low as 20% (Aditi Tandon, 2013; Times of India, 2014). In the last one decade, the expenditure on education in India has been around 3–4.5% of the GDP which is quite lower than other developing countries like South Africa (6%) (PWC Report, 2012). The total budgeted expenditure on technical education in the year the 2012–2013 as percentage of GDP was 4.18%. The gross enrollment ratio (GER) in higher education increased from 8.1 in the year 2001 to 21.1 in the year 2013 (Friedman, 1970). But this increase was associated with degradation of quality. Fig. 2 is a graphical portrayal of expenditure on education as% of GDP for past sixty years and is much below 6% of GDP often promised.

As per the report published by National Knowledge Commission, private universities have extremely poor level of industry engagement, are mostly management dominated, have poor quality of faculty and have very low level of research and development activities. On the contrary, they have good physical infrastructure and are doing well in maintaining it. Similar observations were reported by Upadhayay and Vrat (2013) through an empirical study conducted to assess the quality of technical institutions in India. The findings from their study revealed a significant imbalance in priorities given by technical institutions in India to the enablers of good quality technical education. Private institutions put more weight on low importance enablers like physical infrastructure and co-curricular activities whereas high importance enablers like faculty quality, industry interaction were given very low priorities. There is huge skill gap which institutions need to fill by interacting with industry. Technical institutions in India require closer partnerships with industries for greater national productivity (Anand, 2013). Confederation of Indian Industries (CII) in collaboration with All India Council of Technical Education (AICTE) conducted a survey on 814 technical institutions across the country to evaluate them on IA interaction. The findings of the study revealed that only 8% institutes were '*good*' in terms of IA interaction whereas 34% institutions were '*extremely poor*'. The survey was also taken by the elite government institutions which already have high industry collaborations and get huge government fundings (almost 80% of the total government budget). This gives a plausible justification for the existence of '*Mathew Effect*' in the Indian technical education system. Mathew Effect is a phenomenon where the rich gets richer and poor gets poorer (Vrat, 2012). The IA interaction was found comparably better in southern and western regions of India in the AICTE-CII study. The national average in the findings was only 5.63% higher than the cut off for extremely poor category (AICTE - CII survey of industry-linked technical institutes, 2015). This signifies that a majority of the institutions in India are having a low or poor level of Industry collaborations. Therefore, there is a need to strengthen such collaborations on a larger scale.

The aforementioned factual information provides justification to the need for industry and academia to collaborate for greater productivity and societal benefits. Such collaborations are important in building right academic infrastructure, upgrading the faculty quality, designing and updating academic curriculum, facilitating good quality industrial training and projects for students.

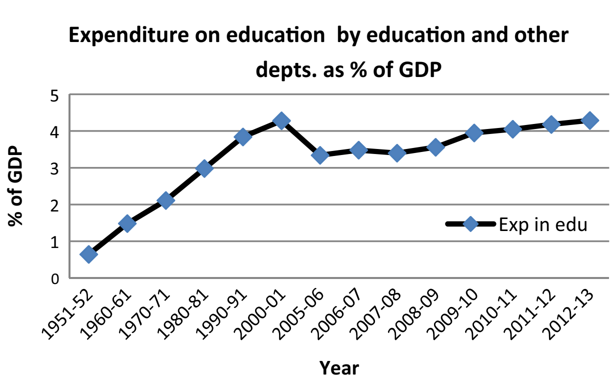

Fig. 2. Expenditure on education by education & other departments as % of GDP. *Source:* MHRD-Report (2013).

3.2. Quality issues in technical education in India

Many research papers, magazines, and newspapers have reported about the poor quality of technical education in India. The private sector in India delivers about 85% of technical education (Debnath & Shankar, 2012). The quality of technical education delivered by the private sector in India is dismally low (Arindam Mukherjee, 2011). As a consequence, a large number of engineering graduates became jobless due to their poor employability. A national employability report stated that only 2.8% engineering graduates in IT service sector in India are employable (Reddy, 2012). The available literature in the area of technical education reports several factors which perhaps are responsible for the poor quality of technical education. Low IA interaction, paucity of good quality faculty, outdated teaching-learning process and curriculum, lack of management commitment, substandard computational resources, low level of research and development, poor quality student intake, lack of academic collaborations and poor alumni interactions are major factors reported in the literature which are responsible for abysmal level quality of technical education in India. Industry, being the external customer, plays a vital role in improving the employability of graduates by providing right inputs on curriculum and syllabi, enhancing technical skills through projects and hands-on training (Pandi, Sethupathi, & Rajesh, 2012). With the exponential increase in student enrollments in engineering stream, provision of a good quality training in the industry appears to be a distant option. Therefore, industry needs to play a bigger role in nurturing young talent by engaging students on a large scale on good quality trainings and projects

(Bhusry & Ranjan, 2012; Sahu, Shrivastava, & Shrivastava, 2008). Debnath and Shankar (2012), Vrat (2009), Khanna (2012) and Pandi et al. (2012) have advocated about the importance of IA interaction in improving the quality of technical education. Vrat (2009) reported about the importance of industry engagement with academia for nurturing the young talent. Industry can play a proactive role in curriculum design, providing good quality industrial internships and projects to the students, developing cutting edge research and development facilities for faculty and students, sharing intellectual and physical resources, and providing consultancies and research projects to the academia. Upadhayay and Vrat (2013) reported in their study about the lack of IA collaborations in the Indian context. Amongst many factors reported in the literature, IA interaction plays a vital role in improving quality of technical education system.

3.3. Application of SD in complex systems

SD is a well-established methodology to model and understand the behavior of complex systems (Forrester, 1958). It has been extensively used for modeling the dynamic behavior of complex non-linear systems. Golroudbary and Zahraee (2015) used SD for evaluating system behavior of electrical manufacturing company. Liao, Wang, Wang, and Tu (2015) developed a computerized SD model to assess the dynamic relationships between IT investment strategy of an organization and market performance. Their study proposed SD as a useful decision support tool for analyzing different IT investment strategies. Liu, Benoit, Liu, Liu, and Guo (2015) analyzed lake watershed system through SD modeling for managing lake water quality. They used two reinforcing loops and three balancing loops in the dynamic hypothesis of their model.

Many research papers have explained policy experimentations through scenario building (Ahmad, Tahar, Muhammad-Sukki, Munir, & Rahim, 2015; Golroudbary & Zahraee, 2015; He & Zhang, 2015; Liao et al., 2015; Liu et al., 2015). Liu et al. (2015) designed three alternative scenarios to Business As Usual (BAU) scenario to simulate the effect of various tools on the improvement of water quality. Das and Dutta (2013) analyzed the impact of product exchange, collection and remanufacturing on bullwhip effect and productivity through SD. Kumar and Kumar (2014) used SD modeling to critically analyze the Indian healthcare supply chain and proposed measures to improve the sustainability of rural healthcare supply chain by reducing the risk of stock outs of medicine. Murthy, Gujrati, and Iyer (2010) developed an SD model to assess the effectiveness of distance education programme in the Indian context. Pedamallu, Ozdamar, Ganesh, Weber, and Kropat (2010) used SD to investigate the role of infrastructural facilities on the quality of primary education in India. They developed a cross-impact model to illustrate the influence of one variable over the others in increasing the enrollment rate. Preliminary SD model presented by Shaffer (2005) discussed implications of distance education learning. Hussein and El-Nasr (2013) studied the education quality control using SD modeling and genetic algorithm. Sim (2014) studied the causal relationships between influencing parameters of vocational education through SD modeling. Dace, Bazbauers, Berzina, and Davidsen (2014) used SD model to analyze the policy mechanisms which promote packaging material efficiency in products. Applications of SD modeling pertaining to varied complex systems were reported by researchers in the review. SD addresses following three points effectively (Sterman, 2010).

(i) Policy resistance; which arises because we often don't understand the full range of feedback operating in the system.
(ii) The principle of bounded rationality; It states that capacity of the human mind for handling complex problems is much smaller than the size of the real world problems and hence the common assumption of a rational decision maker is flawed.
(iii) The law of unintended consequences explains that in the absence of full knowledge of the situation, decisions will have effects that were not anticipated.

SD is suitable for non-linear complex systems with multiple feedback control loops. Long-term dynamic implications can best be studied through it. The system behavior can be well understood by using computer simulations through interactive software products available in the market for SD study. SD software product facilitates multiple scenario building useful for managerial insights.

From the literature reviewed, it is observed that there is a very low level of IA interaction in the Indian technical education. Many research studies have applied SD for the analysis of policy variables of complex systems, other than education. Very few research studies have been reported in the literature which have used SD as a tool to analyzes technical education in the Indian context. Therefore, there search study was carried out to analyze the IA interaction in the Indian technical education system using SD. The long-term implications of IA interactions have been modeled using SD. The model developed has been discussed in the following section.

4. The system dynamics model

4.1. Causal loop diagram

Fig. 3 shows the causal loop diagram for the model being proposed. The first stage of SD modeling involves generating a Causal Loop Diagram (CLD). It explains the feedback structure of the dynamics of a system. A CLD consists of variables connected by the arrows showing causal relationships between them. Each causal link is assigned a polarity to explain how a dependent variable changes with respect to the change in the independent variable.

The major loops in the CLD are denoted by a loop identifier. The loop identifier explains the nature of the loops as "*Reinforcing Loop*" and "*Balancing loop*". The reinforcing and balancing loops are also called positive feedback and negative feedback loops, respectively. The correct way to determine the polarity of a causal loop is to trace the effect of a small change in a variable as it propagates through the loop. It is a positive loop if the feedback reinforces the original change; if it opposes the original change, it is a negative loop (Sterman, 2010). The CLD of the IA interaction model, Fig. 3, explains the causal relationships between the variables of the model. A total of six feedback loops were identified in the model which are labeled as; R1, R2, R3, B1, B2 and B3. The first three loops are reinforcing loops and the remaining are balancing loops.

4.2. Reinforcing loops: R1, R2, and R3

Loop R1 illustrates the importance of employability in the academic supply chain and industrial growth. If industry proactively supports academia in nurturing young talent through its resources, by engaging itself in academia, employability of students will increase considerably. The aforesaid support could be in the form of good quality industrial internships and projects, designing curriculum and syllabi, transferring knowledge of cutting edge technologies, sharing intellectual resources, supporting academia financially for research and development activities, providing consultancies, etc. Such a high level of interaction with academia would trigger the reinforcing loop R1 in positive direction resulting in an increase in the employability level of graduates. The rise in employability level will increase the number of employable gradu-

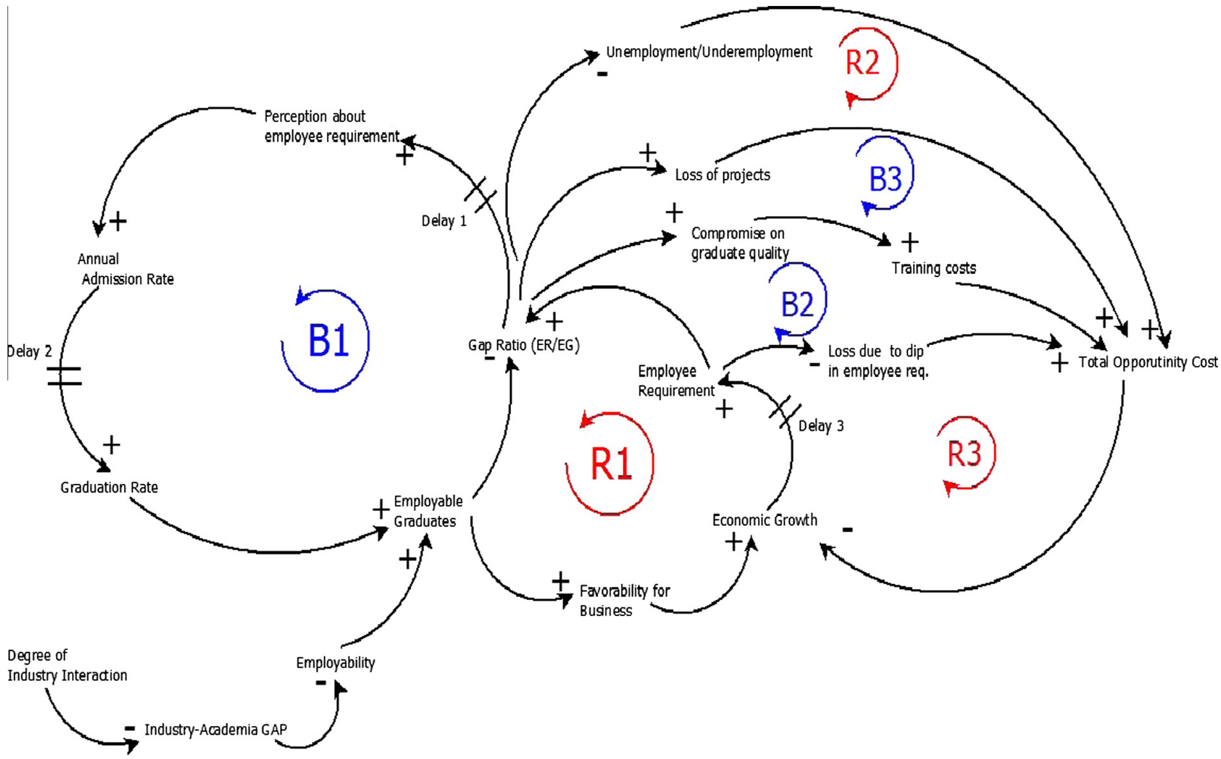

Fig. 3. CLD of IA interaction model.

ates. High quality of human capital is desirable for every business in the current scenario of global competitiveness. Highly employable graduates will favor business growth. Growing businesses expand and create more projects and, therefore, require more good quality employees. If the ratio of employee requirement and employable graduates (Gap ratio) is greater than unity then the perception of greater job prospects in engineering will become stronger. This is because graduates in such a scenario would be hired at higher salaries because of the shortage of talent in the market at that point of time. This will give a push to the annual admissions rate in engineering streams. An increase in annual admissions rate will increase the graduation rate. An increase in graduation rate will again increase the number of employable graduates. Thus, the reinforcing loops R1 repeats again in a similar fashion. The supply of employable graduates to the increase in employee requirement comes with a third order delay resulting in scarcity of talent for the delay period. In engineering stream, the response to the increase in employee requirement comes after four years and by then the requirement may fall down or increase. This delay causes a significant imbalance in the academic supply chain.

There are three delays in this loop; Delay-1 in perceiving employee requirement, Delay-2 in graduation and Delay-3 between economic growth and employee requirement. Delay-1 and Delay-3 are information delays. Delay-2 is a material delay. Delays are ubiquitous features of any complex system. The order of the delay is characterized by the number of stocks between the inflow and outflow of a delay structure. In this loop, the information about the requirement of engineering talent in industries is transferred with a third order delay.

Loop R2 explains the role of unemployment and underemployment in the dynamic system of IA interaction. If the supply (of graduates) is more than the requirement, then the problems of unemployment or under-employment increases which will increase the total opportunity cost. An increase in the total opportunity cost will have a negative impact on the economic growth. Loop R3 has two negative causal relationships; therefore it is a reinforcing loop. A fall in economic growth will cause loss of projects and jobs. This loss adds up to the total opportunity cost. Total opportunity cost closes the loop in a similar way as explained for Loop R2.

Had the system under study been working only on the reinforcing loop R1, then there would have been indefinite exponential growth in the number of employable graduates as well as the industrial productivity. Any system with exponential growth is unstable and, therefore, is bound to collapse. To counteract the uncontrolled growth or decline, balancing loops play a vital role and are discussed in the following section.

4.3. Balancing loops: B1, B2, and B3

Balancing loop B1 is partly same as R1 while moving anticlockwise from gap ratio to employable graduates. Thereafter, the loop gets closed with a negative causal link from employable graduates to the gap ratio. An increase in the number of employable graduates will decrease the gap ratio. Balancing loop B2 explains the tendency of the system to compromise on the quality of graduates. This tendency increases with an increase in the gap ratio. This necessitates the need to train such graduates to bring them at par with industry standards. As a consequence of this, the total opportunity cost increases. Balancing Loop B3 demonstrates the increase in the total opportunity cost due to the loss of industry projects as a result of the unavailability of good quality manpower. In the IA Interaction model, employability plays an important role as an input, which in turn is related causally by the industry-academia gap.

5. Stock and flow diagram

The causal loop diagram was converted to Stock and Flow Diagram (SFD) using an SD software product Stella, version 10.0.

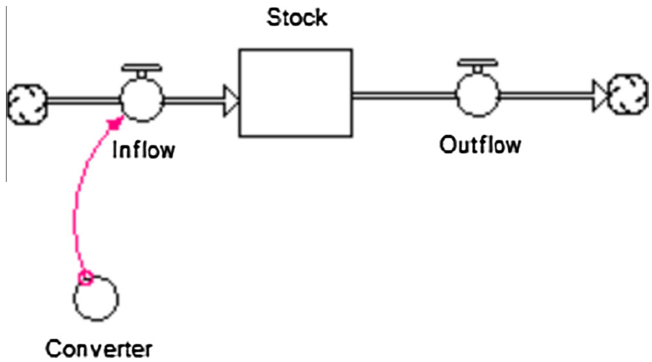

Fig. 4. Basic building blocks of an SD model.

Basic building blocks for an SD model are; stocks, flows, converters and connectors. Fig. 4 shows the basic building blocks which are used in the construction of an SD model. Stocks are accumulations which characterize the state of the system and are represented by rectangles. Inflows to the stocks are represented by arrows pointing into the stock. Outflows are represented by arrows pointing out of the stock. Valves are used to control the flows. The mathematical relationship between stocks and flows can be represented by the following integral form (Sterman, 2010).

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

where t_0 is the initial time, t is the current time and Stock (t_0) is the initial value of the stock. Connectors are used to represent the causal relationship between variables of the model. Converters have built-in functions and graphs.

The SFD in the proposed model consists of four subunits: Academic supply chain, opportunity cost, employability and industry involvement, respectively. Fig. 5 shows the subsystem diagram of the proposed model. The essence of this model is to capture the effect of causal relationships between academia and industry in the form of opportunity cost.

The level of Total Opportunity Cost (TOC) was then used for policy analysis of various scenarios. The TOC for a policy scenario is the sum of all opportunity costs arising out of the system under study. The increase in TOC can be summed as per Eq. (2).

$$\text{Increase in TOC} = \alpha + \beta + \gamma + \delta + \varepsilon \quad (2)$$

where α = Increase in opportunity cost due to loss of projects; β = Increase in training costs; γ = Increase in opportunity cost due to investment in education; δ = increase in opportunity cost due to dip in employee requirement; ε = number of unemployed graduates $\times$ monetary loss per unemployed graduate.

Fig. 6 shows the stock and flow diagram (SFD) for the system dynamic modeling being proposed.

6. Results and analysis

The reference mode and time horizon were set for the proposed model for simulation runs. A reference mode is a set of graphs, data showing the development of the problem over time (Sterman, 2010). The time horizon was chosen as 50 years and was extended 10 years back in history. The model was tested for the different level of industry engagement with academia. Following policy scenarios were formulated: The existing IA interaction model was tweaked to develop two perspectives of intake rate which are discussed below:

(i) *When intake rate is a function of number of students enrolled in a discipline (Follow-the -Crowd/Knee-Jerk reaction model:* As per this model there is no clear picture of demand for engineering disciplines in the market. The admission seekers develop perceptions and take admissions based on the number of students enrolled in an engineering discipline. Their reaction is knee-jerk and they just follow-the-crowd.

(ii) *When intake rate is a function of feedback from industry (Industry-feedback-model):* In this scenario, the feedback of precise information on demand of engineering graduates is given to the admission seekers at a common portal by the industry. The major assumption made in this model is that the admission seekers take the decision only after getting the industry feedback.

Based on the above models following four policy scenarios were developed (see Fig. 7).

Scenario 1-Business as Usual (BAU) - Follow-the-crowd model and very low IA interaction: Under this policy, the industry remains aloof from academia and has myopic approach to looking at immediate monetary benefits in its decision-making. It does not involve itself in improving the quality of technical institutions. It recruits manpower from the available talent in the market. It either fills up the shortages by hiring costly employees from abroad or manages with the poor quality talent available in the country. Moreover, the intake rate is a function of the number of students enrolled in an engineering discipline.

Scenario 2 - Follow-the-crowd model and very high IA interaction: Under this policy, industry proactively involves itself in academia to nurture the young talent and contribute towards the holistic development of technical education. Here, industry plays vital role in improving the academic curriculum, training and improving faculty quality, providing adequate computational resources, facilitate adequate industry exposure to students, provide good quality training and projects to students and counsel students for improving the placements. But, the intake rate is a function of the number of students enrolled in the engineering programme.

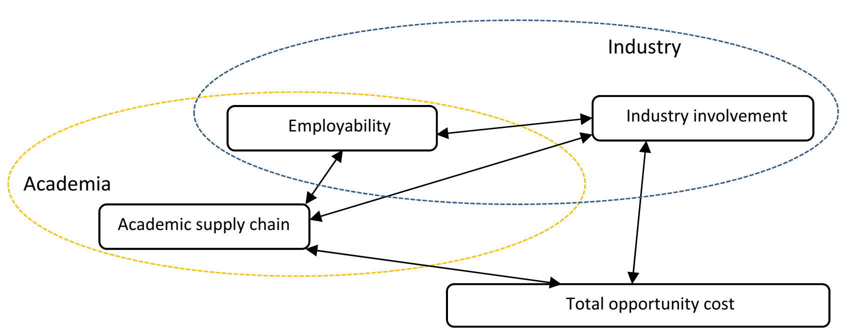

Fig. 5. Sectors of the IA interaction model.

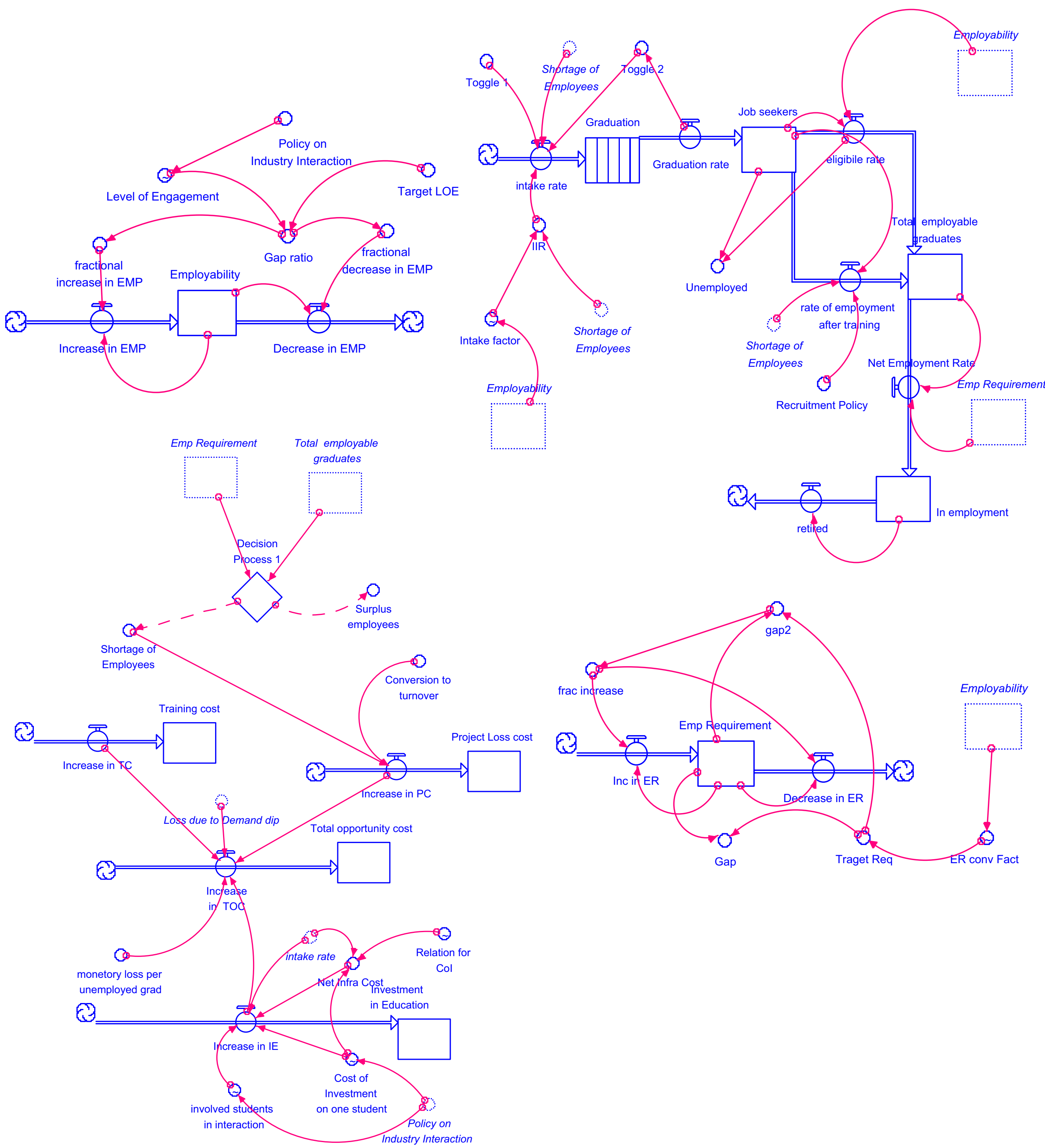

Fig. 6. Stock and flow diagram of IA interaction model.

Scenario 3 - Industry-feedback-model and low IA interaction: The IA interaction in this scenario is very low, but the intake rate is a function of industry feedback.
Scenario 4 - Industry-feedback-model and high IA interaction: In this scenario, the student intake rate is a function of industry feedback and industry engage itself proactively in academia to nurture the young talent. Table 3 presents the initial values used for the policy parameters relevant for simulations.

Initial values of variables employee requirement, employability and intake rate were matched with the engineering education scenario of the year 2004 in India. (*Source:* Times of India (2014) and AICTE - CII survey of industry-linked technical institutes (2015).)

6.1. Model testing

The boundaries of IA model has been critically assessed to determine which variables are to be treated as exogenous, endogenous or excluded altogether. A plausible assessment of the dynamic model has been done through boundary adequacy test,

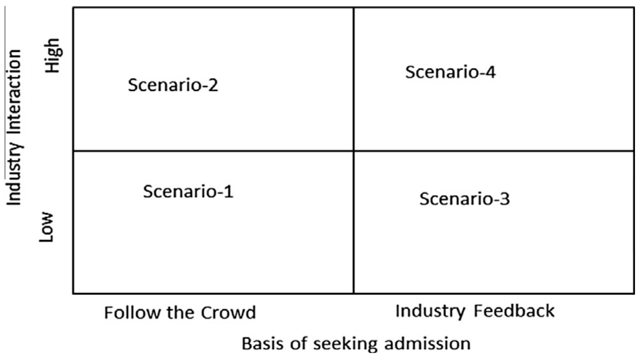

Fig. 7. Framework of policy scenarios.

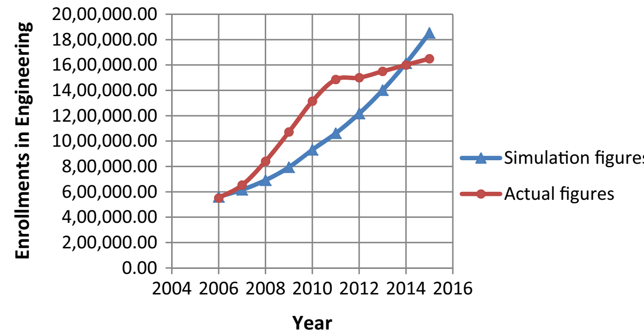

Fig. 8. Comparison of actual results with model results.

structural assessment test, dimensional consistency test, and extreme condition and behavior reproducibility tests.

Reproducibility test: The enrollment rate (intake rate) related data was available in the literature (AICTE, 2013). The model was tested for intake rate by reproducing results from the past. The simulation results were compared with the actual intake rate between the year 2006 and 2015 (Fig. 8). The most widely reported measure of fit is the coefficient of determination R^2 (Sterman, 2010) which was calculated through a statistical software product; SPSS, version 16.0. The R-squared value obtained was 0.713 which can be considered as useful and the relationship between the model variables is significant (Martin, 2012). A value of 0.713 means that 71.3% of the change in the dependent variable (actual enrollment figures) can be explained by the independent variable (simulation figures).

Extreme condition test: The model was subjected to extreme conditions of input variables; Employee requirement; Initial intake rate and Employability. The model was found to be robust in extreme conditions.

Dimensional consistency test: All equations were directly inspected to ensure that all the parameters of the model are dimensionally consistent.

Boundary adequacy test: CLD and SFD of the model were tested for exogenous and endogenous variables. The model was also tested for behavior anomaly. There were no inconsistencies found in the model behavior. Hence, it could be concluded that the model is validated.

Fig. 9 depicts the behavior of employee requirement for all scenarios under study. Employee requirement for Scenario-1(BAU) and scenario-3 is similar. Likewise, scenario-2 and scenario-4 are identical. This behavior can be explained by the fact that the employee requirement is independent of the student intake rate and, therefore, the curves are similar in nature. On the contrary, curves 2 and 4 differ significantly from curves 1 and 3. This change is caused by the difference in the level of industry interaction with academia. For scenarios 2 and 4, the employee requirement increases exponentially first and it becomes stable later. This type of S-shaped growth can be attributed to the presence of balancing and reinforcing loops in the model. Balancing loops tend to control the exponential growth actuated by the reinforcing loops. Since scenario-1 and scenario-3 represent a very low level of IA interaction, the employee requirement goes through a continuous decline due to poor industrial growth. The feedback effect of low industry interaction results in the decrease in employee requirement whereas the high IA interaction increases the employee requirement.

Fig. 10 shows the opportunity cost of involvement of industry in academia for all the four policy scenarios. Lines 1, 2, 3 and 4 in Fig. 10 represent total opportunity costs for scenario-1, scenario-2, scenario-3 and scenario-4, respectively. Scenario-1 and scenario-2 are based on follow-the-crowd model. The opportunity cost of scenario-2 is higher than the opportunity cost of scenario-1 in the initial period of nine years. In the long run, the proactive involvement of industry in academia becomes a profitable proposition. This is because in the initial years industry need to invest in academia in the form physical and intellectual resources and the outcome of this investment is not immediate but is visible after a delay of four years. Therefore, the gap between opportunity costs of curves 1 and 2, start reducing after four years. A similar behavior is observed between curve 3 and curve 4. The only exception is that the crossover point comes in six years, much earlier than the previous case. This is perhaps because in the Industry-feedback-model the losses due to the imbalance in demand and supply of engineering graduates are much lesser as compared to the follow-the-crowd model. It is perceptible from Fig. 10 that the decision makers in industry get biased by the tendency to think of cause and effect as local and immediate, but in dynamically complex system such as engineering education, cause and effect are distant in time and space (Sterman, 2010). Therefore, the industry with the myopic approach is unable to see the long-term benefits of proactive involvement in academia and as a consequence, it remains reluctant for IA engagement.

In Figs. 11 and 12, lines 1 and 2 represent shortages of employees and unemployed graduates, respectively. In business as usual scenario (scenario 1), poor industry interaction, and low employability adversely affect the quality of available human capital in the region which in turn affects the investment level. Low level of investment brings down productivity and, therefore, results in low employee demand. As a result, the shortage of employees falls to zero in due course of time. On the other side, a huge supply of poor quality graduates adds up exponentially to the alarmingly high pool of unemployed graduates. Therefore, Fig. 11 reveals the inherent lacunae in the BAU scenario (scenario 1) which perhaps

Table 3
Initial values for the policy parameters used in the simulation run.

Industry involvement level	Initial settings	Output variables
Very low (1), Excellent (5)	Employee requirement = 600,000; Employability = 0.2; Intake rate = 600,000	Employee shortage, Enrollment rate, Unemployment rate, Total opportunity cost

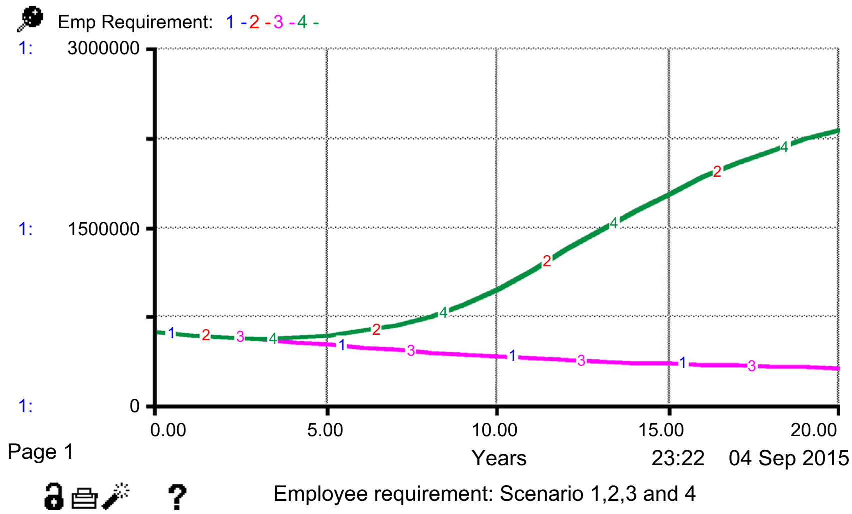

Fig. 9. Employee requirement: Scenario-1, scenario-2, scenario-3 and scenario-4.

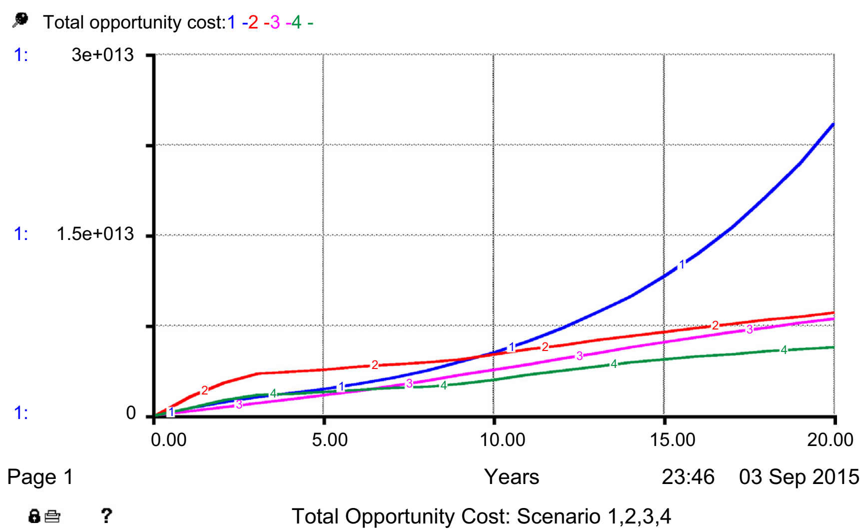

Fig. 10. Total opportunity cost (scenario 1, 2, 3 and 4).

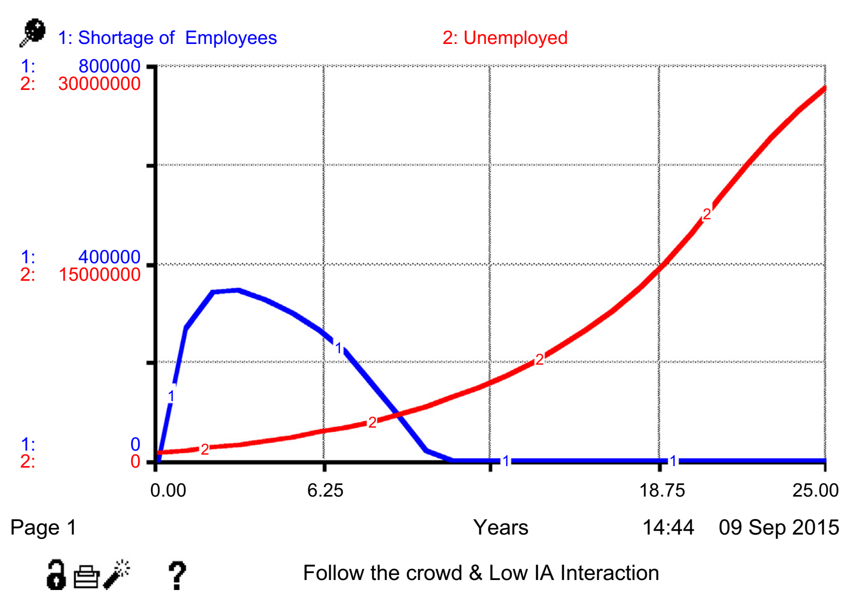

Fig. 11. Shortage of employees and unemployed graduates (Scenario-1).

Fig. 12. Shortage of employees and unemployed graduates (Scenario-2).

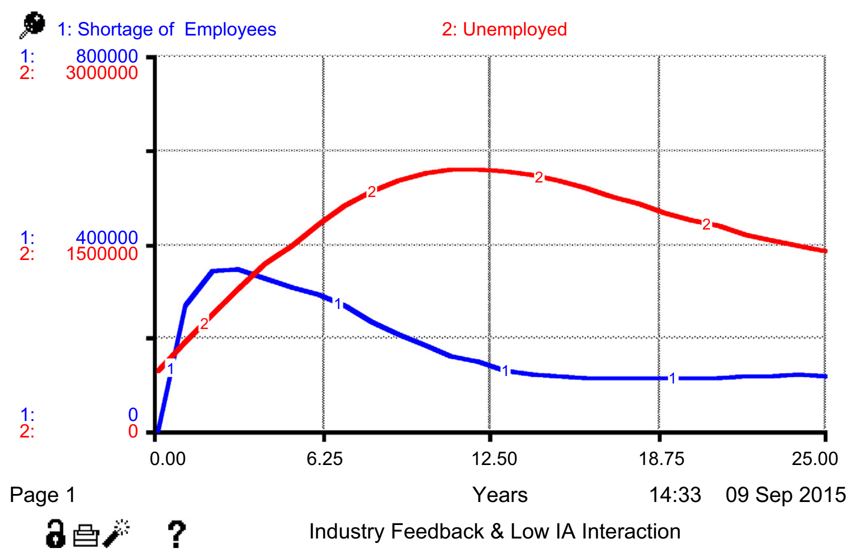

Fig. 13. Shortage of employees and unemployed graduates (Scenario-3).

will transform the so-called demographic dividend (young talent) to the demographic disaster (unemployed graduates). Further compounding is the worry, whether the increasing enrollment rate will transfer a major chunk of these enrollments to the unemployed pool after graduation. Paradoxically, the enrollment rate is otherwise being viewed as a positive sign in the current practice of educational growth. Fig. 12 explains the system behavior in scenario-2 when the intake rate is a function of shortages of employees (Industry-feedback-model). Scenario-2 puts up comparatively a better picture than scenario-1 as the shortage of employees is seen only for a smaller time frame as compared to scenario-1 (Fig. 11). The level of unemployed graduates comes down and is controlled at a definite level.

Scenario-3 (Fig. 13) is relatively better than scenario-1 as the growth of unemployed graduates is contained at a level. This is due to the increased accuracy in demand prediction by the admission seekers arising out of industry feedback given to them regarding engineering disciplines. But the persistent level of the shortage of employees and unemployed graduates causes loss to industry, academia and students. Scenario-4 (Fig. 14), portrays a better picture for employability as the unemployed pool falls down drastically in a shorter time span and then becomes constant. Whereas, employee shortage shows damped oscillation behavior which is perhaps due to the lag in supply to continuously increasing demand in the optimistic scenario. Employee shortage never falls down to zero due the persistent delay in supply to the continuously increasing demand. According to SD, the presence of a third order delay produces oscillations in the response variable. The dampening effect observed in employee shortage in scenario-4 can be attributed to the system correction in response to the market demand.

Managerial implications: Amongst the four policy scenarios tested for IA interaction model, scenario-4 gives better results in terms of total opportunity cost, level of unemployed graduates and employee requirement. Therefore, based on the impact on quality of technical education, scenario-4 is the best possible option and scenario-1 is the worst option. The Indian technical education system is currently experiencing the adverse effects of scenario-1, which are low employability of engineering graduates, outdated curriculum, low industrial growth, poor quality of faculty, and higher level of unemployment, low level of research and innovation and imbalances in demand and supply of engineering grad-

Fig. 14. Shortage of employees and unemployed graduates (Scenario-4).

uates. As an outcome of this research, following points are suggested to the stakeholders and policy makers of technical education in India:

(i) Industry should not have a myopic view on investment in education which is actually in congruence to what Friedman said, "In a free economy, there is one and only one social responsibility of business-to use its resources and energy in activities designed to increase its profits so long as it stays with the rules of the game" (Friedman, 1970). The statement, if understood from the angle of SD advocates business to invest in society, as in longer run the society will give more than what was invested. Therefore, industry should not take Corporate Social Responsibility as a burden imposed through intervention by the government but as an opportunity to nurture young talent who will later contribute to enhancing their productivity. Hence, the initiatives should be taken to bring awareness amongst industry about the benefits of proactive engagement with academia.

(ii) The industry should also play a proactive role in counseling admission seekers and providing information about the future prospects in the engineering discipline. This can be done by increasing interactions with schools, through organizing career awareness programme in schools. Such engagement would curb the demand-supply imbalance in the technical education.

7. Limitations and future scope

The SD model developed has treated industry engagement levels as the exogenous variables. A more in depth study could be done to find the impact of various modes of industry engagement on employability. The model has intuitively established values and relationships for total opportunity costs. Researchers can initiate a case study to find out the total opportunity cost for all models of industry engagement with academia. The study can further be carried forward to analyze the impact and role of technical education, through SD modeling, on the success of 'Make in India' drive.

8. Conclusion

The study reported in this paper analyzed the impact of industry engagement with academia on the quality of technical education through SD approach. The simulation results of IA model have been validated and support the view that the proactive involvement of industry in academia is a more economical proposition in the long run. Four different scenarios of industry engagement were developed to examine their impact on the quality of technical education. The scenario based on the current state of technical education was found to be the worst scenario amongst all. Scenario-4 was found to be quite effective in improving the quality of technical education.

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