Applying System dynamics to simulate Iran's engineering post graduates' employment status

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ABSTRACT

Iran's universities have a tradition of ~~been used to enroll~~ students admission with~~-~~out considering market's capacity for university graduates; a~~. A~~ fact which has led to problems such as lack of experts in some fields, under employment and unemployment in many others. While, forecasting market's capacity for university graduates and enrolling students based on the predicted capacity is the best way to hinder such problems.

In this paper, we applied~~aimed to apply~~ System D~~d~~ynamics to forecast demand of Iran's market for engineering post graduates and university's supply of engineering post graduates~~ to make it possible~~ to predict post graduates' employment status in country's near future. The results show that there will be ample job opportunities for Ph~~d~~D graduates such that they will not face unemployment or under employment in upcoming years. Ph~~d~~D students will have a good occupational status in near future while master students' employment status will aggravate in onward years such that most Master graduates will be relegated to jobs requiring less knowledgeable workers such as careers that require a bachelor's degree or even non degree jobs.

KEYWORDS:

System dynamics, engineering post graduates, employment, I~~i~~ran

1. Introduction

Evidence shows that during recent decades, students' admission in Iran's universities had not been in line with country's market's needs for academic human resources [1];. a A fact which has led to problems such as lack of experts in some fields and excess of them in many others. Graduates unemployment and under employment are the most vivid results stemming from this problem.

Previous studies pertaining graduates occupational status do not draw a bright future for graduates' employment in Iran. Master and Ph.D. graduates' unemployment[1] or unemployment of more than fifty percent of architecture graduates[2] are amongst these predictions.

Researchers have named Iran's low industrial and economic capacities as the main reasons leading to unemployment of many university graduates [3,4]. The only way Iran can get rid of such problem is to adapt students' admission rate with the market's forecasted capacity for university graduates or try to expand knowledge intensity of country's industry to make it a suitable place for graduates' employment.

In this research, we have decided to simulated Iran's market's future capacity for engineering post graduates from one side and the number of engineering PhDd graduates, PhD students and master graduates from the other side to make it possible to predict post graduates' employment status in country's near future.

~~To do so, we have applied system dynamics. A scientific method which helps us to understand and model the complex relationships forming the aforementioned problem.~~

2. System dynamics

System dynamics, a well-developed systematic tool often used to describe system behaviors with feedback loops for accurate projections and a well-established methodology to quantify complex feedbacks in system interactions[interactions [5], was developed by Forrester in Massachusetts Institute of Technology (MIT)[6].

This technique provides a very powerful set of concepts for understanding and modeling complex systemic behavior that has been taken up in a wide range of application areas. At it'sits heart it concerns the results of the interplay of two forms of feedback loop – positive or reinforcing loops that lead to continual growth or decay, and negative, balancing loops that lead to stability[stability [7]. Sterman has developed some steps to create system dynamics model such as depicted in Fig. 1[6].

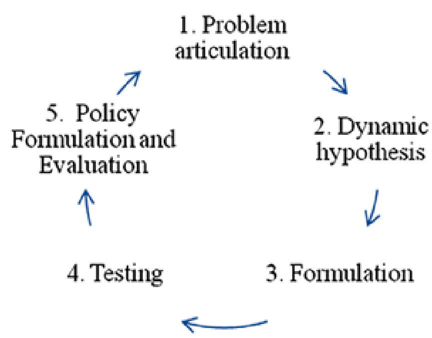

fig1. System dynamics modeling process

Modeling is a feedback process that goes through constant iteration and an iterative cycle. It is embedded in the larger cycle of learning and action constantly taking place in organizations:

Step 1: Problem articulation: in this step, we need to find the real problem, identify the key variables and concepts, determine the time horizon and characterize the problem dynamically for understanding and designing policy to solve it.

Step 2: Dynamic hypothesis: modeler should develop a theory of how the problem arose. It guides modeling efforts by focusing on certain structures. In this step, we need to develop causal loop diagram that explain causal links among variables and convert the causal loop diagram into flow diagram.

Step 3: Formulation: to define system dynamics model, after we convert the causal loop diagram into flow diagram, ~~weshould~~we should translate the system description into level, rate and auxiliary equations. We need to estimate some parameters, behavioral relationships and initial conditions. Writing equations will reveal gaps and inconsistencies that must be remedied in the prior description.

Step 4: Testing: the purpose testing is comparing the simulated behavior of the model to the actual behavior of the system.

Step 5: Policy formulation and evaluation. Once modelers have developed confidence in the structure and model behavior, we can utilize it to design and evaluate policies for improvement. The interactions of different policies must also be considered, because the real systems are highly nonlinear, the impact of combination policies is usually not the sum of their impacts alone.

2.1. SD's application in modeling educational systems

Researchers have mentioned many advantages for applying system dynamics to model different sectors of higher educational systems. Frances et al [8], call SD an efficient method to develop educational ~~policy's~~policies and improve planning. Oyo [9] mentions following advantages for using SD to model such systems:

- Model feedbacks or interactive views in dynamic systems like higher education
- Incorporate non-linear relationships inherent in higher educational quality issues
- Address complexity situations while experimenting their behavior over time
- Accommodate soft factors that underpin higher education quality issues
- Model time delays that underpin certain policies on quality

Kennedy [10-15] applies SD to model different sectors of higher education in a series of researches. He mentions following advantages as factors prioritizing SD over other methods such as neural networks, statistical methods and machine leaving algorithms for simulating such systems

- Accuracy: This is in terms of the analysis of data so that it is not misleading
- A method that gives a realistic approach to problem solving in terms of how easy it is to use and understand
- Simplicity: A simple method which does not use complex methodologies in problem solving
- A method which can deal with complex, nonlinear problems

3. Modeling the system

3.1. Reference modes

To clarify how has the problem aroused, we have gathered the historical data[1] comparing the number of engineering post graduates and market and university's available capacity to hire them in last five years from publications information base of statistical ~~centre~~center of Iran [16] and Iranian institute of research and planning in higher education [17] as depicted in figures 2 and 3.

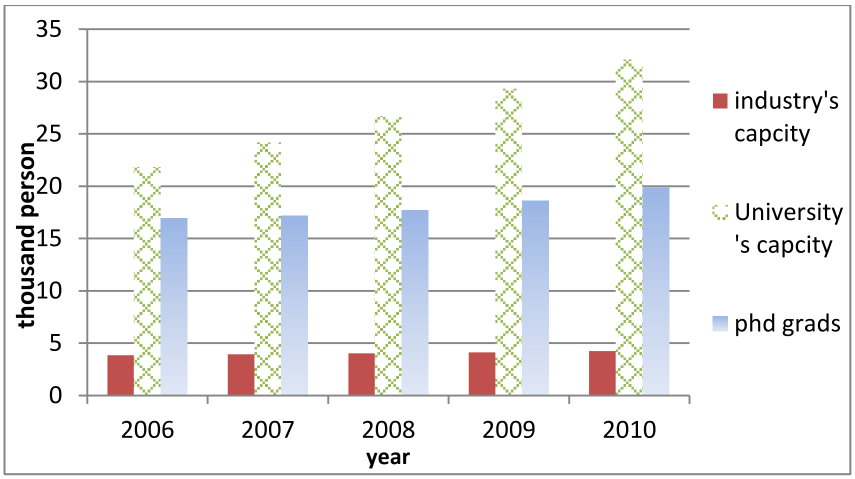

Fig2. PhD~~d~~ engineering graduates ~~vs~~vs. university and industry's capacity

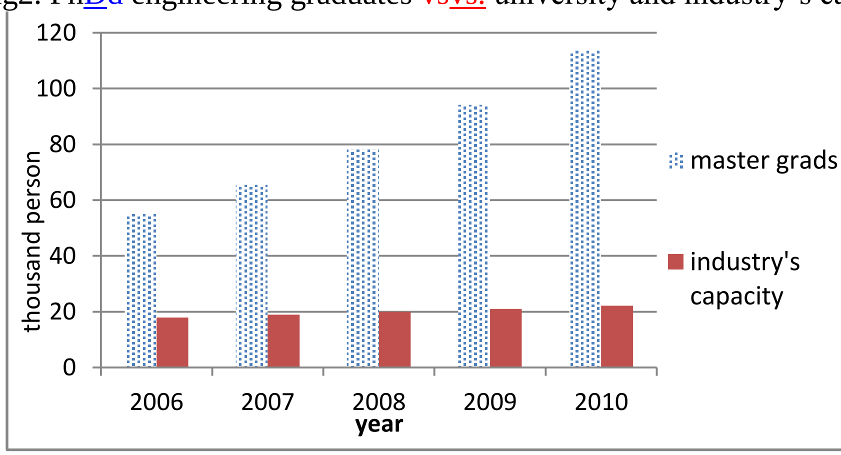

Fig3. Master engineering graduates vs university and industry's capacity

As it's shown in figures 2 and 3, during last five years, there have always been ample employment opportunities for engineering PhD~~d~~ graduates in both university and industry. But on the other hand, there has always been a remarkable difference between industry's demand and

[1]. Because of ~~unavailibilty~~unavailability of some needed data, they were calculated indirectly using mathematical formulas. For example, the number of graduates in year 2010 was multiplied by 0.3(approximate engineering graduates ratio) to obtain number of engineering graduates.

university's supply of Master graduates. This difference has been experiencing a significant growth; which unfortunately worsens Master graduates employment status~~.~~

~~3.2. Iran's engineering post graduates' employment status model~~.

There are two key stock variables which determine Iran's engineering post graduates' employment status in each year. The first one is the market's employment capacity and the second is the number of recently graduated students. Obviously, if the number of graduates will be greater than market's capacity in a specific year, then we should expect some graduates to face unemployment or under employment that year. There are also many other variables with complex relationships between them which make it possible to simulate the exact value of each of aforementioned variables. mathematical formulas existing with in variables were extracted with one of following ways: Using formulas mentioned in the models discussed in literature review discussing similar subjects, generating formulas with statistical methods using available historical data-we extracted needed data from ~~iran's~~Iran's center of statistics[16] and institute of research and planning in higher education-or creating qualitative formulas using experts' opinion. Then we used VENSIM to relate defined variables to each other through extracted formulas. This phase happened with in a feedback process which led us to formation of a comprehensive dynamic model simulating Iran's post graduates' employment status in country's near future. ~~we~~We chose 2006 to 2025(final year of Iran's twenty year vision plan) as simulation period. To make it easier to understand the structure and behavior of the constructed model, we have described it in four following sub systems.

~~3.3.~~3.2.Engineering students' admission and graduation sub system

This sub system shows the flow of engineering students' admission and graduation in Iran's higher education system. As designed, a specific percent of graduates with bachelor degree will enroll in master courses and the same happens for Master graduates who want to further study for Ph.D. The following rules and assumptions are considered in this sub system:

1. ~~each~~Each individual is only active for thirty years and will be retired then after.
2. The admission rate in each level is equal to last five years average admission rate.

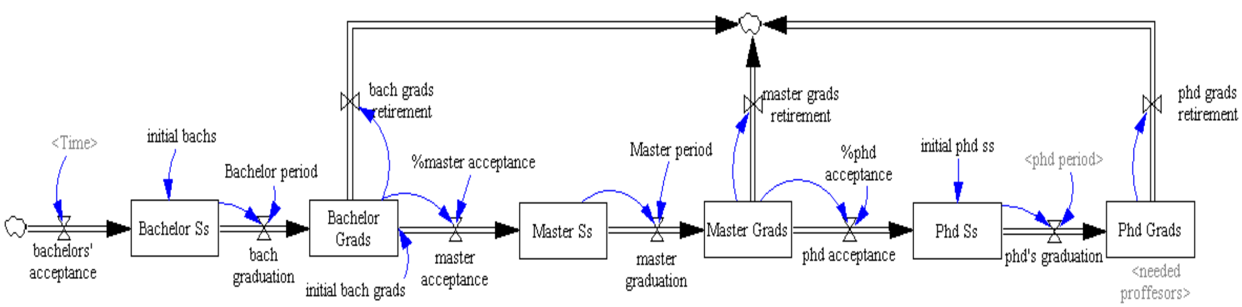

Fig4.Engineering students' admission and graduation sub system

~~3.4.~~3.3.Market's capacity for engineering post graduates

There are two main employment destinations for engineering Post graduates in Iran; first, universities, to work as a researcher or a professor and second, industry -to work as a researcher in R&D sector. Figure 5 –shows the part of model which is designed to simulate the hiring capacity of different parts of industry for engineering post graduates.

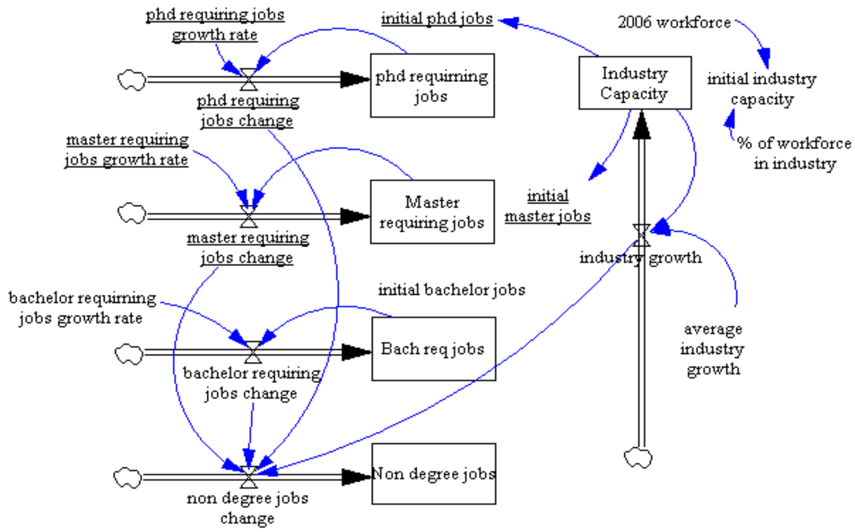

Fig5. Industry's capacity for engineering post graduates

Extracting recent ~~years~~year's historical data on number of students and students/professor ratio, we calculated last five years' growth rate of both variables and assumed that this rate is going to be the same in onward years. Then, the amount of needed professors was easily calculated by dividing the first variable by second one.
As illustrated in the sub-system in figure 6, if there will be not enough professors to occupy job ~~oppurtunities~~opportunities provided in universities, these positions will be allocated to PhD~~phd~~ students and Master graduates respectively.

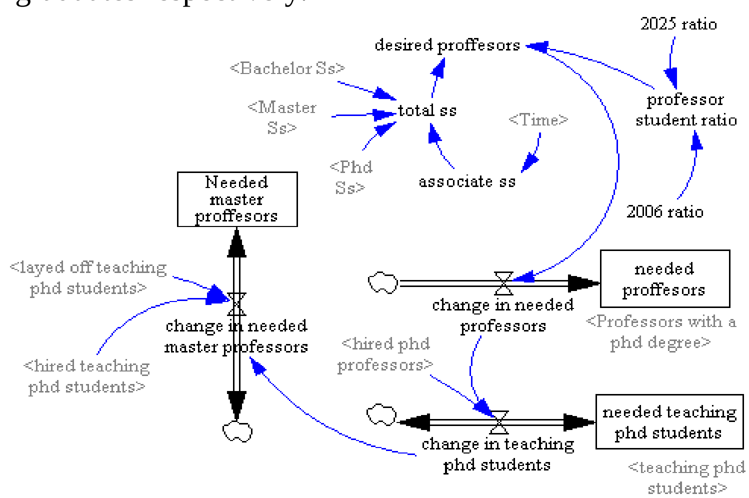

Fig6. University's capacity for engineering post graduates

~~3.5.~~3.4.Post graduates employment status sub system

Considering the output of aforementioned sub systems, this part of the model is designed to simulate the key ~~vatiables~~variables~~'~~' ~~behaviour~~behavior. Graduates are allocated to different job opportunities based on following algorithm.

For PhD~~d~~ graduates:

To get employed in universities as professors or researchers or in industry as R&D~~r&d~~ researchers is their first priority.

If the number of post graduates is greater than the number of vacant job ~~oppurtunities~~opportunities, they have to be relegated to less knowledge intensive jobs such as jobs ~~requiring master~~requiring master or bachelor graduates i.e. they will be under employed; or they may even face unemployment.

For ~~phd~~PhD students:

If the number of ~~Ph.d~~PhD graduates is less than the number of vacant job ~~oppurtunities~~opportunities requiring ~~ph.d~~Ph.D. holding graduates, unoccupied jobs will be allocated to ~~phd~~ PhD students ~~i.e~~i.e., ~~phd~~ PhD students will chose these jobs as part time careers.

For Master graduates:

If there are still vacant job ~~oppurtunities~~opportunities in universities which ~~havn't~~haven't been fulfilled with ~~ph.d~~Ph.D. graduates nor ~~phd~~ PhD students, then these job opportunities will be allocated to Master graduates. Rest of Master graduates will choose industrial jobs which require a masters degree as their first priority and if number of these kind of jobs is not enough, then graduates should be relegated to careers that require a bachelors degree, ~~non degree~~non-degree jobs or even unemployment.

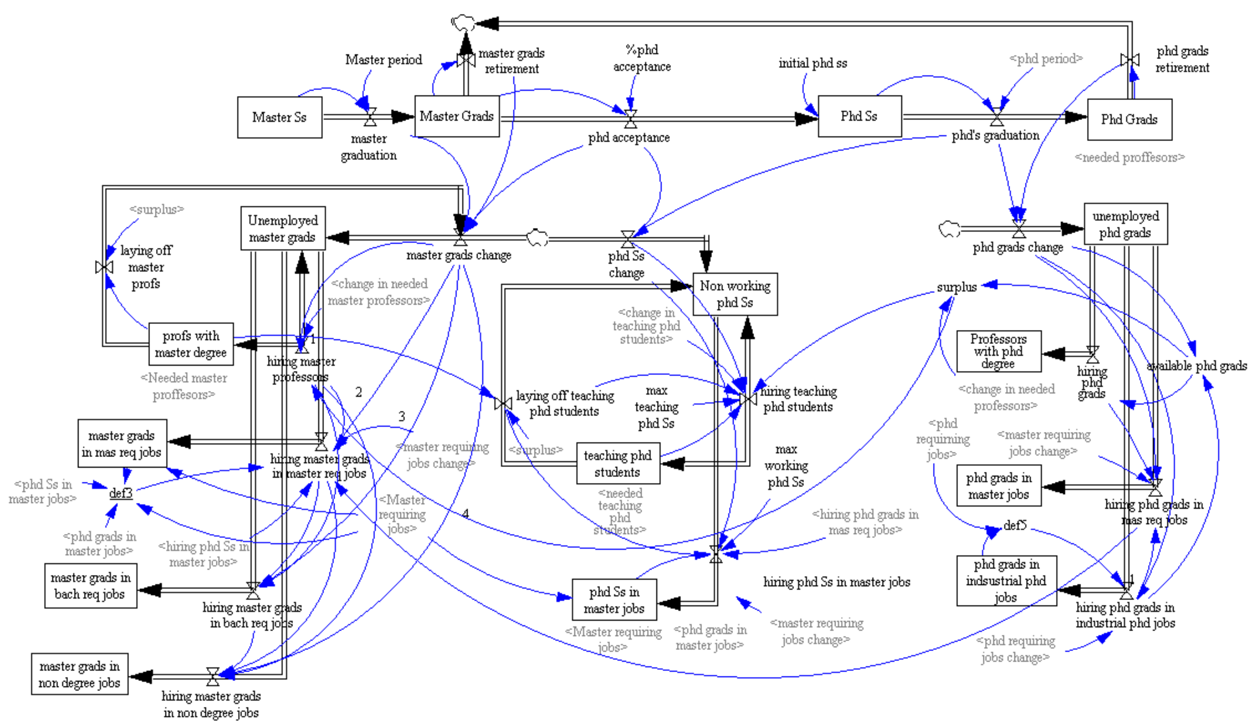

Fig7. Post graduates' employment status sub-system

4. Model Validation

There are different tests proposed to ensure model's validity. Thus, ~~We~~we have tested our model's accuracy and validity according to the proposed tests as follows:

4.1. Model's Error rate

Barlas[18] calls a valid model is one which it's error rate is less than 5%. To check our model's accuracy based on ~~barlas's~~ Barlas's formula, we calculated model's key variables' error rates as depicted in table1.

$$Errorrate = \frac{|\bar{S} - \bar{A}|}{\bar{A}}$$

$\bar{S} = \frac{1}{n}\sum_{i=1}^{n} Si$ Si is the simulated amount of data in ~~i~~i th year.

$\bar{A} = \frac{1}{n}\sum_{i=1}^{n} Ai$ Ai is the actual amount of data in ~~i~~i th year.

Table1. Comparison of simulated data ~~vs~~vs. actual data

Variable	Simulated($\bar{S}$)	Actual($\bar{A}$)	Error rate
~~Indusry's~~Industry's capacity growth rate	1046987	1046882	0.0001
growth rate of jobs that require a ~~phd~~ PhD degree	2155.54	2156.4	0.0004
growth rate of jobs that require a master degree	9393.3949	9412	0.002
growth rate of jobs that require a bachelor degree	102891	102823	0.0007
Master students' graduation rate	2279.435	2175.5	0.0478
Bachelor students' Graduation rate	10737.14	10671.75	0.0061

As all error rates are less than 5%, we can claim that our model is a valid one according to Barlas's proposed test. Then we have tested the model based on Sterman's[19] proposed validation tests. Extreme conditions, boundary adequacy, integration error, parameter

~~assessmet~~assessment, system improvement and structure assessment were the tests which were applied on the model to assure it's validity. Finally, after promoting the model with some corrective actions, the model became apt enough to pass all proposed tests; ensuring users that they are using a sound and valid model.

5. Results

After model is completed and verified, it's time to run it to see the results. To make it easier to understand the achieved results, we have discussed engineering post graduates' employment status in three separated sections as follows.

5.1. Ph.D. graduates' employment status

Figure 8 is showing engineering ~~ph.d~~Ph.D. graduates' employment status. According to great capacity expansion of Iran's higher education system in onward years, there will be ample job opportunities for ~~Phd~~PhD graduates in universities. Such that number of engineering ~~Phd~~PhD graduates hired as professors in universities will increase from 13000 in 2006 to 81500 in 2025. On the other side, experiencing an increase of only 2200 new ~~phd~~ PhD requiring job opportunities in industry, there will be no tangible growth in this section's capacity for ~~Phd~~PhD graduates; this way, most of ~~Phd~~PhD graduates will be employed in universities as ~~researchrs~~researchers and professors and will not face unemployment or underemployment from 2006 to 2025.

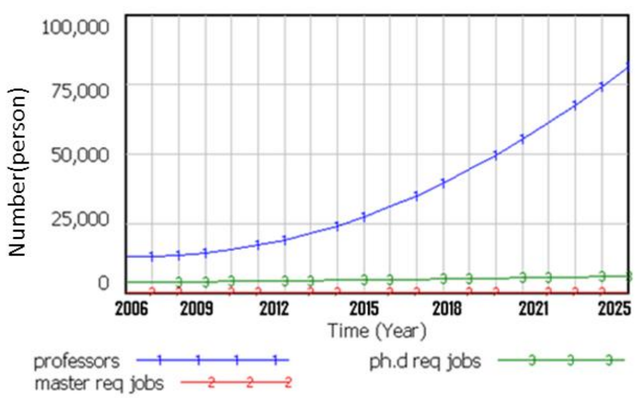

Fig8. ~~Phd~~PhD ~~graduates'employment~~graduates' employment status

5.2. ~~Ph.d~~PhD students' employment status

There are always some ~~phd~~ PhD students who prefer to have a part time job in industry. On the other hand, if there will be lack of ~~Phd~~PhD graduates to fulfill university's need for new professors and researchers, then ~~phd~~ PhD students will be hired for these academic positions. So, there may always be a specific number of ~~Phd~~PhD students who are employed in each section of university or industry. Figure 9 is showing engineering ~~ph.d~~PhD graduates employment status in university and in industry's master requiring jobs.

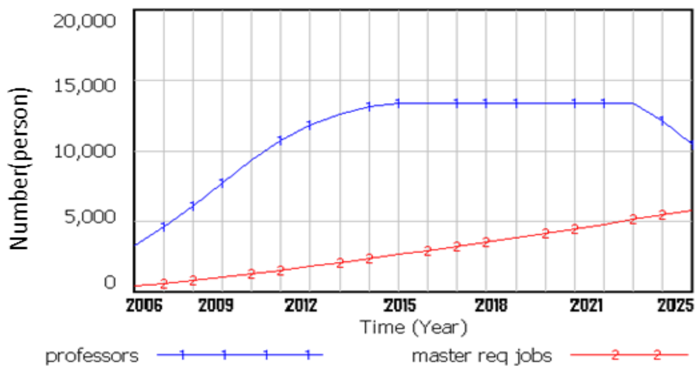

Fig9. Phd students' employment status

As depicted in the diagram, there are always some ~~phd~~ PhD students' who are employed in universities. This happens because the number of ~~Phd~~PhD graduates is always less than number of job opportunity's offered by universities during simulation period. In last three years of simulation, we see a decrease in number of ~~phd~~ PhD students who are employed in universities; this is because there is an upsurge in number of engineering ~~Phd~~PhD graduates- who will be employed in universities as professors- in these years; A matter which causes ~~phd~~ PhD students to be fired from universities and let ~~Phd~~PhD graduates to be replaced with them.

As it is assumed that there are always a certain percent of ~~phd~~ PhD students who will choose to have an industrial job, ~~phd~~ PhD students employed in industry sector will face an upward trend until 2025.

5.3. Master graduates employment status

Figure 10 is showing master engineering graduates' employment status.

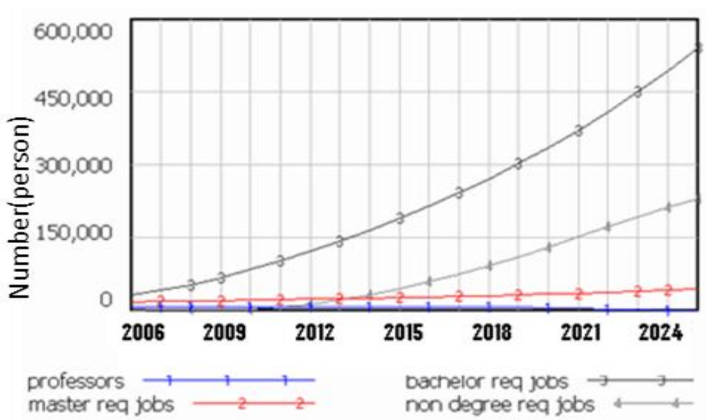

Fig10. Master graduates' employment status

As there are always more graduates than available master ~~requirning~~requiring job opportunities during simulation period, majority of Iran's master engineering students will be relegated to jobs that require a ~~bachelors~~bachelor's degree or even less(under employment). Such that as shown in diagram, there will be 520000 Master graduates employed in bachelor requiring jobs and 200000 in ~~non degree~~non-degree jobs in 2025.

From the other side, as Ph.D. graduates and students will not be able to meet universities need for professors quantitatively, there will be around 6000 Master graduates working in universities as professors until 2015; after this year, Master graduates will be fired from universities and

Ph.D. graduates will be replaced with them; because of the upsurge in the number of Ph.D. graduates in these years.

6. Discussion

As results show, Percentage of engineering Ph.D. graduates being employed in universities will rise from 80% in 2006 to 90% in 2025. ~~on~~On the contrary, there will be a 10% decrease (from 20% to 10%) in percent of graduates employed in industry. This happens because Iran has decided to increase ~~it's~~its higher education's capacity ~~in next years both quantitatively and qualitatively~~ and consequently there will be a ~~in~~ need ~~of~~ for more professors to teach ~~enrolled~~ the students and to carry out~~perform~~ research in universities~~es~~; while country's low pace of growth in industry sector will not provide ample PhD degree ~~requiring~~ job opportunities ~~in this section~~. In summary, it can be said that there will be enough job opportunities for engineering PhD~~d~~ graduates in both university and industry ~~to~~ preventing them from ~~being occupied in~~ jobs with~~requiring~~ lower academic degrees or becoming unemployed in onward years.
The percentage of engineering PhD~~phd~~ students working in universities as professors will decrease from 50% to 20% during simulation period. This happens because number of PhD~~d~~ graduates will surpass university's hiring capacity in final years of simulation ~~and these group of graduates will be replaced by phd students who were formerely employed in universities~~. Although students are not supposed to be employed during their schooling but results show there will always be enough job offerings from universities to let a considerable percent of them to be employed as professors.
The p~~P~~ercentage of Master graduates employed in universities as professors will decrease from 10% to 0% and those occupied in industry in master requiring jobs will also face a 22% decrease (from 32% to 10%) from 2006 to 2025. However, the~~while~~ percentages~~s~~ of Master graduates employed in jobs which require a bachelor degree and ~~non degree~~non-degree jobs will stay constant and increase from 0 to 29% respectively. This shows that ~~All an indication of master graduate's worsening in employment. i.e.~~ most Master graduates should be relegated to jobs requiring less knowledgeable workers (under employment). This happens because industry's capacity growth rate is much less than master students' graduation rate in onward years.
To overcome the predicted unfavorable future for Master graduates, following recommendations ~~are~~ can be suggested:

1. ~~To increase~~Increase the growth rate of knowledge intensive jobs in country's industry.
2. ~~To decrease~~Decrease admission rate of higher education in master's degree; to adapt number of Master graduates to existing master degree requiring job opportunities in Iran's industry.

7. Conclusion

In this research we used system dynamics to model and simulate Iranian universities' and market's future capacity for engineering post graduates ~~from one side and the number Master graduates, phd students and Phd graduates from the other side to make it possible~~ to predict engineering post graduates occupational status in country's near future. We assumed~~draw~~ three possible occupational future for each graduate:~~;~~ employment, underemployment or unemployment. The ~~achieved~~ results show that there will be ample job opportunities for PhD~~d~~ graduates such that they will not face unemployment or under employment. PhD~~d~~ students will have a good occupational status in near future. But master students' employment status will aggravate in onward years such that most Master graduates will be relegated to jobs requiring less knowledgeable workers~~ such as careers that require a bachelors degree or non degree jobs~~. ~~Finally, ~~Increasing industry's knowledge intensity andor adapting university enrollment ~~with ~~to market's capacity expansion were two soloutions~~remedies~~ suggested to improve Master graduates employment status.

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Appendix

Vensim codes

variable	Variable's complete name	Descriptions
Initial bachs	bachelor students in 2006	574978
Bachelor Ss		∫ (bachelors' acceptance-bach graduation, initial bachs)
Bachelor period		4.3 year
Bach graduation	Bachelors' graduation	Bachelor Ss/Bachelor period
Initial bach grads	Initial bachelor graduates	363130
Bachelor Grads	Bachelor graduates	∫ (bach graduation-bach grads retirement-master acceptance, inital bach grads)
Bach grads retirement	Bachelor graduates retirement	Bachelor Graduates/30
Retirement time		30 years
%master acceptance	Percent of master acceptance	4.5%(last 5 years' average)
Initial master students		36827
Master students		∫ (master acceptance-master graduation, Initial master students)
master graduation		Master Ss/Master period

variable	Variable's complete name	Descriptions
Master period		2.5years
Initial Master graduates		55051
Master Grads		∫ (master graduation-Master graduates retirement-~~phd~~ PhD acceptance, Initial Master graduates)
Master graduates retirement		Master graduates/30
%~~phd~~ PhD acceptance	Percent of ~~phd~~ PhD acceptnace	2.7%
Initial ~~phd~~ PhDstudents		4407
Phd students		∫(~~phd~~ PhD acceptance-Phd's graduation, Initial ~~phd~~ PhD students)
Phd's graduation		Phd students/~~phd~~ PhD period
Phd period		5.5 years
Initial Phd graduates		0.6*needed professors+~~phd~~ PhD requiring jobs
Phd grads	Phd graduates	∫(Phd's graduation-Phd graduates retirement,Initial ~~phd~~ PhD students)
Phd graduates retirement	Phd graduates retirement	Phd graduates/30
Average industry growth		0.014
Industry growth		Average industry growth *Industry capacity
2006 workforce	Total employment in 2006	20476344[16]
% of workforce in industry	Percent of workforce employed in industry	31.35%[16]
Initial industry capacity		2006 workforce* % of workforce in industry
Industry capacity		∫(industry growth, initial industry capacity)
~~phd~~ PhDrequiring jobs growth rate		0.024[16]
Phd requiring jobs change		~~phd~~ PhD requiring jobs growth rate*~~phd~~ PhD requiring jobs
Initial ~~phd~~ PhD jobs		Industry Capacity*0.4(effectively employed grads coefficient)*0.002
Phd requiring jobs		∫(Phd requiring jobs change, Initial ~~phd~~ PhD jobs)
master requiring jobs growth rate		5.4%[16]

variable	**Variable's complete name**	**Descriptions**
Master requiring jobs change		master requiring jobs growth rate*Master requiring jobs
Initial master jobs		Industry capacity*0.4(effectively employed grads coefficient)*0.0093
Master requiring jobs		∫(master requiring jobs change, Initial master jobs)
Bach req jobs	Bacheor requiring jobs	∫(Bacheor requiring jobs change, Initial bachelor jobs)
Bacheor requiring jobs change		Bach requiring jobs * Bacheor requiring jobs growth rate
Bacheor requiring jobs growth rate		0.0695[16]
Initial bachelor jobs		Industry capacity*0.4(effectively employed grads coefficient)*0.104
Non degree jobs		∫(Non degree jobs change, Initial industry capacity - Bach requiring jobs -Master requiring jobs-~~phd~~ PhD requiring jobs)
Non degree jobs change		industry growth-bach requirning jobs change-master requiring jobs change-~~phd~~ PhD requiring jobs change
Needed teaching ~~phd~~ PhD students		∫(Change in teaching ~~phd~~ PhD students, Needed professors- Professors with ~~phd~~ PhD degree)
Change in teaching ~~phd~~ PhD students		change in needed professors-hiring ~~phd~~ PhD professors
Needed master professors		∫(Change in needed master professors, Needed professors- Professors with ~~phd~~ PhDdegree- Teaching ~~phd~~ PhD Ss)
Change in needed master professors		change in teaching ~~phd~~ PhD students-(hiring teaching ~~phd~~ PhD Students-laying off teaching ~~phd~~ PhD Students)
Total students		associate Ss+Master Ss+Phd Ss
desired professors		total Ss/ professor student ratio
2006 ratio	Professor/student ratio in 2006	40[101]
professor student ratio		2006 ps ratio +RAMP((2025 ratio-"2006 ratio")/(2025-2006), 2006, 2025)
2025 ratio	Professor/students ratio in 2025	27.2[94,95,101]
Desired professors		des eng Ss/professor student ratio
Professor student		2006 ratio+RAMP((2025 ratio-2006 ratio)/(2025-

variable	Variable's complete name	Descriptions
ratio		2006), 2006, 2025)
Phd grads change	Change in Phd graduates	Phd's graduation-Phd graduates retirement
Unemployed Phd graduates		∫(Phd grads change- hiring ~~phd~~ PhD grads- hiring ~~phd~~ PhD grads in mas req jobs-hiring ~~phd~~ PhD grads in industrial ~~phd~~ PhD jobs,Phd graduates- Professors with ~~phd~~ PhDdegree-Phd grads in indsustrial ~~phd~~ PhD jobs- Phd grads in master jobs)
Professors with ~~phd~~ PhDdegree	Phd holding professors	∫ (hiring ~~phd~~ PhD grads, needed professors*0.6)
hiring ~~phd~~ PhDprofessors	Change in ~~phd~~ PhDholding professors	min(Phd grads change-hiring ~~phd~~ PhDgrads,def+change in needed professors)
Def5	deficiency	~~phd~~ PhD requirning jobs-Hiring ~~phd~~ PhD grads in industrial ~~phd~~ PhD jobs
~~phd~~ PhD grads in master jobs	~~phd~~ PhD graduatess employed in master required jobs	∫(hiring ~~phd~~ PhD grads in mas req jobs,Phd graduates-Professors with ~~phd~~ PhD degree-Phd grads in indsustrial ~~phd~~ PhD jobs)
Hiring ~~phd~~ PhD grads in mas req jobs	Hiring ~~phd~~ PhD graduates in master requring jobs	min(Phd grads change-hiring ~~phd~~ PhD grads in industrial ~~phd~~ PhD jobs-hiring ~~phd~~ PhDprofessors,def12+master requiring jobs change)
Phd grads in indsustrial ~~phd~~ PhD jobs	Phd graduates hired in indsustrial ~~phd~~ PhD requiring jobs	∫(hiring ~~phd~~ PhD grads in industrial ~~phd~~ PhD jobs,min(~~phd~~ PhD requirning jobs,Phd grads))
Hiring ~~phd~~ PhD grads in industrial ~~phd~~ PhD jobs	Hiring ~~phd~~ PhD graduates in industrial ~~phd~~ PhD requiring jobs	min(Phd grads change, ~~phd~~ PhD requiring jobs change+def5)
available ~~phd~~ PhD grads	Available Phd graduates	Phd grads change-hiring ~~phd~~ PhD grads in industrial ~~phd~~ PhD jobs
surplus		max(0,available ~~phd~~ PhD grads-change in needed professors)
Master students		∫ (master acceptance-master graduation,38178)
master graduation	Masters graduation	Master students/Master period
Master period		2.5 years
Master graduates		∫(Master graduation-Master graduates retirement-~~phd~~ PhD acceptance, 73914)
Master graduates retirement		Master graduates/30
Master grads change	Master graduates change	master graduation-Master graduates retirement-~~phd~~ PhD acceptance
Unemployed		∫(Master grads change-hiring master grads in bach req

variable	Variable's complete name	Descriptions
Master graduates		jobs-hiring master grads in master req jobs-hiring master professors-hiring master grads in ~~non degree~~non-degree jobs,Master graduates-master grads in mas req jobs-Master grads in bach req jobs-master grads in ~~non degree~~non-degree jobs-profs with master degree)
hiring master professors		min(Master graduates change, change in needed master professors+def7)
profs with master degree		∫ (hiring master professors, min(Master graduates, Needed master profs))
def7	deficiency	Needed master professors-profs with master degree
hiring master grads in master req jobs	hiring master graduates in master requiring jobs	Min (master requiring jobs change-Hiring ~~phd~~ PhDSs in master jobs+def3, Master grads change-hiring master professors)
master grads in mas req jobs	master grads in master requiring jobs	∫(hiring master grads in master req jobs, min(Master graduates- profs with master degree,Master requiring jobs-Phd Ss in master jobs))
def3	deficiency	Master requiring jobs-Phd Ss in master jobs-master grads in mas req jobs
def1	deficiency	Bach req jobs-"Master grads in bach req jobs"
hiring master grads in bach req jobs	hiring master graduates in bachelor requirng jobs	min(Master grads change-hiring master grads in master req jobs- hiring master professors,def1+bachelor jobs change)
Master grads in bach req jobs	Master grads in bachelor requring jobs	∫(hiring master grads in bach req jobs,min(Master graduates-profs with master degree-master grads in mas req jobs,Bach requiring jobs))
def3	deficiency	Master requiring jobs-Phd Ss in master jobs-master grads in mas req jobs-Phd grads in master jobs
back order		Bach requiring jobs-Master grads in bach req jobs
back order1		Non degree req jobs-master grads in non degree jobs
Phd Ss change	change in ~~phd~~ PhD students	~~phd~~ PhD acceptance-Phd's graduation
Non working ~~phd~~ PhDSs	Non working ~~phd~~ PhDstudents	∫ (~~phd~~ PhD Ss change-change in teaching ~~phd~~ PhD students-Hiring ~~phd~~ PhDSs in master jobs, Phd students- Teaching ~~phd~~ PhDstudents-Phd Ss in master jobs)
Hiring teaching ~~phd~~ PhDstudents	Change in Phd students who teach	min((max teaching ~~phd~~ PhDstudents*(Phd students+~~phd~~ PhDSs change)-Teaching ~~phd~~ PhDstudents),min(~~phd~~ PhDSs change,change in teaching ~~phd~~ PhDstudents+def6))
Teaching ~~phd~~ PhD students	Phd students who teach	∫change in teaching ~~phd~~ PhD students,min(Needed teaching ~~phd~~ PhD students, max teaching ~~phd~~ PhD students*Phd students))

variable	Variable's complete name	Descriptions
max working ~~phd~~ PhD Ss	Maximum ~~phd~~ PhD students who work	10%
Max teaching ~~phd~~ PhD students	Maximum Phd students who teach	50%
Hiring ~~phd~~ PhD Ss in master jobs	Hiring ~~phd~~ PhD Students in master requiring jobs	min(max working ~~phd~~ PhD Ss*(Phd students+~~phd~~ PhD Ss change)- Phd Ss in master jobs, min(~~phd~~ PhD Ss change-(hiring teaching ~~phd~~ PhD students- laying off teaching ~~phd~~ PhD students), master requiring jobs change-hiring ~~phd~~ PhD grads in mas req jobs+def8))
Phd Ss in master jobs	Phd Students hired in master requiring jobs	∫Hiring ~~phd~~ PhD Ss in master jobs,min(Master req jobs, max working ~~phd~~ PhD Ss*Phd students))
Def2	Deficiency	Non degree req jobs-master grads in ~~non degree~~non-degree jobs
ny need	Next year's need	Bacheor requiring jobs change-hiring master grads in bach req jobs