Ethnicity, Exclusion and Globalization:
An enquiry into Primary Level Data on India through Graph Theory and Bio-informatics.

Sugata Sen
(Panskura Banamali College)

Soumya Sengupta
(Panskura Banamali College)

Paper prepared for the 35th IARIW General Conference

Copenhagen, Denmark, August 20-25, 2018

Session 2C: Globalization and Inclusive Growth I

Time: Tuesday, August 21, 2018 [14:00-17:30]

Ethnicity, Exclusion and Globalization:

An enquiry into Primary Level Data on India through Graph Theory and Bio-informatics.

Dr. Sugata Sen[1] and Soumya Sengupta[2]

Ethnicity-based exclusion is one of the major problems of modern India to achieve holistic development. Indian society is characterized by multiple forms of exclusion associated with group identities in various spheres of society, polity, and economy. In India ethnicity-based exclusion started to appear from the *vedic* ages with the help of some religio-philosophical arguments of *Brahmanical Social Order*. It is said that the *Brahmanical Social Order* promoted a hierarchical social system in the name of caste to exploit a group of people by another in the face of limited resource. Genetic studies have established that the lower strata of this hierarchical structure carry a distinctly different genetic origin. In the name of Hindu philosophy, the *Brahmanical* system became successful to exploit the genetically different groups within the society to appropriate surplus values. This work wants to show this society as a network of its members. So the inter-personal relations or the inter-nodal incidences in the network are determined through the predefined social customs and norms. The hierarchical social structure through the caste system became successful to convert the society into an incomplete network. So, this work assumes that the sub-optimal outcome of any development programmes in the existence of ethnicity-based exclusion is purely a problem of social network structure. This network structure is purely randomized in nature and complete network is the most desired social structure. Through greater interaction between the members of a society the complete

[1]Associate Professor of Economics,Panskura Banamali College, Panskura, Purba Medinipur, West Bengal,INDIA 721152
Email: sensugata@gmail.com
(Corresponding Author)

[2]Faculty of Computer Science,Panskura Banamali College, Panskura, Purba Medinipur, West Bengal,INDIA 721152
Email: ssg747@gmail.com

network structure can be achieved. This work wants to know the inclusionary outcome of different development programmes through greater interaction between different social groups under different social network structures. To that extent the laws of genetic crossover have been used through Genetic Algorithm (GA) to find the outcomes of social interactions. Support of Markov process has been taken to carry forward the successive iterations through GA. To initiate the Markov process, the society is assumed as a network of different social groups. It is observed that the outcome of the Markov process vary substantially in different social network structures. Inclusionary outcome of the development programmes improves with the improvement of non-zero ties within the social network. Here it is posited that globalization as a process of technology driven market oriented process will lower the social cohesiveness and increase centrality within the society.

Thinking the society as an interconnecting graph or network was first conceived by Milgram and Travers. They (Milgram & Travers, 1967) have shown that the whole world is a small village with respect to interpersonal ties and hence the society can be represented through a network graph. This concept of sicial network was further strengthened through the idea of “Six drgree separation”. Ritgen et. al. have shown the importance of social order and cohesion for economic development (Ritzen & Woolcock, 2000). Borgatti et.al. (Borgatti, Mehra, Brass, & Labianca, 2009) have extensively discussed the use of network analysis in the social sciences. They have shown that matrix algebra and graph theory can be used extensively to formalize the expresssion of the society as a network. They have also discussed that the outcome of any operation within a network society purely depends upon the shape and cohesion level of that very society. This discussion finds that the individual outcomes not only depend upon the characteristics of the individual but also on his social network. Thus the key task of social network analysis is to invent graph theoritic properties of the network and the relative position of the individual on that very network. The node's position in a network determines in part the opportunities and constraints that it encounters. Finally they have concluded that the adaptation machanishm behind the nodes or the internodal interaction would help the nodes to becomes homogeneous. Lack of these interactions in different spheres of the society create heterogenous sub-groups within the society with varied levels of inclusion.

The term 'Social exclusion' as a process of marginalization starts to appear in the contemporary social sciences with the works of German sociologist Max Weber (Parkin, 1979), though the existence of it can be identified in earlier studies. Weber saw exclusionary closure as the attempt of one group to secure for itself a privileged position at the expense of some other group through a process of subordination. Modern usage of the term social exclusion appears to have originated in France where the socially excluded were referred to as those who were administratively excluded by the state (Lenoir, 1974) (Duffy, 1997). The United Nations Development Programme has conceptualized social exclusion as the lack of recognition of basic rights, or where that recognition existed, lack of access to political and legal systems necessary to make those rights a reality (Figueiredo, 1997). According to Centre for Analysis of Social Exclusion at the London School of Economics (LSE) 'An individual is socially excluded if (a) he or she is geographically resident in a society but (b) for reasons beyond his or her control, he or she cannot participate in the normal activities of citizens in that society, and (c) he or she would like to so participate' (Burchardt, 1999). Buvinic summarizes the meaning of social exclusion as 'the inability of an individual to participate in the basic political, economic, and social functioning of the society', and adds that social exclusion is the 'denial of equal access to opportunities imposed by certain groups of society upon others' (Buvinic, 2005).So exclusion of any individual refers to the situation where the very identity fails to create a viable fruitful network with others in the society. So underdevelopment and exclusion appears not only due to the characteristics of the individuals but also due to the characteristics of the network where he or she exists.

In India, exclusion revolves around societal institutions that exclude, discriminate against, isolate and deprive some groups on the basis of group identities such as ethnicity, gender, location of residence etc. Naturally in India the social network structure is determined by multiple forms of exclusion associated with group identities in various spheres of society, polity, and economy. Ethnicity-based exclusion in India is unique in nature and is the outcome of hierarchical caste structure. This type of social hierarchies appeared from the philosophical foundation of *Brahmanical* social order. There are very few theoretical attempts at economic interpretation of the caste system, but they do recognize that caste as a system of social and economic governance is determined by certain religious ideological notions and customary rules and norms which are unique and distinct (Akerlof, 1976) (Scoville, 1991) (Lal, 1988). The economic organization of the caste system is based on the division of people in social groups, in which the social and economic rights of each individual caste are predetermined or ascribed by birth and are made hereditary. The entitlement to economic rights is unequal and hierarchical. The system also provides for a community-based regulatory mechanism to enforce the system through the instrument of social ostracism, and is further reinforced with justification from some philosophical elements in Hindu religion (Lal, 1988) (Ambedkar, 1987a). The fundamental characteristic of predetermined and fixed social and economic rights for each caste, with restrictions on change, implies 'forced exclusion' of certain castes from civil, economic and educational rights that other castes enjoy. Caste based exclusion is, thus, reflected in the inability of individuals from the lower castes to interact freely and productively with others and this also inhibits their full participation in the economic, social, and political life of the community (Bhalla & Lapeyere, 1997).

In this hierarchical caste structure the ethnic tribals form the lowest stratum of the society. These tribals or the untouchable communities of India share a common heritage, culture and identity which is distinctly different from the mainstream Hindu society. Apart from heritage, culture and identity, they also bear a distinctly different genetic origin also. Genetic studies on different ethnic groups in India have shown that these groups have different genetic structure and also affinity to different social groups available at different parts of the world. A study of Bamshad et.al . (Bamshad & al., 2001) has shown that the upper castes of India have a higher affinity to Europeans than to Asians. Indian upper castes are significantly more similar to Europeans than to the lower castes and tribals. To come to this conclusion, they have compared mtDNA and y-chromosome variation of different social groups available throughout the world. The study concluded that the higher or privileged castes in India have a definite genetic sequence which is distinctly different from lower castes and the tribals.

This caste system can be explained as an instrument to control resources by one group of human beings at the cost of the others on the face of limited resources. Over a long period of time with the support of philosophical legitimacy the upper caste Hindus have become able to exclude a group of human beings with a different genetic origin to appropriate the resources. The upper caste Hindus have become successful to project the group of people with different genetic origin as lower caste or untouchables in the society. According to Karl Marx all societies in the world are organized on the basis of social exclusion and social inclusion. Exclusion appears due to the struggle for allocation of limited resources. Social exclusion stems from the control of means of production. Therefore, class formation and division occur on the basis of property ownership and control of surplus value (Irmak & Guclu, 2012). Caste-based exclusion is undoubtedly a process of division of society to control the power and production. The social norms that legitimized the caste-based exclusion are nothing but some instruments to impose the ideas of ruling class to the ruled class. In Marxist connotation these ideas are nothing but some tools to sustain exploitation (Marx & Engels, 1845).

It is thought that the root of ethnic differences in India has appeared from the differences in genetic origins of different social groups. The foundation of ethnicity-based marginalization in India can be traced from the Hindu Social Order or more specifically from *Brahmanical* Social Order which originated from The *Rigveda*. Ethnicity based conflicts started to appear in India since the *vedic* Age (2000 BC to 1400 BC)(Dutt, 1928). Hierarchical social relationships appeared during the later *vedic* period.The contemporary social network of India has a strong historical perspective which can find its root from this period. The formation of inter personal ties as well as the social network on the basis of Hindu religious order started to take shapes from this age. With the development of market at different levels this network gained more strength. The political economy put legitimacy on the social network appeared on the basis of hierarchical relations (Thapar, 1966) .

With the spread of civilization at the Gangetic valley that come into existence due to the economic forces of the market and settled urban centric life started to re-appear in the indian society after the decline of Indus valley civilization (period). In 600 BCE *16 Mahajanpada* or extended chiefdoms came to existence. The rulers of these*mahajanapadas* used the existing social order for smooth governance and appropriation of surplus values (Thapar, The Penguin History of Early India : From the origines to AD 1300, 2003). Though these chiefdoms consolidated themselves to kingdoms and large empires, the underlying social structure continued or was strengthened with the changes in political structures. Apart from the ethnicity-based network in the society some urban-centric cliques started to appear in the existing social network. Location based hierarchies in the society started to appear. Naturally the existing social network reorganized itself through new inter sections between the ethnicity and location of residence without changing the hierarchical philosophy of the Hindu society. The ruling ethnic groups residing at urban areas became the most privileged node in the network whereas the 'lower' ethnic groups residing at rural areas were pushed further towards the periphery. The centrality of the urban privileged classes became more consolidated. The foreign rulers of the Sultani and Mughal era (period) also did not want to influence the underlying social milieu of the *Brahmanical* philosophy based social order to ensure smooth governance (Thapar, A History of India, 1966). The legitimacy of the hierarchical social network was so powerful that it strongly influenced the existence of Islam as a religion of Social Liberation in India. With the influence of the hierarchical Hindu structures the egalitarian Muslim society started to show the existence of hierarchies in its socio-political structure (Chowdhury, 2009). This hierarchical social network established itself as a region specific feature instead of a religion specific network.

After the Mughal age the Britishers tried to change the social relations partially. They followed a policy of simultaneous exclusion and inclusion towards the ethnically marginalized tribal community. Reorganization of traditional ties started to include the existing excluded in the mainstream in adverse terms (Sonowal, 2008). 'Unfavourable inclusion' with inequal treatment, may carry the same adverse effects as 'unfavourable exclusion'. Prof. Sen (Sen A. , 2000) has shown that the situations where some people are being kept out are same as where some people are being included – in deeply unfavourable terms. But the process of unfavourable inclusion into the mainstream Indian society actually started in later *vedic* age. It has been discussed in the previous sections that who were defeated in the ethnic conflicts during the *vedic* age were compelled to follow the mainstream society with deeply adverse terms. This process continued in the name of cultural assimilation even after the *vedic* age. These inclusionary processes actually failed to fit the tribals into the upper strata of the hierarchical Hindu society – they started to find themselves as the lowest section of the Hindus and mentioned themselves as the 'lower caste'.

Thus the Indian social network on the basis of Hindu social norms have confined the tribals either to the lowest strata of the society or kept them outside of the dominant society. In other words, they were either unfavourably included or involuntarily excluded. It was inevitable for the tribals to face exploitation either as the lowest strata of the society or as the excluded (Sonowal, 2008). Thus the Indian society has a strong core-peripheral network structure with many intersectionalities among different social characteristics.

Improvement of interaction between the different social groups of the society can eliminate the menace of exclusion for the holistic development of the society. Gradual improvement of interaction among the agents within the society can ensure the systematic change in the social networks. Here the ideas of Genetic Algorithm can be used to assess the outcome of interaction among different social groups. Genetic Algorithm (GA) is a method for solving both constrained and unconstrained optimization problems based on a natural selection process that mimics biological evolution. Genetic Algorithms (GAs) are adaptive heuristic search algorithm based on the evolutionary ideas of natural selection and genetics. They represent an intelligent exploitation of a random search to solve optimization problems. The algorithm repeatedly modifies a population of individual solutions. At each step, the genetic algorithm randomly selects individuals from the current population and uses them as parents to produce the children for the next generation. Over successive generations, the population 'evolves' toward an optimal solution. The basic techniques of the GAs are designed to simulate processes of natural systems necessary for evolution, especially those who follow the principles first laid down by Charles Darwin of "survival of the fittest.". So selection, crossover and mutation are the most important parts of the genetic algorithm. Performance of GA is influenced mainly by these operations. While breeding, the system accepts two chromosomes as parents on the basis of a pre-existing logic i.e. the fitness of the parents are calculated through some logic or existing norms. Crossover is a genetic operation to vary the pattern of a chromosome or chromosomes from one generation to the next. Currently a number of crossover techniques are available to breed new generations. In this study bitwise crossover is considered, where the new genotype chromosome takes the best value of each bit from the parent strings on the basis of the fit function. Subsequently, a new child genotype is created by appending the bitwise best values from the parents. Mutation is a genetic operation used to sustain genetic diversity in one generation achieved through crossover from the previous generation. It is analogous to biological mutation. By mutation individuals are altered according to the fit function. (Sengupta, 2015).The concept of GA has been used in different fields of science and technology to get the desired output.

Use of Genetic Algorithm in Environmental Science has been noted by Haupt et.al. (Haupt, 2008) among others. They have used the GA to find the best output from many time series information collected under different environmental situations. Robert E. Marmelstein (Marmelstein R. , 1997)presented Application of Genetic Algorithms to Data Mining in search of optimum output. Neha Deotale et.al (Deotale, 2014) considered the problem of Automated Train Attribute Scheduling using Genetic Algorithm for Railway Scheduling with the help of GPS . Here GA has been used to find the best set of attributes to minimize the causalities and improving the efficiency of the rail movement. Ruidan Su et.al(Su R. e., 2014)) proposed a parallel multi population genetic algorithm (PMPGA) to optimize the train control strategy, which reduces the energy consumption at a specified running time. Byonghwa Oh et. al. (Oh & et.al., 2010) have proposed a new GA based route search algorithm to face challenges in providing information that reflects the fluctuations of dynamic real-time traffic and road situations. Here the GA finds the best routes dynamically considering road conditions. Halim Ceylan (Ceylan, 2004) used the genetic algorithm approach to solve the problems related to traffic signal control and traffic assignment. Wei Li (Li, 2004) describes a technique of applying Genetic Algorithm (GA) to network Intrusion Detection Systems. Yafeng (Yin, 2000) has applied GA for selecting the optimal feature subset from an initial feature set of larger size. He found that GA has the potential to achieve the optimum result more efficiently in various fields of applied computing.

Bhandari et.al. (Bhandari, Murthy, & Pal, 1996) have modelled the Genetic algorithm as a finite state Markov chain. They have proved that the initial string can be converted to the best chromosome through Markov process. It is also shown that genetic algorithm can be converted into the global optimal solution with any initial population.

Lozano (Lozano, Larranaga, Grana, & Albizuri, 1999) have used Markov process for convergence to the optima of the hybridisation between genetic algorithm and simulated annealing. Here they have extended the genetic algorithms with a probabilistic Boltzmann reduction operator to prove their convergence to the optima.

Leung and Gao (Leung & Gao, 1997) have used the framework of Markov chain to analyze the problem of premature convergence in genetic algorithms. He has introduced the concept of degree of population diversity to quantitatively characterize and theoretically analyze the problem of premature convergence within the framework of Markov chain. They have assumed that the specified algorithms use proportional selection, one-point crossover, and bit mutation. Finally it is proved that the degree of population diversity converges to zero with probability one, such that the search ability of a genetic algorithm decreases over time or resulting in premature convergence.

Larget and Simon (Larget & Simon, 1999) have used Markov chain with Monte Carlo algorithms for the Bayesian Analysis of Phylogenetic Trees. Phylogenetic Tree is a branching diagram which shows the inferred evolutionary relationships among various entities. They have employed a Markov chain Monte Carlo sampler to sample trees and model parameter values from their joint posterior distribution. Here the Markov chain logic has demonstrated that a Bayesian approach to phylogenetic inference has substantial advantages over the approach of other traditional approaches.

Krishna and Murthy (Krishna & Murty, June, 1999) have shown that traditionally genetic algorithm used in clustering analysis employed either an expensive crossover operator to generate valid child chromosomes from parent chromosomes or a costly fitness function, or both. Here genetic algorithm has been used as classical gradient descent algorithm to solve genetic K-means algorithm. Using finite Markov chain theory, it is proved that the genetic K means algorithm converges to the global optimum easily.

Virtual genetic crossovers or applying the rules of genetic algorithm are possible only when the nodes have inter connections between them. So the application of the GA on the society is possible if the society is seen as a network of different nodes. In their book Borgatti et.al. (Borgatti, Everett, & Johnson, 2013) have extensively discussed the use of network analysis in social sciences. There they have also provided some basis measurements and instituments to analyze the network characteristics of the society. In this book they have taken the help of graph theory, spatial topology and network theories to deduce various measures related to networks and to understand the dynamic nature of the network. Before the publication of Borgatti's book Robins et.al. (Robins, Pattison, Kalish, & Lusher, 2007) have shown that the society can be explained through different types of networks. The existence of a particular type of network is purely probabilistic which actually depends upon the existence and non existence of internodal incidences. Thus, the existence of incidences are also randomized. The randomization of the incidences can be explained as the main reasons behind different types of shapes of the society. On the other hand, the randomization of this incidences actually states that the society is nothing but a continuum between inclusion and exclusion. Thus differents types of sthapes of social network signify different inclusanary status of the whole society.

In this perspective, it is interesting to study the social structure and inclusionary nature of that very structure under globalisation. Globalisation as a process believes in the dominance of free market tenets. Naturally, globalisation will try to ensure lesser government and more market (Healy, Arunachalam, & Mizukami, 2016). With the reduction of the government the measures to include the traditionally excluded will undoubtedly be hampered. At the same time, the traditionally excluded groups will not be able to grapple with the market based competition with lower stock of human capital. So, it is expected that the current wave of globalisation will create new clusters of excluded agents. As a result, the existing social network structure of India with a prevalence of high ethnicity based exclusion will definitely take a different form with lesser inter nodal incedences.

So, it appears that India is a space where groups with different genetic origin reside. These groups clash with each other to control the limited resources over a long time. Ethnicity based exclusion in the name of caste is a manifestation of this clash. Caste appeared in india as a religio philosophical instrument to exclude one group by another. Here exclusion is a process to exploit a group by another. As society can be explained as a network, the presence of exclusion in a society creates incomplete network within the society. This lack of cohesiveness within the society is deliberately created to appropriate resources. The incomplete networks are not the outcome of sponteneous process – but is created conciously. It is thought that the existing social covesiveness will further deteriorate with the advent of current wave of globalisation. So this work wants to know to what extent the social network structures are important to achieve the desired inclusionery development outcomes. Development of inter-personal interactions and improvement of social cohesiveness can be achieved through the idea of Genetic Algorithm. This work is interested to know the importance of social network structures through the outcomes of Markov process to carry forward the application of Genetic Algorithm. Markov method plays an important role to predict the outcome of a dynamic long-run interactive process. Thus, this work questions the importance of network structure in the process of inclusionery development. Such that the specific hypotheses of this work are

- Greater interactions among different social groups improve the inclusionary status of a society.
- Outcome of inclusive growth depends upon the existing social network structure.
- Globalisation will worsen the social cohesiveness of India and consequently will increase the ethnicity-based exclusion.

Methodology

A graph theoretic model is developed with the help of network analysis, GA and Markov process. The model is tested on a sample of 320 households collected through multi-stage stratified random sampling without replacement (Appendix – I). Respondents' information is collected through primary level participatory survey through a questionnaire. The collected information is tabulated and used for testing the conclusions of the developed model. To that respect the ideas of Euclidian distance, graph theory, Boolean algebra and matrix algebra have been used.

Model

In this study the use of genetic algorithm has been shown as a use of Markov chain. In a society a household or a chromosome can simultaneously become members of different social groups on the basis of different inherent characteristics. This multiplicity of respondent characteristics will definitely reduce the society to different inserting subsets. If there are n characteristics of the society and if each characteristic has m states, then we would have m^n mutually exclusive intersections within the society. If we treat each of these intersections as a sub set of the whole society then it can be said that the society consists of $m^n = M$ subsets.

Let us assume that the length of the chromosomes in all the sub sets is L. From each of the sub sets we can select representative chromosomes through a selection operator. This selection operator will work through a fitness function F. the fitness function F is expressed through the inclusion status of the concerned chromosome. Thus from the population we create a mating pool (P) of m^n or M chromosomes. Then iteration t delivers M solution or chromosome string. Such that

$$P^t = \{ S_1^{(t)} , S_2^{(t)}, S_3^{(t)} , \dots \dots \dots S_M^{(t)} \}$$

Each string $S_i^{(t)}$ is evaluated on the basis of its inclusion status expressed through the fitness function F. Members of P^t can undergo reproduction through crossover and mutation to create new population of solution for the next iteration.

Here genetic algorithm is used for chromosomal crossover to maximize a function f(x), $x \in D$ where D is a finite set. The problem here is to find x_{opt} such that

$$f(x_{opt}) \geq f(x); \text{ for all } x \in D$$

Here D is a finite discrete domain. If L is the number of parameters to be considered using GA and A_i represents the finite set of possible values of the i th parameter then $D= A_1,A_2,\cdots\cdots,A_L$

In this study we have considered $A_i = \{0,1\}$ and hence here all the strings are binary in nature of L number of parameters.

Now P^0 corresponds to the pre crossover population and here each chromosomal string in this pool corresponds to a household representing a node or intersection.

After every crossover we evaluate the f(x) of each offspring of the pool. This crossover is an artificial version of natural selection, a Darwinian survival of the fittest among string creations. In this process individual strings of a current pool are crossed with respect to the empirical probability distribution based on the fitness function F.

Thus we can consider any mating pool as a state of a Markov Chain and the probability of creating an offspring through crossover between S_i and S_j can be expressed as η_{ij} such that i=1…M, j=1…..M and i≠j. Thus a transition matrix of i X j is created where $\sum_{j=1}^{M} \eta ij = 1$ and $0 \leq \eta_{ij} \leq 1$. Thus this transition matrix T is a M x M square matrix. Each element of T represents the transitional probability from S_i to the offspring create through the crossover of S_i and S_j.

A distribution matrix Q^0 corresponding to P^0 can be conceived with the relative fit of each string on that phase. Thus Q^0 is a 1 X M matrix. Thus this matrix is created following the bellow stated arguments:

- Calculate the fitness value $F(S_i)$, for each chromosome S_i (i= 1,2,3….M).

- Find the total fitness of the mating pool F = $\sum_{i=1}^{M} F(S_i)$

- Calculate the g_i^t, as the element of Q^t corresponding to S_i as $g_i = \frac{F(S_i)}{F}$ where S_i (i = 1,2,….M)

To construct T each chromosome from P^0 is crossed with all the available chromosomes on the said mating pool. Thus each chromosome performs M crossovers and delivers M offspring. If each chromosome is treated as a tuple then the vector V_i created by S_i will include M elements. These M alements are S_{ij} – offspring of crossover of S_i with S_j. So

$$V_i = (S_{ij})$$

Where i≠j and i = 1,2, …M

j = 1,2,…M

Now if η_{ij} is the probability of getting the inclusion status related with S_{ij} then

$$\eta_{ij} = \frac{F(S_{ij})}{F(\mathrm{Vi})}$$

Here F is the corresponding fitness function and i≠j . i = 1,2, …M; j = 1,2,…M

Continuing the process of crossover, we get M vectors with M elements in each vector. Such that we get a M x M probability matrix called T.

The distribution matrix Q^t together with T constitute with Markov process which will systematically carry forward the process of genetic algorithm till x_{opt} is reached.Let η_{ij}^t be the probability of the GA results in Q^t at the t th state given the initial stage as Q^0. Thus $Q^t = Q^{t-1} . T$.

The aim of this study is to derive efficiency of the Markov chain on the perspective of different social network structures. Depending upon different perspectives the society can take different shapes as well as density. The society can be a complete network or an incomplete graph. It can also be decentralized or highly centralized. If W is the set of all probable network structures of the society then

$$W = \{W_1, W_2, \ldots\ldots W_n\}$$

If the whole society is represented as a complete connected graph of M nodes, then it can be written that $W_1 = \{ S_i, e_{ij} \mid i=1,2,3,\ldots.M \text{ and } i \neq j\}$ where the total number of edge is $\frac{M(M-1)}{2}$.

On the other hand, if we think the society about an incomplete decentralized network then the society can be represented through a Hamiltonian circuit. From the available social structure W_1, H can be generated where

$$H = \{ h_i \mid i = 1,2,3\ldots..\alpha\}$$

Here h_i is Hamiltonian circuit where

$$h_i = \{ S_i, e_{ij} \mid i=1,2,3,\ldots.M \text{ and } i \neq j\}$$

From H, h_{opt} will be selected through selection operator using a fit function on the basis of minimum cumulated edge weight of a particular Hamiltonian circuit. Thus $W_2 = \{ S_i, e_{ij} \mid i=1,2,3,\ldots.M \text{ and } i \neq j\}$ where the total number of edge is M and

$$W_2 = h_{opt} = \min_{1-\alpha} \quad \sum_{i,j=1}^{M} e_{ij}^{\beta} \text{ where } i \neq j \text{ and } \beta = 1,2,\ldots. A$$

This Hamiltonian structure is nothing but a decentralized circular structure of the society.

On the other hand, we can think about a centralized star network structure of the society through defining a node as the center. This centrality can be defined through a selection operator on the basis of a certain fit function. In this structure if s* is at the center then the societyW_3 = { S_i, e_{ij} | i=1,2,3,….M and i ≠ j} where degree of incidence of s* is M-1 and the degree if incidence of other M-1 nodes is 1.

Thus the whole work reduces to the comparison of the stationarity under Markov process $Q^t = Q^{t-1}$. T within W.The stationarity or the stable state of the genetic operation is achieved when $Q^* = Q^*.T$.

As W comprises of n elements we will end up with n stationery conditions. Thus we get $Q^{SS} = (Q_\theta^* | \theta = 1,2, \dots n)$. Here Q^{SS} is the set of stationery conditions under different social network structures.

If it is found that the $Q_\theta^*$are different to each other on the basis of a fitness function then it can be concluded that social network structure is very important for achieving desired inclusive output. This fitness function can be formulated on the basis of operation time and inclusionary status of different nodes or representative chromosomes. This fitness function will also consider the improvement of nodes at the stationarity over the initial state. On the other hand, it can be said that at the time of formulation of development programmes apart from considering the individual characteristics, social structure should be considered. Network specific inclusive programmes is the requirement of the time.

If I is the improvement of a node or representative chromosome at the stationarity over the initial state then $I_{i\theta}^*$shows the improvement of ith chromosome at the stationarity state under the θ network structure. The comparison between the available values of $I_{i\theta}^*$ can be used to deduce the desired network structure and inclusionary programme.

Findings

The society as a whole can be denoted as the population. This society can be characterized as the combinations of different characteristics like location of residence, gender and caste. Such that a society consists of the rural and urban areas; males and females as well as scheduled tribe communities and other communities. It is also observed that the inclusion status of any household is significantly influenced by the intersection of these characteristics. As these characteristics are independent of each other we can get 2^3 combinations or intersections of these characteristics. These intersections are shown as follows:

Table: 1

Node selection scheme

	Location of residence and gender			
	Urban (U)		Rural (R)	
Caste	Female (F)	Male (M)	Female (F)	Male (M)
Scheduled tribe (S)	USF (S_1)	USM (S_2)	RSF (S_5)	RSM (S_6)
Other castes (O)	UOF (S_3)	UOM (S_4)	ROF (S_7)	ROM (S_8)

Each of these intersecting sets consists of several households conceived as chromosomes or strings of genes. Each of these genes or capability variables has been used to determine the exclusion status of the households on the basis of their characteristics. Such that each of these chromosomes are of equal length which is here 17 i.e. each chromosome has 17 genes. Each of the intersecting sets are treated as a node represented by the best chromosome of the node concerned. The best chromosome from each of the nodes are selected through the inclusion status. Here the fitness is defined through the existence of highest number of zero in the chromosome. Our capability variables are binary in nature where 1 means exclusion on the concerned variable and zero is the inclusion on that gene. The inclusion exclusion status of each of the intersecting sets represented by their representing chromosomes are expressed through the following table.

Table: 2		
Node-wise inclusion exclusion status		
Nodes	Level of exclusion	Level of inclusion
S_1	09	08
S_2	07	10
S_3	06	11
S_4	04	13
S_5	11	06
S_6	09	08
S_7	05	12
S_8	05	12

Here these eight chromosomes are used as the mating pool such that

$$P^0 = \{ S_1^{(0)} , S_2^{(0)}, S_3^{(0)} , \ldots \ldots \ldots S_8^{(0)} \} \text{ and}$$

$$S_i^{(0)} = \{\gamma_i \mid i = 1,\ldots 17 \text{ and } \gamma = 0 \text{ or } 1\}$$

In a hypothetical situation W_1 the society or the mating pool P^0 is thought as a networked complete graph having the subsets $S_1, \ldots, S_8$ as the nodes. Such that the society has 8 nodes and 28 edges. So the edge weight matrix of the society is as follows.

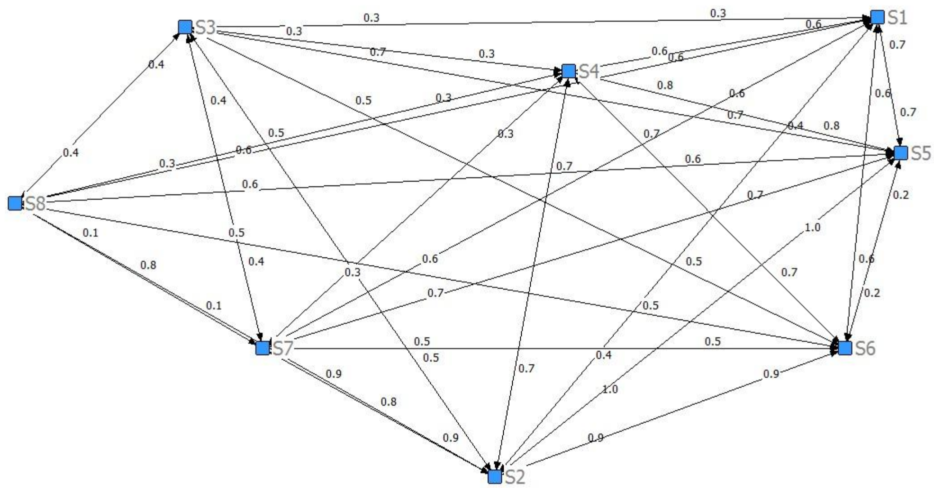
Table: 3								
Edge weight matrix								
	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
S_1	-	$e_{1.2}$	$e_{1.3}$	$e_{1.4}$	$e_{1.5}$	$e_{1.6}$	$e_{1.7}$	$e_{1.8}$
S_2		-	$e_{2.3}$	$e_{2.4}$	$e_{2.5}$	$e_{2.6}$	$e_{2.7}$	$e_{2.8}$
S_3			-	$e_{3.4}$	$e_{3.5}$	$e_{3.6}$	$e_{3.7}$	$e_{3.8}$
S_4				-	$e_{4.5}$	$e_{4.6}$	$e_{4.7}$	$e_{4.8}$
S_5					-	$e_{5.6}$	$e_{5.7}$	$e_{5.8}$
S_6						-	$e_{6.7}$	$e_{6.8}$
S_7							-	$e_{7.8}$
S_8								-

The $e_{i.j}$ of the edge weight matrix can be determined through the normalized Euclidian distance in the exclusion space. We can conceive the exclusion space as a three dimension Cartesian space of health, education and income exclusions.The determination of the edge weight has been discussed in full details in Appendix - II. The calculated inter-nodal edge weights are as follows.

Table: 4								
Edge weight matrix under complete network structure								
	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
S_1	-	0.4	0.25	0.5747	0.7139	0.5763	0.6376	0.5787
S_2		-	0.4527	0.6887	1.0469	0.8918	0.8691	0.8186
S_3			-	0.3288	0.6988	0.529	0.4301	0.3747
S_4				-	0.8234	0.6537	0.2589	0.2581
S_5					-	0.1796	0.6665	0.6043
S_6						-	0.525	0.4537
S_7							-	0.0824
S_8								-

Using these edge weights, the society or the mating pool P^0 can be described with the following complete graph.

Graph - I



The above depicted complete network is the initial mating pool under W_1. From this mating pool we can generate the initial distribution matrix and stochastic transition matrix. Here the initial distribution matrix Q^0 corresponding to P^0 is a [1 X 8] matrix. To create this matrix fitness value $F(s_i^0)$ of each of the chromosome s_i^0 is calculated. The fitness is determined through the inclusion status or the number of zero in each string s_i^0. After calculating the $F(s_i^0)$ the total fitness F of the mating pool is calculated. Thus the following table is generated.

Table: 5		
Fitness Table of Q^0 under W_1		
Chromosome	Fitness	Relative Fitness $g_i^0 = \frac{F(s_i^0)}{F^0}$
s_1^0	8	0.0987654320987654
s_2^0	10	0.123456790123456
s_3^0	11	0.135802469135802
s_4^0	13	0.160493827160493
s_5^0	6	0.0740740740740741
s_6^0	8	0.0987654320987654
s_7^0	12	0.148148148148148
s_8^0	13	0.160493827160493
Population	81	1

Each element of the initial distribution matrix Q^0 is nothing but the relative fitness of each of the string available in the initial mating pool. Thus

$$g_i^0 = \frac{F(s_i^0)}{F^0} \quad \text{where i= 1,2,....8}$$

Thus the initial distribution matrix

Q^0 = [0.0987654320987654 0.123456790123456 0.135802469135802 0.160493827160493 0.0740740740740741 0.0987654320987654 0.148148148148148 0.160493827160493]

Now our transition matrix T is a [8 x 8] square matrix presented as follows

$$T= \begin{bmatrix} 0.094118 & 0.117647 & 0.152941 & 0.152941 & 0.105882 & 0.105882 & 0.129412 & 0.141176 \\ 0.109890 & 0.109890 & 0.142857 & 0.142857 & 0.120879 & 0.120879 & 0.120879 & 0.131868 \\ 0.131313 & 0.131313 & 0.111111 & 0.121212 & 0.121212 & 0.121212 & 0.121212 & 0.141414 \\ 0.128713 & 0.128713 & 0.118812 & 0.118812 & 0.118812 & 0.118812 & 0.128713 & 0.138614 \\ 0.109756 & 0.134147 & 0.146341 & 0.146341 & 0.073171 & 0.097561 & 0.134146 & 0.158536 \\ 0.109756 & 0.134146 & 0.146341 & 0.146341 & 0.097561 & 0.085366 & 0.134146 & 0.146341 \\ 0.120879 & 0.120879 & 0.131868 & 0.142857 & 0.120879 & 0.120879 & 0.098901 & 0.142857 \\ 0.117647 & 0.117647 & 0.137255 & 0.137255 & 0.127451 & 0.117647 & 0.127451 & 0.117647 \end{bmatrix}$$

Then according to the Markov Process $Q^t = Q^{t-1}.T$. Thus

Q^0 = [0.098765 0.123457 0.135802 0.160494 0.074074 0.098765 0.148148 0.160494]

Q^1 = [0.117112 0.123652 0.133758 0.136758 0.114329 0.113358 0.12311618 0.13791701]

Q^2 = [0.11587484 0.124184 0.13517122 0.13787523 0.111693 0.111747 0.12421556 0.13923888]

.

.

.

Q^6 = [0.1159618 0.12414734 0.1350614 0.1377899 0.111869 0.11186903 0.12414734 0.13915417]

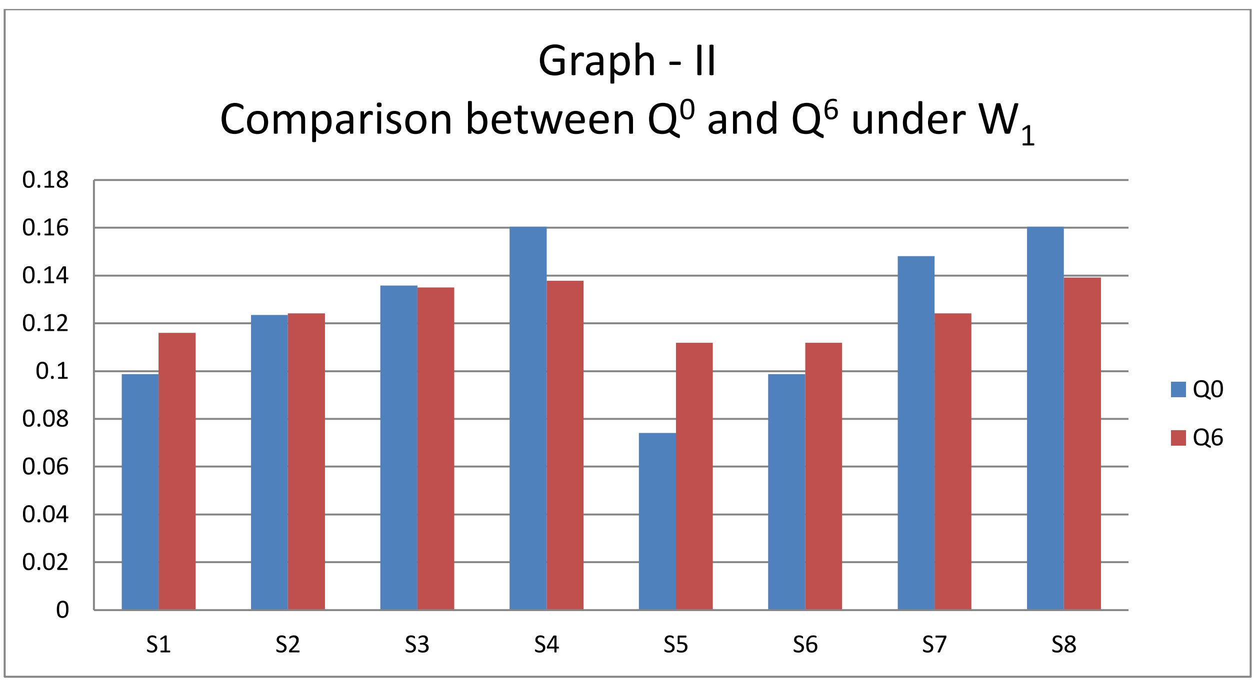
Q^7 = [0.1159618 0.12414734 0.1350614 0.1377899 0.111869 0.11186903 0.12414734 0.13915417]

This Markov process reaches the stable state after the 6 iterations. This means that

$$Q^6 = Q^7$$

$$\text{or } Q^6 = Q^6 . T$$

Now comparing the Q^6 with Q^0 we get the following diagram.



It appears from the above discussion that nodes S_1, S_3, S_5, and S_6 have registered improvement in their respective relative fitness while S_2, S_4, S_7 and S_8 have registered deterioration in the same.

Table: 6		
Node-wise improvement and deterioration after Markov process under W_1		
Nodes	Intersections	Status relative fitness at stable state in reference to the initial state
S_1	USF	IMPROVED
S_2	USM	IMPROVED
S_3	UOF	DETERIORATED
S_4	UOM	DETERIORATED
S_5	RSF	IMPROVED
S_6	RSM	IMPROVED
S_7	ROF	DETERIORATED
S_8	ROM	DETERIORATED

The following table can be derived from the above.

Table: 7				
Character-wise improvement and deterioration after Markov process under W_1				
	Number of nodes where present	Number of nodes where improved	Number of nodes where deteriorated	Improved nodes : deteriorated nodes
Scheduled Tribe	4	4	0	Very large
Other Castes	4	0	4	0
Females	4	2	2	1
Males	4	2	2	1
Rural	4	2	2	1
Urban	4	2	2	1

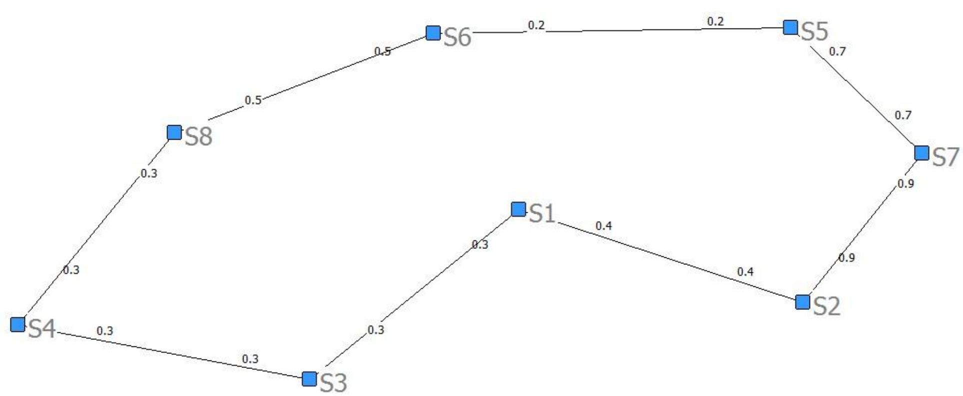
It appears that under W_1 that is under the complete network structure the inclusion status of the scheduled tribe community and the females will improve through applying the rules of genetic algorithm. In other words, it can be said that the existing development programmes can deliver better results through establishing greater interaction among the different ethnic groups and the males and females.

We can reduce this networked complete graph to a set of Hamiltonian circuits. The Hamiltonian circuit having the minimum cumulated edge weight is used as the initial structure to apply the genetic cross-over. The algorithm to determine the minimum

Hamiltonian circuit is given in Appendix - IV. Thus in this hypothetical situation W_2 the mating pool is presented through the following matrix.

Table: 8								
Edge weight matrix under Minimum Hamiltonian circuit or W_2								
	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
S_1	-	0.45	0.25	-	-	-	-	-
S_2	0.45	-	-	-	-	-	0.8691	-
S_3	0.25	-	-	0.3288	-	-	-	-
S_4	-	-	0.3288	-	-	-	-	0.2581
S_5	-	-	-	--	-	0.1796	0.6665	-
S_6	-	-	-	-	0.1796	-	-	0.4537
S_7	-	0.8691	-	-	0.6665	-	-	-
S_8	-	-	-	0.2581	-	0.4537	-	-

<u>Graph: III</u>



The above depicted minimum Hamiltonian circuit is the initial mating pool under W_2. From this mating pool we can generate the initial distribution matrix and stochastic transition matrix. Here the initial distribution matrix Q^0 corresponding to P^0 is a [1 X 8] matrix as under W_2. To create this matrix same procedure as under $W_1$is followed.

Thus the initial distribution matrix here is same as $W_{1.}$

Q^0 = [0.0987654320987654 0.123456790123456 0.135802469135802 0.160493827160493 0.0740740740740741 0.0987654320987654 0.148148148148148 0.160493827160493]

Now our transition matrix T is a [8 x 8] square matrix presented as follows

T=

0.258	0.322	0.419	0	0	0	0	0
0.322	0.322	0	0	0	0	0.355	0
0.361	0	0.305	0.333	0	0	0	0
0	0	0.316	0.316	0	0	0	0.368
0	0	0	0	0.24	0.32	0.44	0
0	0	0	0	0.296	0.259	0	0.444
0	0.355	0	0	0.355	0	0.290	0
0	0	0	0.368	0	0.316	0	0.316

Then according to the Markov Process $Q^t = Q^{t-1}.T$. Thus

Q^0 = [0.0987654320987654 0.123456790123456 0.135802469135802 0.160493827160493 0.0740740740740741 0.0987654320987654 0.148148148148148 0.160493827160493]

Q^1 = [0.114352 0.124253 0.133595 0.155079 0.09961 0.099992 0.119411 0.153707]

Q^2 = [0.117835 0.119341 0.137747 0.150133 0.095905 0.106338 0.122586 0.150114]

.

.

.

Q^{57} = [0.120623 0.120623 0.140078 0.14786 0.097276 0.105058 0.120623 0.14786]

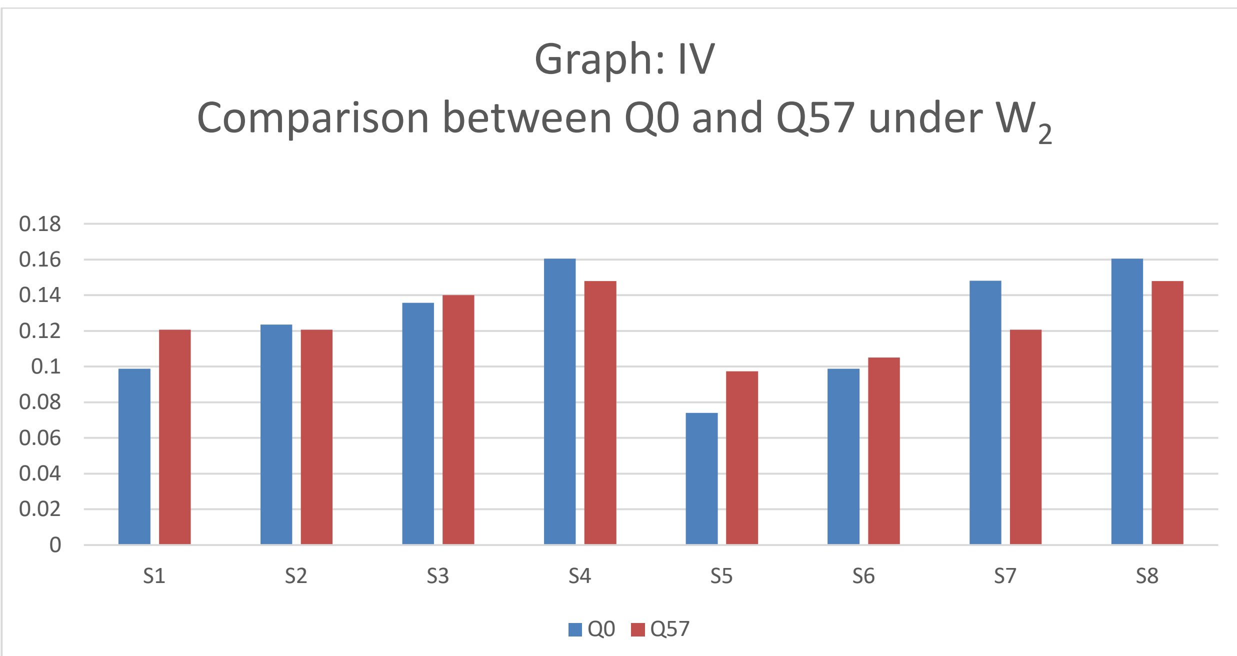
Q^{58} = [0.120623 0.120623 0.140078 0.14786 0.097276 0.105058 0.120623 0.14786]

This Markov process reaches the stable state after the 57 iterations. This means that

$$Q^{57} = Q^{58}$$

$$\text{or } Q^{57} = Q^{57}.\, T$$

Now comparing the Q^{57} with Q^{0} we get the following diagram.



It appears from the above discussion that nodes S_1, S_3, S_5 and S_6 have registered improvement in their respective relative fitness while S_2, S_4, S_7 and S_8 have registered deterioration in the same.

Table: 9		
Node-wise improvement and deterioration after Markov process under W_2		
Nodes	Intersections	Status relative fitness at stable state in reference to the initial state
S_1	USF	IMPROVED
S_2	USM	DETERIORATED
S_3	UOF	IMPROVED
S_4	UOM	DETERIORATED
S_5	RSF	IMPROVED
S_6	RSM	IMPROVED
S_7	ROF	DETERIORATED
S_8	ROM	DETERIORATED

The following table can be derived from the above.

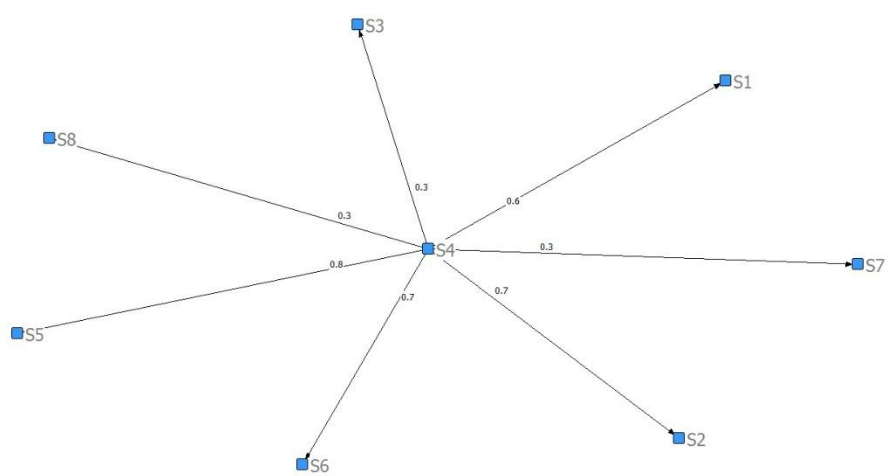
Table: 10				
Character-wise improvement and deterioration after Markov process under W_2				
	Number of nodes where present	Number of nodes where improved	Number of nodes where deteriorated	Improved nodes : deteriorated nodes
Scheduled Tribe	4	3	1	3
Other Castes	4	1	3	0.33
Females	4	3	1	3
Males	4	1	3	0.33
Rural	4	2	2	1
Urban	4	2	2	1

It appears that under W that is under the decentralized circular structure the inclusion status of the scheduled tribe community and the females will improve through applying the rules of genetic algorithm. In other words, it can be said that the existing development programmes can deliver better results through establishing greater interaction among the different ethnic groups and the males and females.

Alternative to $W_1$and W2 we can think about a hypothetical network structure where the society takes the form of a centralized star structure – described as W_3. Thus in the hypothetical situation W_3 the mating pool is presented through the following matrix and the centralized star structure.

Table: 11								
Edge weight matrix under centralised star structure under W_3								
	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
S_1	-	-	-	0.5747	-	-	-	-
S_2	-	-	-	0.6887	-	-	-	-
S_3	-	-	-	0.3288	-	-	-	-
S_4	-	-	-	-	-	-	-	-
S_5	-	-	-	0.8234	-	-	-	-
S_6	-	-	-	0.6537	-	-	-	-
S_7	-	-	-	0.2589	-	-	-	-
S_8	-	-	-	0.2581	-	-	-	-

Graph: V



Thus the above depicted star structure is the initial mating pool P^0under W_3. From this mating pool we can generate the stochastic transition matrix. But the initial distribution matrix under W_3 will be the same as under W_1.

Thus the initial distribution matrix under W_3 is

Q^0 = [0.0987654320987654 0.123456790123456 0.135802469135802 0.160493827160493 0.0740740740740741 0.0987654320987654 0.148148148148148 0.160493827160493]

Now our transition matrix T is a [8 x 8] square matrix presented as follows

T=

0	0	0	1	0	0	0	0
0	0	0	1	0	0	0	0
0	0	0	1	0	0	0	0
0.129	0.129	0.119	0.119	0.119	0.119	0.129	0.137
0	0	0	1	0	0	0	0
0	0	0	1	0	0	0	0
0	0	0	1	0	0	0	0
0	0	0	1	0	0	0	0

Then according to the Markov Process $Q^t = Q^{t-1}.T$. Thus

Q^0 = [0.0987654320987654 0.123456790123456 0.135802469135802 0.160493827160493 0.0740740740740741 0.0987654320987654 0.148148148148148 0.160493827160493]

Q^1 = [0.02065760.0206580.0190690.8585750.0190690.0190690.0206580.022247]

Q^2=[0.11050960.110510.1020090.2434340.1020090.1020090.110510.11901]

.

.

.

Q^{146} = [0.068421040.0684210.0631580.5315790.0631580.0631580.0684210.073684]

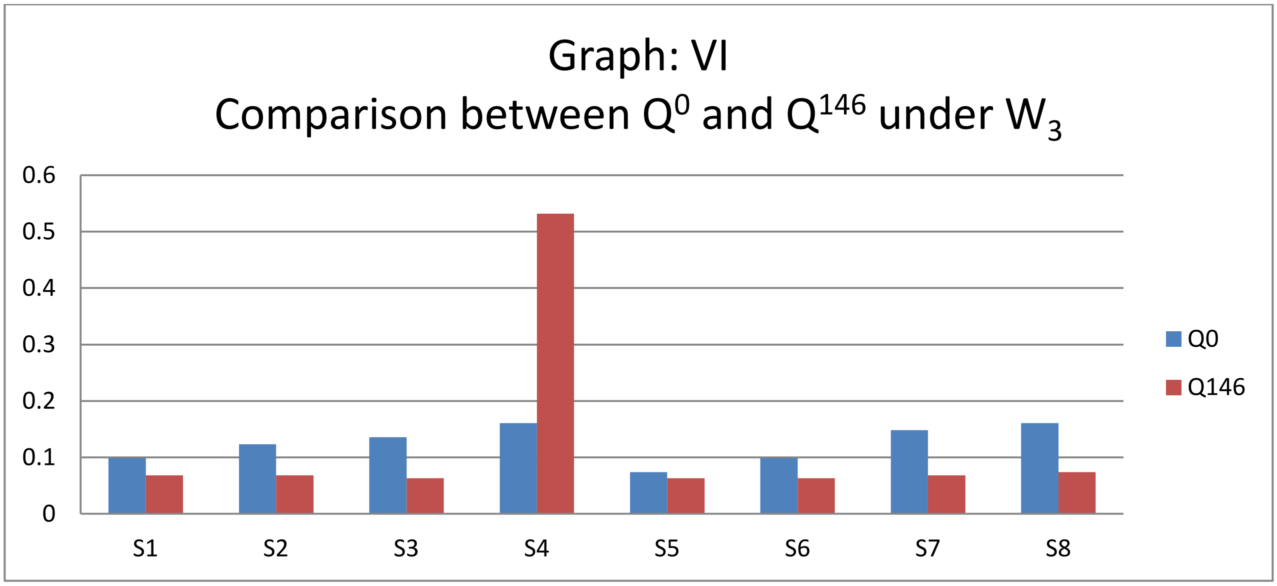
Q^{147} = [0.068421040.0684210.0631580.5315790.0631580.0631580.0684210.073684]

This Markov process reaches the stable state after the 146 iterations. This means that

$$Q^{146} = Q^{147}$$

$$\text{or } Q^{146} = Q^{146}.\,T$$

Now comparing the Q^{146} with Q^{0} we get the following diagram.



It appears from the above discussion that only the central node S_4 has registered spectacular improvement with respect to fitness while nodes S_1, S_2, S_3, S_5, S_6, S_7 and S_8 have registered deterioration in the same.

Table: 12		
Node-wise improvement and deterioration after Markov process under W_3		
Nodes	Intersections	Status relative fitness at stable state in reference to the initial state
S_1	USF	DETERIORATED
S_2	USM	DETERIORATED

S_3	UOF	DETERIORATED
S_4	UOM	IMPROVED
S_5	RSF	DETERIORATED
S_6	RSM	DETERIORATED
S_7	ROF	DETERIORATED
S_8	ROM	DETERIORATED

The following table can be derived from the above.

Table: 13

Character-wise improvement and deterioration after Markov process under W_3

	Number of nodes where present	Number of nodes where improved	Number of nodes where deteriorated	Improved nodes : deteriorated nodes
Scheduled Tribe	4	0	4	0
Other Castes	4	1	3	0.33
Females	4	0	4	0
Males	4	1	3	0.33
Rural	4	0	4	0
Urban	4	1	3	0.33

It appears that under W_3 that is under the centralized star structure the inclusion status of the other caste communities, the males and the urban dwellers will improve by applying the rules of genetic algorithm. The exclusion status of the existing excluded groups like the scheduled tribes, females and the rural peoples will deteriorate further. In other words, it can be said that the existing development programmes will extend the exclusionary processes further instead of allowing the excluded to participate.

Table: 14

Comparison of relative fitness of chromosomes under initial state and stable state of W_1, $W_2$and W_3

	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8
W_1	0.017196	0.000691	-0.00074	-0.0227	0.037795	0.013104	-0.024	-0.02134
W_2	0.021857	-0.00283	0.004275	-0.01263	0.023202	0.006293	-0.02753	-0.01263
W_3	-0.03034	-0.05504	-0.07264	0.371085	-0.01092	-0.03561	-0.07973	-0.08681

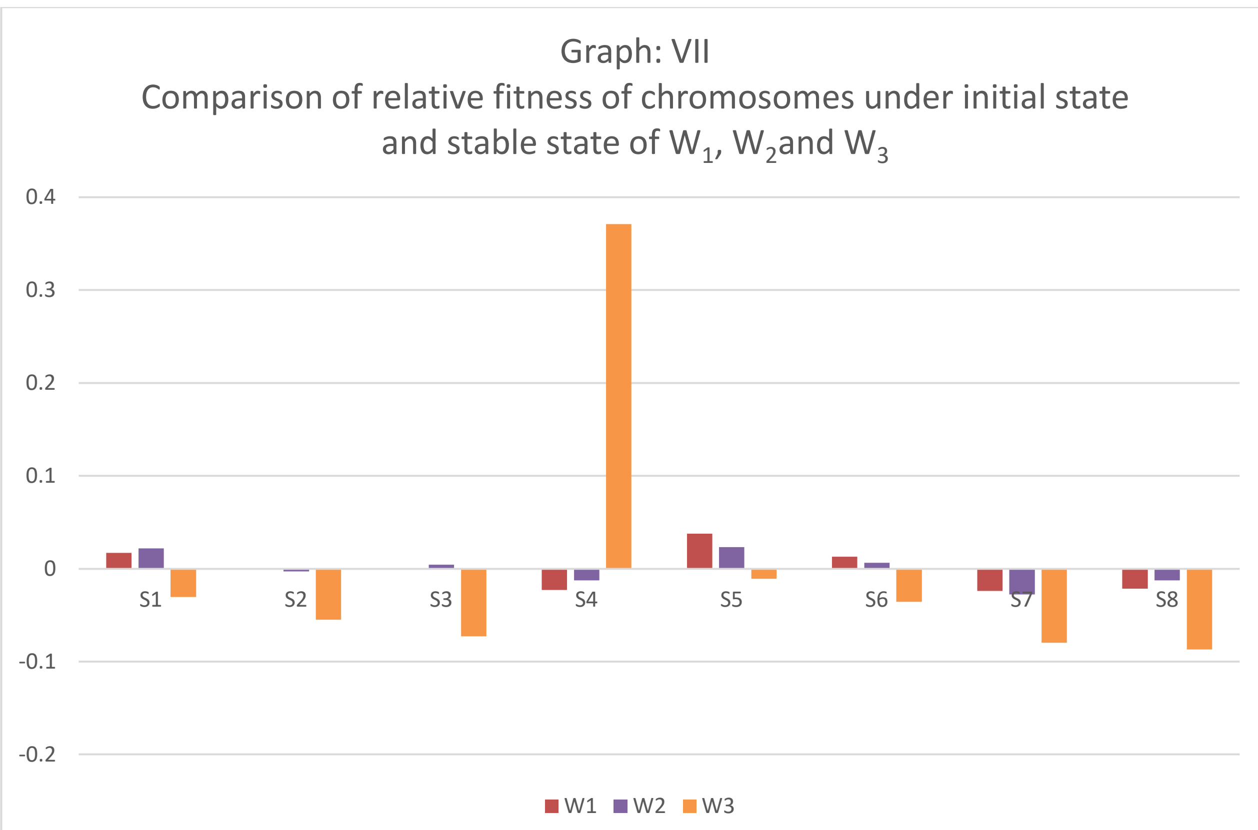


Table : 15			
Comparison between W1, W_2 and W_3			
Character	Improvement Ratio Under W_1	Improvement Ratio Under W_2	Improvement Ratio Under W_3
Scheduled Tribe	Very large	3	0
Other Castes	0	0.33	0.33
Females	1	3	0
Males	1	0.33	0.33
Rural	1	1	0
Urban	1	1	0.33
1 means no change in exclusion status. > 1 means improvement in exclusion status with highest value as infinitely large. <1 means deterioration in exclusion status with lowest value as 0.			

Table: 16			
Cohesion density and time to achieve stationarity under different network structures			
	W_1	W_2	W_3
Cohesion density index	1	0.28	0.25
Shape	Complete network	Incomplete decentralised Hamiltonian circuit	Incomplete centralised star structure
Time for stationarity	6 iterations	57 iterations	146 iterations

It appears from the above discussion that improvement of inclusionary status varies largely with the change in social network conditions. Under the highly centralized network, none of the social characteristics demonstrated improvement with respect to the inclusionary status. On the other hand, under decentralized Hamiltonian structure the inclusionary status of two characteristics improved, that of two characteristics deteriorated and that of two characteristics remained the same. But the inclusionary status of the traditionally excluded like STs improved. The inclusionary status of the STs improved spectacularly under the complete network structure. Here the status of one characteristic deteriorated while that of four characteristics remained the same. Thus, with the increase in the cohesion density within the society the inclusionary status of the traditionally excluded castes improved. Again, the time to achieve stationery state improves with the improvement of cohesion density. Thus cohesion density is a major factor to achieve the desired outcomes under inclusionary development programmes. So, at the time of formation of inclusionary development programmes network cohesion should be given due importance and network specific inclusionary programmes should be developed. To get the desired outcome the plan formulators should primarily take steps to estimate the social network structure. After estimating the structure steps should be taken to improve cohesion within the society. State should play a proactive role to transform the society to the desired structure. It is true that the lack of cohesiveness within the Indian society has a long history and has the support of *Brahmanical* philosophical thoughts. To that respect the social outlook of the Hindu society should be changed. Peoples should embrace each other irrespective of caste, creed and economic status to achieve higher level of development with a given resource.

Globalisation has thrown new challenges in the path to eradicate this menace from the Indian society. The current form of globalization has mainly bought technology driven market oriented growth. This type of development has benefitted the groups with better human capital. The report of the Task Force on Higher Education in Developing Countries has rightly indicated that the developing countries will not be benefitted from the current wave of globalization without the improvement of overall level of education (The Task Force on Higher Education in Developing Countries, 2000). Education is the most important factor to achieve the benefits of knowledge based economy under globalization. Naturally the social groups endowed with better level of education will perform better in the era of globalization. If we go through the literacy rates (Appendix – V) and enrolment rate at different levels of different social groups (appendix – VI) we would observe that the traditionally excluded groups have lower academic achievements in relation to the higher castes. So, the traditionally excluded groups like the STs will be further excluded with the current wave of globalization. The inter caste divergence will increase with the advent of globalization. The effect of this academic divergence is clearly depicted by the level of enterprise ownership and enterprise employment of different social groups in India (Appendix – VI). The STs are lagging far behind the other castes in achieving decent income and employment in modern globalized India. Naturally, the current wave of globalization has actually deteriorated social cohesion instead of improving it. Under the era of global integration, the social structure has become more centralized. So, globalization has carried the greater danger of higher level of exclusion of greater number of social groups in India.

So, on the basis of the above discussion it can be concluded that greater interaction among different social groups can largely influence the expected outcome of any inclusionary development programme. But this expected outcome depends on the existing social network structure of the society. Due to some strong religio-philosophical reasons, India has a long history of incomplete network among different ethnic groups. This lack of cohesiveness within the Indian society is one of the greatest challenges to India in achieving desired inclusive growth. The current wave of globalization can deteriorate the situation with more centralization within the society.

Appendix – I

Sampling

In the first stage four districts of West Bengal were randomly chosen –two from the strata of relatively higher per capita income districts and two from the strata of relatively lower per capita income districts (Bureau of Applied Economics and Statistics, Govt. of West Bengal, 2009). The existence of West Bengal as a benchmark in the discourses of inclusive development is proven within India. That is why sample has been chosen from the state of West Bengal only. The four sample districts are Purba Medinipur and Howrah (also called Haora) – from the strata of relatively high per capita income districts; Cooch Behar (also called Koch Behar or Koch Bihar) and Paschim Medinipur – from the strata of relatively low per capita income districts. At the second stage, two community development blocks from each district were chosen randomly. In the third stage, two villages were selected randomly from each community development block. Ultimately, 20 households from each of the selected villages were chosen randomly. Thus the sample size is 320. The study was undertaken in 16 villages under 8 blocks of 4 districts of West Bengal. Data were collected from these households through field survey based on questionnaire interview method. Survey was undertaken between December 2015 and March 2016.

Appendix – II

Determination of edge weight or inter nodal distance

To calculate the inter-nodal distance in the exclusion space or the edge weight we have tried to measure the level of social exclusion of each node or the representative chromosome. To develop an appropriate measure of social exclusion from development programmes we have mainly followed Chakraborty & D’Ambrosio (Chakraborty & D'Ambrosio, 2002), Camara *et.al* (Camara, Monteiro, Ramos, Sposati, & Koga, 2002), Poggi (Poggi, 2003), Bosset, D’Ambrosio & Peragine (Bossert, D'Ambrosio, & Peragine, 2004) and Acharya (Acharya, 2010). Chakraborty and D’Ambrosio have looked into social exclusion as functioning deprivation and tried to locate relevant functioning those have greater effect on the life. They first looked at functioning failures, the number of functioning from which the person is excluded. In this respect they marked certain indicators over a limited number of domains or functioning. They referred to it as the deprivation score or the number of exclusions of the person concerned. A person’s exclusion in a given domain has been obtained by adding up his exclusions over the concerned variables. At the same time Camara *et.al* used the term dimension for domains or functioning. Like Chakraborty and D’Ambrosio, in the study of Camera *et. al.* also each dimension is captured by a set of variables. They have put 0 for attaining the desired level, 1 for over attainment and -1 for under attainment with respect to each variable. In the same line Poggi has also tried to define the functioning failures. His paper identified the socially excluded individual using Sen’s capability approach. Like Camara *et.al,* Poggi also identified certain items under each functioning and for each selected item he assigned to each individual a score of zero or one. A score of one means that the individual can afford the item, has the item or does not have the ‘problem’. Instead a score equal zero means that the individual is deprived in that item. He sum up the score of each item representing the same functioning and gave equal weights to the items. Then divided each functioning score by the number of items belonging to such functioning in order to be able to compare the distribution of different functionings. Thus for each functioning, an individual receives a score between zero and one. A score equal one means that the functioning has been fully achieved. Finally, he has used vector analysis for measuring the appropriate level of social exclusion. Bosset, D'Ambrosio and Peragine have said that Social exclusion manifests itself in the lack of an individual's access to functionings. They have also calculated social exclusion through the number of functioning failures. Their notion of social exclusion is obtained as an aggregate of the levels of deprivation experienced by an individual in each of the functionings. In a final step, these individual indicators of exclusion are aggregated across individuals to arrive at a class of measures of exclusion for society as a whole. In all cases, they use the arithmetic mean as the requisite aggregator function. Indicators of discrimination as discussed by Acharya tried to capture discrimination in different spheres, forms and personnel who may practice discrimination. Prevalence of discrimination was measured by simple percentage. Fixed scores were awarded to different levels of discrimination. The average score for each respondent was computed for sphere, form and provider separately – which may be called sectoral indexes. These average scores were used to compute a composite index of discrimination.

In reference to the above studies we have also constructed our own measure of social exclusion from development programmes in West Bengal. Our survey of literature within this study has found that the most of the studies tried to functionalise social exclusion through the notion of functioning or capability deprivation, such that the main domains of social exclusion according to those studies are health, education and income. The domains or aspects accepted by this work to measure social exclusion are also health, education and income. Under each of these domains certain development programmes have been chosen to functionalise the idea. Some questions or variables under each domain are put forwarded to capture the views of the respondents.

We have used dummy or binary variable to incorporate the views of the respondents into the model. 0 is assigned to the answer 'yes' for each question and 1 otherwise. The answer 'yes' or assigning 0 to any question means the respondent is not excluded with respect to the concerned variable. On the other hand answering 'no' or assigning 1 to any question means that the respondent is excluded with respect to the concerned variable. The score from each variable of each respondent for exclusion from income domain is added and divided by 5 to get the average (as income domain has five variables). This average value may be regarded as the measure of exclusion in the field of income delivery mechanism. Mathematically this may be presented as follows:

$$ME_j = \frac{1}{5}\sum_{i=1}^{5} e_{ij}^{M}$$

where ME_j is the measure of exclusion in the field of income delivery programme of jth individual. e_{ij}^{M} , i = 1,2 ….5 is the score on each variable under the indicator of income delivery programme of jth individual.

The measure for exclusion in the ground of health delivery programmes has two components with equal weights. These are measure of exclusion in the field of curative health and measure of exclusion in the field of preventive health.

The score from each variable of each respondent for exclusion from different variables under curative health care is added and divided by 7 to get the average (as the domain of curative health has 7 variables). This average value may be regarded as the measure of exclusion in the field of curative health delivery mechanism. Mathematically this may be presented as follows:

$$CHE_j = \frac{1}{7}\sum_{i=1}^{7} e_{ij}^{CH}$$

where CHE_j is the measure of exclusion in the field of government sponsored curative health delivery mechanism of jth individual. e_{ij}^{CH} , i = 1,2 ….7 is the score on each variable under the indicator of curative health delivery mechanism of jth individual.

Likewise, the score of each respondent for exclusion from three variables under preventive health care is added and divided by 3 to get the average. This average value may be regarded as the measure of exclusion in the field of government sponsored preventive health delivery mechanism. Mathematically this may be presented as follows:

$$PHE_j = \frac{1}{3}\sum_{i=1}^{3} e_{ij}^{PH}$$

where PHE_j is the measure of exclusion in the field of government sponsored preventive health delivery mechanism of jth individual. e_{ij}^{PH} , i = 1 …. 3 is the score on each variable under the indicator of preventive health delivery mechanism of jth individual.

Thus the composite measure of exclusion from Govt. sponsored health delivery programme is the average of curative health exclusion measure and preventive health exclusion measure having equal weight to each component. Mathematically,

$$HE_j = \frac{1}{2}[CHE_j + PHE_j]$$

$$\Rightarrow HE_j = \frac{1}{2}[\frac{1}{7}\sum_{i=1}^{7} e_{ij}^{CH} + \frac{1}{3}\sum_{i=1}^{3} e_{ij}^{PH}]$$

In the domain of education we have two variables and like the others the answer s are expressed in binary form.

$$EE_j = \frac{1}{2}\sum_{i=1}^{2} e_{ij}^{E}$$

where EE_j is the measure of exclusion in the field of government sponsored education delivery mechanism of jth individual. e_{ij}^{E} , i = 1 …. 3 is the score on each variable under the indicator of education delivery mechanism of jth individual.

Here it is to be kept in mind that voulantary exclusion from any programme has been treated as inclusion under the said programme.

The above discussion ensures that each Sectoral Index (ME_j, HE_j and EE_j) takes the values from 0 to 1 i.e., 0 ≤ Sectoral Index ≤ 1. The higher the value of the sectoral index the higher will be the level of exclusion on that particular sector. If 3 dimensions of exclusion from government programmes are considered, then a composite measure will be represented by a point Dj = (ME_j, HE_j and EE_j) on the 3 dimensional Cartesian space. In the 3 dimensional space, the point O = (0,0,0) represents the point indicating the best situation, representing no exclusion while the point I = (1,1,1) represents the highest level of exclusion. Then the measure of exclusion for jth individual is SE_j, is measured by the normalized Euclidean distance of the point Di from the ideal point 0= (0,0,0). The exact formula to calculate normalized Euclidean distance in an n dimension Cartesian space (Simmons, 1963) (Malik & Arora, 2010) is

$$\frac{1}{n}\sqrt{(x_1 - y_1)^2 + (x_2 - y_2)^2 + \cdots + (x_n - y_n)^2}$$

In our three dimension space of ME_j, HE_j and EE_j the same can be written as

$$SE_j = \frac{1}{\sqrt{3}} [\sqrt{\left(ME_j - 0\right)^2 + \left(HE_j - 0\right)^2 + \left(EE_j - 0\right)^2}]$$

Household level data collected on the basis of primary level survey (Appendix – I) are used to find the social exclusion score of the representative household of each node.

To find the inter nodal distance in the exclusion space the same idea of normalized Euclidean Distance in the three dimensional Cartesian space has been used. Thus the inter nodal distance between two nodes in the exclusion space is

$$\frac{1}{\sqrt{3}} [\sqrt{\left(ME_i - ME_j\right)^2 + \left(HE_i - HE_j\right)^2 + \left(EE_i - EE_j\right)^2}]$$

Where i = 1,2,…,8 and j = 1,2,…,8.

Appendix – III

Crossover and Markov Chain algorithms

Corssover (chro1[],chro2[])

Here Chro1[] and chro2[] are two linear array which represent two parent chromosome. Array off[] represent new offspring and M represent total number of chromosome.

Step1. (Begin main loop)

Repeat step 2 to 4 for i = 1 to M do

Step2 . (Begin inner loop)

Repeat step 3 to 4 for j = 1 to M do

Step 3: off[j] = BitwiseAND(chro1[i] , chro2[j])

Step 4 : (Save/ Print new offspring)

Database= off[j]

Reset off[]

(End of Step 2 loop)

(End of Step 1 loop)

Step 5 : Exit

BitwiseAND (a[],b[])

Here a[] and b[] are two temporary linear array and L is the length of each chromosome.

Step1 : Repeat step 2 for i = 1 to L do

Step 2: return(a[i] & b[i])

(End of loop)

Step3 : Exit

* Bitwise AND operation table

Chro1[]	Chro2[]	Off[]
0	0	0
0	1	0
1	0	0
1	1	1

<u>Markov Chain</u>

Input : Given two observed independent outcomes S_i and S_j, what are the posterior densities of probabilities η_{S_i} and η_{S_j}.

Output : Number of iteration N.

Procedure :

Step 1 . Declare an initial value of Q=(N, η_{S_i} , η_{S_j}) and set equal to Q^n. ($Q = Q^n$) and set N = 1 (Initialize counter)

Step 2 : Calculate the posterior probability of Q^n

Step 3: Draw Q^t from the proposal distribution. (N and η_{S_i} clearly must be drawn from different distributions.)

Step 4 : Calculate the posterior of Q^t following step 2.

Step 5 : Evaluate whether to accept Q^t by comparing the posteriors, and update Q^n.

if $Q^n \neq Q^t$ then
Set N=N+1 and goto step 3.

Step 6 : Repeat steps 3-5 until convergence or reasonable stopping point.

Step 7 : Exit

Appendix – IV

Minimum Hamiltonian Circuit (G = (*S*, *E*))

START

1. Select a node S from G[S] to be a starting node of the circuit.
2. Compute a minimum spanning tree T for G from starting node S using MST(G, c, r)
3. Let L be the list of nodes traversed in a preorder tree walk of T
4. **Return** the minimum weighted Hamiltonian cycle H that traversed the vertices in the order L

END

MST(*G* = (*V*,*E*), *c*, *r*)

Step 1. for each node *u* ϵV[G]

Step 2. do key[*u*] := NULL

Step 3. p[*u*] := NIL [p[u] is a parent of node u]

Step 4. key[*r*] := 0

Step 5. *Q* := *V*[*G*] [Q is a priority queue of set of all nodes not in the tree]

Step 6. while (*Q* != Empty)

do*u*:= EXTRACT-MIN(*Q*)

for each *v*ϵ Adj[*u*]

do if *v*ϵ*Q* and *c(u,v)*< key[*v*]

then p[*v*] := *u*

key[*v*] := *c(u,v)*

[End of if structure]

[End of Inner Loop]

[End of Step 6 Loop]

Step 7: Exit

Appendix – V

literacy Rate of All Social Groups and ST Population (1961-2011)		
Year	All Social Group	ST
1961	28.3	8.53
1971	34.45	11.30
1981	43.57	16.35
1991	52.21	29.60
2001	64.84	47.10
2011	72.99	58.96
Source: Registrar General of India		

Appendix – VI

Percentage Enrolment of ST students to all categories			
Year	Primary	Upper Primary	Secondary
1995-1996	8.8	6.1	4.9
1996-1997	9.2	6.3	4.9
1998-1999	9.6	6.7	5.1
1999-2000	9.4	6.9	5.0
2000-2001	9.7	7.2	5.4
2002-2003	9.7	6.9	5.4

2003-2004	9.8	7.5	5.6
2004-2005	10.5	8.1	5.6
2005-2006	10.6	8.5	5.7
2006-2007	10.8	8.5	6.1
2007-2008	10.8	8.2	6.3
2009-2010	11.2	8.6	6.3
2010-2011	11.0	8.7	6.4
Source: Selected Educational Statistics, MHRD, Govt. of India, 2010-11			

Appendix – VII

Trends in Enterprise Ownership and Employment by Caste Category, 1990- 2005				
Year	ST		Non SC/ST (Other)	
	Enterprise ownership	Employment	Enterprise ownership	Employment
1990	2.6	2.0	87.5	90.6
1998	4.2	3.8	87.3	89.4
2005	3.7	3.4	86.4	88.5
Source: Economic Censuses of 1990, 1998 and 2005				

[We thankfully acknowledge the help and assistance of Dr. Anindita Bhoumik and Dr. Harekrishna Jana to complete this paper.]

Works Cited:

Acharya, S. S. (2010). Caste Pattern of Discrimionation in Rural Public Health Care Services. In S. Thorat, & K. S. Newman (Eds.), *Blocked by Caste: Economic Discrimination in Modern India* (pp. 208 - 229). New Delhi: Oxford University Press.

Akerlof, G. (1976). The Economics of Caste, the Rat Race and Other Woeful Tales. *Quarterly Journal of Economics, XC*(no 4), 599 - 617.

Ambedkar, B. R. (1987a). Philosophy of Hinduism. In V. Moon (Ed.), *Dr. Babasaheb Ambedkar: Writings and Speeches* (Vol. 3, pp. 1 - 94). Mumbai: Education Department, Govt. of Maharastra.

Bamshad, M., & al., e. (2001, May 8). *Genetic Evidence on the Origins of Indian Caste Populations*. Retrieved May 7, 2017, from Genome Research: www.genome.org

Barooah, V. K. (2010). Inequality in Health Outcomes in India: The Role of Caste and Religeon. In S. Thorat, & K. S. Newman (Eds.), *Blocked by Caste: Economic Discrimination in Modern India* (pp. 179 - 207). New Delhi: Oxford University Press.

Bhalla, A., & Lapeyere, F. (1997). 'Social Exclusion: Towards an Analytical and Operational Framework'. *Development and Change, 28*(2), 413 - 434.

Bhandari, D., Murthy, C., & Pal, S. (1996). Genetic Algorithm with Elitist Model and its Convergence. *International Journal of patttern Recognation and Artificial Intelligence10, No. 06*, 731-747.

Borgatti, S. P., Everett, M. G., & Johnson, J. C. (2013). *Analyzing Social Network.* London: SAGE Publications Ltd.

Borgatti, S. P., Mehra, A., Brass, D. J., & Labianca, G. (2009). Networl analysis in the Social Sciences. *SCIENCE*, 892-895.

Burchardt, T. (1999). *The Evolution of Disability Benefits in the UK: Re-weighting the Basket* (Vol. CASE paper 26). London: London School of Economics.

Bureau of Applied Economics and Statistics, Govt. of West Bengal. (2009). *Statistical Abstract West Bengal 2008.* Kolkata: Bureau of Applied Economics and Statistics, Govt. of West Bengal.

Buvinic, M. (2005). 'Social Inclusion in Latin America'. In M. Buvinic, J. Mazza, M. Buvinic, & J. Mazza (Eds.), *Social Exclusion and Economic Development* (pp. 3 -32). Baltimore: The Johns Hopkins University Press.

Ceylan, H. a. (2004). Traffic signal timing optimisation based on genetic algorithm approach, including drivers' routing. *Transportation Research Part B: Methodological, 38*(4), 329--342.

Chowdhury, I. U. (2009). *Caste-based Discrimination in South Asia: A Study of Bangladesh.* New Delhi: Indian Institute of Dalit Studies.

Das, S. (2010). Caste, Ethnicity, and Religeon: Linkages with Employment and Poverty. In S. Thorat, & K. S. Newman (Eds.), *Blocked by Caste: Economic Discrimination in Modern India* (pp. 354 - 367). New Delhi: Oxford University Press.

Deotale, N. (2014, June). Automated Train using Genetic Algorithm for Railway Scheduling with GPS. *International Journal of Current Engineering and Technology, 4*(3), 1553-1555.

Desai, S., Adams, C. D., & Dubey, A. (2010). Segmented Schooling: Inequality in Primary Education. In S. Thorat, & K. S. Newman (Eds.), *Blocked by Caste: Economic Discrimination in Modern india* (pp. 230 - 252). New Delhi: Oxford University Press.

Deshpande, A., & Newman, K. S. (2010). Where the Path Leads: The Role of Caste in Post-university Employment Expectations. In S. Thorat, & K. S. Newman (Eds.), *Blocked by Caste: Economic Discrimination in Modern India* (pp. 88 -122). New Delhi: Oxford University Press.

Duffy, K. (1997). *Review of the International Dimension of the Thematic Priority on Social Integration and Exclusion.* Swindon: ESRC.

Dutt, R. C. (1928). From the Earliest Times to the Sixth Century B.C. In A. V. Jackson (Ed.), *History of India.* London: The Grolier Society.

Eaton, R. M. (1997). *The Rise of Islam and the Bengal Frontier, 1204 - 1760.* New Delhi: Oxford University Press.

Figueiredo, C. G. (1997). *Social Exclusion and Anti-Poverty Policy: A Debate.* Geneva: ILO.

Haupt, S. E. (2008). *Artificial intelligence methods in the environmental sciences.* Springer Science & Business Media.

Healy, E., Arunachalam, D., & Mizukami, T. (2016). Social Cohesion and the Challenge of Globalization. In E. Healy, D. Arunachalam, & T. Mizukami, *Creating Social Cohesion in an Interdependent World* (pp. 03-32). LondonPalgrave Macmillan.

Irmak, F., & Guclu, I. (2012). Revisiting Marx and Dahrendorf on social exclusion and inclusion. *International Journal of Human Sciences, 9*(2).

Jodhka, S. S., & Newman, K. S. (2010). In the Name of Globalisation: Meritocrity, Productivity, and the Hidden Language of Caste. In S. Thorat, & K. S. Newman (Eds.), *Blocked by Caste: Economic Discrimination in Modern India* (pp. 52 -87). New Delhi: Oxford University Press.

Krishna, K., & Murty, M. N. (June, 1999). Genetic K-Means Algorithm. *IEEE TRANSACTIONS ON SYSTEMS, MAN, AND CYBERNETICS—PART B: CYBERNETICS*, 433-439.

Lal, D. (1988). Hindu Equilibrium. In D. lal, *Cultural Stability and Economic Stagnation* (Vol. I). Oxford: Clarendon Press.

Larget, B., & Simon, D. L. (1999). Markov Chain Monte Carlo Algorithms for the Bayesian Analysis of Phylogenetic Trees. *Molecular biology and evolution*, 750-759.

Lenoir, R. (1974). *Les Exclus.* paris: Seuil.

Leung, Y., & Gao, Y. (1997). Degree of Population Diversity—A Perspective on Premature Convergence in Genetic Algorithms and its Markov Chain Analysis. *IEEE TRANSACTIONS ON NEURAL NETWORKS*, 1165-1176.

Li, W. (2004). Using genetic algorithm for network intrusion detection. *Proceedings of the United States Department of Energy Cyber Security Group*, 1--8.

Lozano, J., Larranaga, P., Grana, M., & Albizuri, F. (1999). Genetic Algorithm: bridging the convergence gap. *Theoritical Computer Science*, 11-22.

Madheswaran, S., & Attewell, P. (2010). Wage and Job Discrimination in the Indian Labour Market. In *Blocked by Caste: Economic Discrimination in Modern India* (pp. 123 - 147). New Delhi: Oxford University Press.

Marmelstein, R. (1997). Application of Genetic Algorithms to Data Mining. *Proceedings of 8th Midwest Artificial Intelligence and Cognitive Science Conference* (pp. 58-65). AAAI.

Marx, K., & Engels, F. (1845). *The German Ideology.* Retrieved August 16, 2017, from Marxists Internet Archive: https://www.marxists.org/archive/marx/works/1845/german-ideology/

Milgram, S., & Travers, J. (1967). An Experimental Study of the Small World Problem. *Psychology Today, 32*(4), 425-443.

Nambissan, G. B. (2010). Exclusion and Discrimination in Schools: Experiences of Dalit Children. In S. Thorat, & K. S. Newman (Eds.), *Blocked by Caste: Economic Discrimination in Modern India* (pp. 253 - 286). New Delhi: Oxford University Press.

Oh, B., & et.al. (2010). Genetic Algorithm-based Dynamic Vehicle Route Search using Car-to-Car Communication. *Advances in Electrical and Computer Engineering*, 81-86.

Parkin, M. (1979). *Marxism and Class Theory: A Bourgeois Critique.* London: Tavistock.

Ritzen, J., & Woolcock, M. (2000). Social Cohesion, Public Policy and Economic Growth: Implications for Countries in Transition. Paris. Retrieved June 30, 2018, from http://documents.worldbank.org/curated/en/914451468781802758/820140748_200404140033848/additional/28741.pdf

Scoville, J. G. (1991). 'Towards a Model of Caste Economy'. In J. G. Sciville (Ed.), *Status Influence in Third World Labour Markets: Caste, Gender and Custom* (pp. 386 - 93). New York: Walter de Gruyter.

Sen, A. (2000). 'Social Exclusion: Concept, Application, and Scrutiny'. *Working Paper, Social Development Paper No. 1, June.* Bangkok: Asian Development Bank.

Sengupta, S. (2015, April). "A New Generation of Optimization process using Genetic Algorithm. *International Journal of Innovative Technology & Adaptive Managemen, 2*(7).

Sharma, A. (1979). *Thresholds in Hindu - Buddhist Studies.* Calcutta: Minerva Associates (Publications) Pvt. Ltd.

Sonowal, C. J. (2008). *Studies on Tribes and Tribals.* Retrieved March 14, 2016, from http://www.krepublishers.com/02-Journals/T%20&%20T/T%20&%20T-06-0-000-000-2008-Web/T%20&%20T-06-2-000-000-2008-Abst-PDF/T%20&%20T-06-2-123-08-162-Sonowal-C-J/T&T-06-2-123-08-162-Sonowal-C-J-Tt.pdf

Su, R. e. (2014). Optimization of High-Speed Train Control Strategy for Traction Energy Saving Using an Improved Genetic Algorithm. *Journal of Applied Mathematics, 2014*, 7.

Thapar, R. (1966). *A History of India* (Vol. I). London: Penguin Books.

Thapar, R. (2003). *The Penguin History of Early India : From the origines to AD 1300.* New Delhi: Penguin Books.

The Task Force on Higher Education in Developing Countries. (2000). *Higher Education in Developing Countries: Peril and Promise.* Washington DC: The World Bank.

Thorat, S., & Attewell, P. (2010). The Legacy of Social Exclusion: A Correspondence Study of Job Discrimination in India's Urban Private Sector. In S. Thorat, & K. S. Newman (Eds.), *Blocked by Caste: Economic Discrimination in Modern India* (pp. 35 - 51). New Delhi: Oxford University Press.

Thorat, S., & Newman, K. S. (2010). Economic Discrimination: Concept, Consequences and Remedies. In S. Thorat, & K. S. Newman (Eds.), *Blocked by Caste: Economic Discrimination in Modern India.* New Delhi: Oxford University Press.

Thorat, S., Kundu, D., & Sadana, N. (2010). Caste Ownership of Private Enterprises: Consequences of Denial of Property Rights. In S. Thorat, & K. S. Newman (Eds.), *Blocked by Caste:Economic Discrimination in Modern India* (pp. 311 - 327). New Delhi: Oxford University Press.

Thorat, S., Mahamallik, M., & Sadana, N. (2010). Caste System and Pattern of Discrimination in Rural Markets. In S. Thorat, & K. S. Newman (Eds.), *Blocked by Caste: Economic Discrimination in Modern India* (pp. 148 -176). New Delhi: Oxford University Press.

Xu, J. a. (2002). An EHW architecture for real-time GPS attitude determination based on parallel genetic algorithm. In *Evolvable Hardware, 2002. Proceedings. NASA/DoD Conference on* (pp. 133--141). IEEE.

Yin, Y. (2000). Genetic-algorithms-based approach for bilevel programming models. *Journal of Transportation Engineering, 126*(2), 115--120.