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Research Article

Estimation of Production functions for Jobshop Scheduling problem using Genetic Algorithm

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Abstract

A main characteristic of a job shop production system is that various products are manufactured on same machines; the processing times will also vary. The manufacturing lead time is mainly defined by the waiting times in front of the work centers and the processing times at the machines. Due to the strong varying routings and occupation times, the number of orders arriving at the units strongly varies per time unit (day or week). So when it is chosen to measure the number of produced parts in a period, it will be difficult to define a standard or desired level of production and also it will be difficult to compare the performed productivity between periods. This is because each order has different processing times and thus a different total lead time in comparison with other orders. The incoming orders do vary in amount, design, urgency and processing time, which result in a very complex material flow control. It is very hard to define how the different orders will be distributed among the machines in next periods. Machine utilization and variation of the orders will generally lead to long waiting times for orders on the floor. A difficulty is the production speed of a work centre is dependent of another unit. In fact, the amount of work to be done by a unit varies a lot per period. This unknown distribution and machine utilization leads to a difficult determination of productivity standards and goals for the coming periods and the control on productivity over time. Hence an attempt is made in the following paper to estimate the production functions of jobshop scheduling problem applicable to glassware manufacturing unit and production functions with operating characteristics are presented. The near optimal solution to JSSP is obtained by genetic algorithm and productivity is estimated and presented.

Keywords: *Job shop production system, Genetic Algorithm etc.*

Productivity and jobshop Problem

There are many subsystems of production/ manufacturing system such as product Design, process planning, work / job scheduling, order release, inventory, quality control and verification. Productivity depends not only on functions of manufacturing system, but also on the factors influencing the system. Productivity needs to be viewed as one of a group of performance criteria against which managers can assess, evaluate and base decisions regarding the organizational systems they are managing. Production function approach is usually used by economists to formulate some general mathematical expression for output as a function of input factors. In the present paper an attempt is made to minimize the flow time of jobshop (Glassware manufacturing unit) and production functions interms of labour and capital are evaluated. Total flow time indicates the amount of time job j spends in the system. It is a measure, which indicates the waiting time of jobs in a system, and it gives some idea about in-process inventory due to a schedule. Cobb-Douglas model was applied to data on output and input for estimating the CD function.

The Cobb-Douglas production function can be expressed as $Y = A * L^a * K^{(1-a)}$, Where: Y is real output , A is a scalar , L is a measure of the flow of labor input , K is a measure of the flow of capital input, a is a fractional exponent, $0 < a < 1$, representing labor's share of output. A more general form of the function would be $Y = A * L^a * K^b * T^c$ where T is a third input (land, energy); for Cobb-Douglas, the fractional exponents sum is unity. Capital investment in case of jobshop is measured interms of job completion time which in turn provides time of consumption of LPG and electricity, which are capital overheads apart from the raw material and labour costs.

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Jobshop Problem and formulation

A Job Shop scheduling problem consists of a finite set J of n jobs $\{J_i\}$ i = 1 to n to be processed on a finite set M of m machines$\{M_k\}$ k =1 to m. Each job J_i must be processed on every machine and consists of a chain of operations O_{i1}, O_{i2}, ….. , O_{im} which have to be scheduled in a predetermined given order (precedence constraint). There are N operations in total, O_{ik} is the operation of job J_i which has to be processed on machine M_k for an uninterrupted processing time period tik and no operation may be pre-empted. Each job has its own individual flow pattern through the machines, which is independent of the other jobs. Each machine can process only one job and each job can be processed by only one machine at a time (capacity constraints). The duration in which all operations for all jobs are completed is referred to as Makespan and the amount of time each job spends in the system is known as Flow Time. Many jobs in industry and work floors require completing a collection of tasks while satisfying temporal and resource constraints. Temporal constraints say that some tasks have to be finished before others can be started; resource constraints say that two tasks requiring the same resource cannot be done simultaneously (e.g., the same machine cannot do two tasks at once). The objective is to create a schedule specifying when each task is being processed and what resources it will use which satisfy all the constraints while taking as little overall time as possible. This is the Job- Shop- Schedule Problem. The complexity of attaining near optimal solution increases with increase in size of the problem as search space increases as shown in figure1.

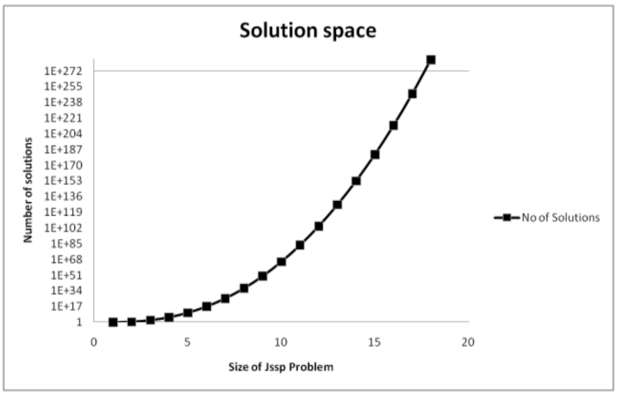


Figure 1: Complexity of JSSP

In a classical Job Shop problem, n jobs are processed on m machines, in which the main assumptions are as follows:

1. All jobs are available at time zero.
2. Each job is processed by one machine at a time
3. An operation is not preemptable.
4. A machine can process only one operation at a time
5. The processing times are fixed and sequence independent.
6. The processing order of each job is given and fixed.

Objective Function: Minimization of Total Flow time = $\sum_{i=1}^{n} Fi$ **; Subjected to**: Ts- Te ≤pi, Ts ≥ 0, Where Ts = Start Time of the job, Te = End Time of the Job, pi = Duration of job i. (Processing Time).

A bulk of optimization approaches are based on Mathematical optimization which consist of either linear or mixed integer programming. Mathematical optimization techniques have the ability to incorporate a number of design related information in the model thus formulating the problem accurately. Therefore they are very attractive as far as formulation of the problem is concerned. But because they consume a lot of time in finding out solutions, their use is limited to small size problems only. The approximation based approaches are broadly classified as tailored algorithms and general algorithms. Tailored algorithms mainly consist of different types of dispatching rules and heuristics, whereas general algorithms include techniques that are based on local search and AI. The application of AI tools (GA) is considered as a comparatively recent development in this area. GA has been extensively used in solving the JSSP. Hence Solving JSSP with genetic algorithm is extensively studied in this paper.

Genetic algorithm for solving JSSP

Genetic Algorithms use a vocabulary borrowed from natural genetics. We have a set of individuals called population. An individual has two representations called phenotype and genotype. The phenotype represents a potential solution to the problem to be optimized in a straightforward way used in the original formulation of the problem. The genotype, on the other hand, gives an encoded representation of a potential solution by the form of a chromosome. A chromosome is made of genes arranged in linear succession and every gene controls the inheritance of one or several characters or features. Each individual has its fitness, which measures how suitable is the individual for the local environment. The Darwinian Theory tells us that among individuals in a population, the one that is the most suitable for the local environment is most likely to survive to have greater numbers of offspring. This is called a rule of survival of the fittest. The objective function f of the target optimization problem plays the role of an environment, therefore, the fitness of an individual F measures how good is the corresponding potential solution in terms of the original optimization criteria. The implementation of Genetic Algorithm for jobshop scheduling is indicated in the figure 2.

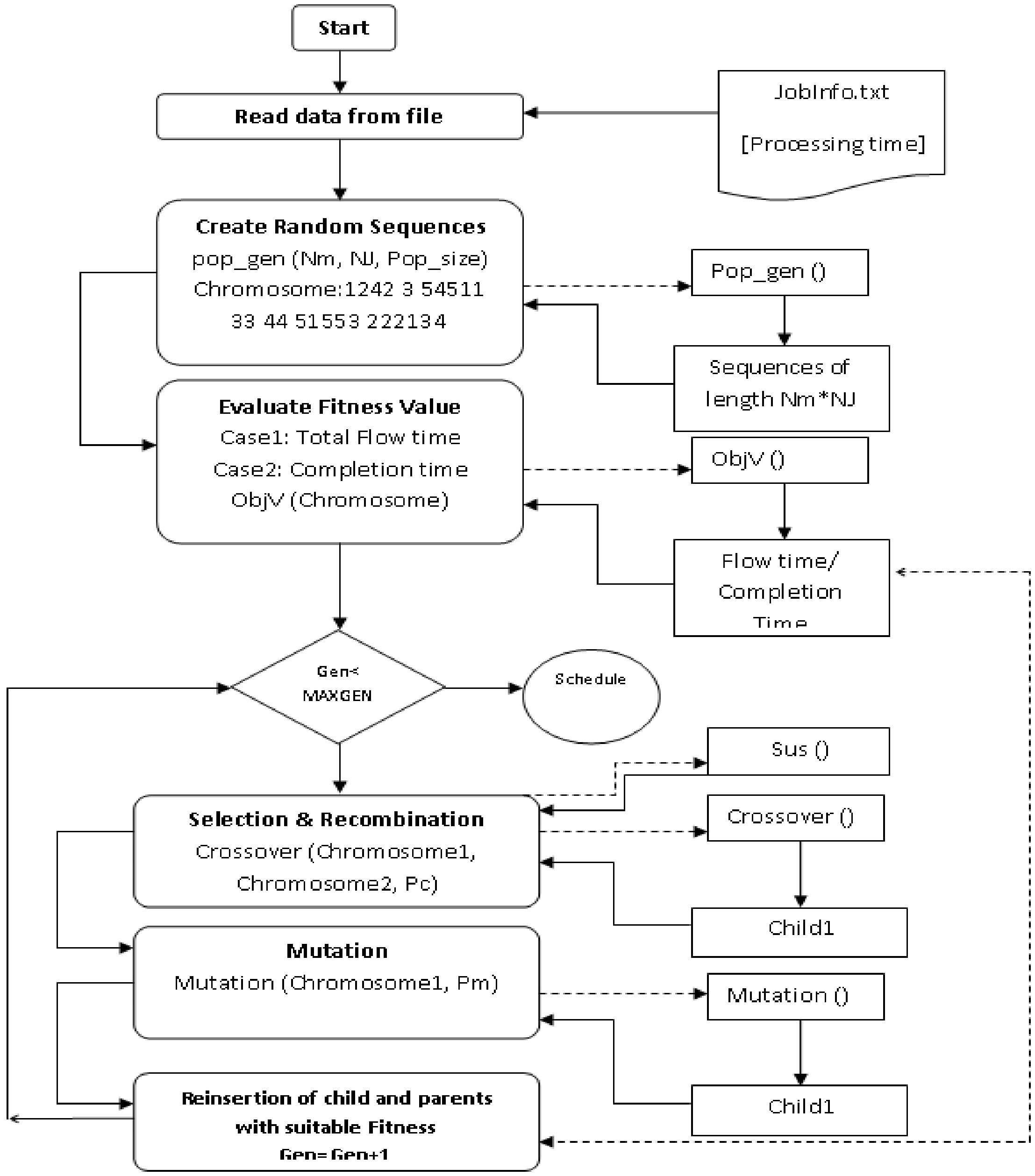


Figure 2: Genetic Algorithm for JSSP

2	**1**	**4**	**2**	**2**	**3**	**5**	**1**	**2**	**5**	**3**	**4**	**2**	**5**	**5**	**4**	**3**	**1**	**1**	**3**	**5**	**3**	**4**	**4**	**1**

The permutation based population generator is developed which will produce random population. Each sequence is a random sequence of operations on the machines. The population is generated based on random number generator with permutation encoding. If the number of machines is 5 and numbers of jobs are 5 with population size of 50, then 50 sequences of length 5x5=25 numbers are generated randomly. 1111122222333334444455555 is a sample format of initial population. The advantage of such a population is that all ones represent the job1 and their occurrence in the sequence indicates the assignment on the Machines subjected to their Precedence constraints. The code is developed using MATLAB software and it is tested with various benchmark problems for the following inputs. The chromosome represents an order job based type in which, for 5x5 Jssp, 25 numbers are indicated as shown below figure 2.

2→ job2 and its first occurrence indicate the assignment of job on machine M3. This assignment is as per precedence constraints. The next number is 1→ job1 and it is assigned to M3. 4→J4 and it is assigned on M3.2→job2 and it is assigned to M1 and again occurrence of 2 indicates same job, but it has to be processed on M2, and so on. Hence, the precedence constraints are taken care while assigning the job on to machine in a particular sequence. The assignment of the jobs on to the machines is indicated in the figure # shown below. In each sequence the same procedure is followed.

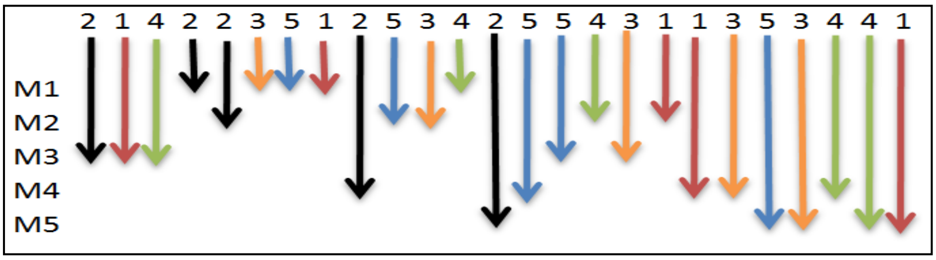
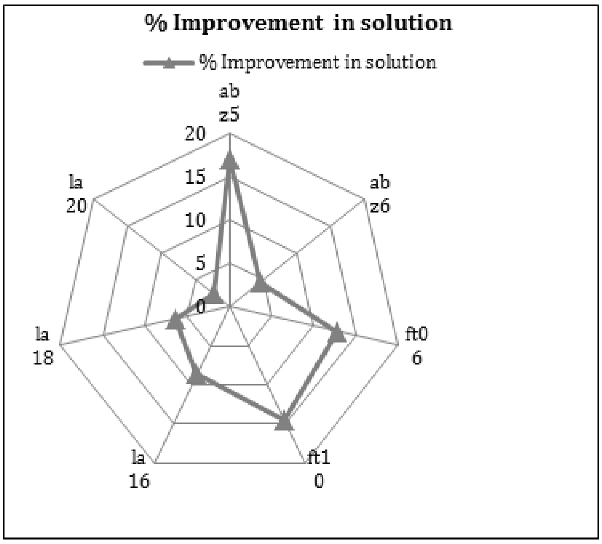


Table 1: Processing times and Routing Matrix

	01	02	03	04	05	Routing Matrix				
J1	1	2	4	5	4	M3	M1	M2	M4	M5
J2	1	2	5	8	5	M3	M1	M2	M4	M5
J3	1	2	10	4	2	M1	M2	M3	M4	M5
J4	2	2	6	3	1	M3	M1	M2	M4	M5
J5	1	2	4	2	2	M1	M2	M4	M3	M5



No.of.Machines	10
No .of Jobs	10
No. of. Variables (NVARS)	100
Population Size	200
Max Generations	500
Generation Gap	0.9
Crossover probability	0.9
Mutation probability	0.08
Migration Rate	0.9

Table 2: Comparison of solution with Bench mark problems

Problem	Best Solution	Best Solution with GA	% Improvement in solution
abz5	1234	1023	17.09886548
abz6	943	901	4.453870626
ft06	55	48	12.72727273
ft10	930	795	14.51612903
la16	945	863	8.677248677
la18	848	793	6.485849057
la20	902	881	2.328159645

Results

The developed code is tested for bench mark problems and improvement is solution is observed when genetic algorithm is used for scheduling jobshop problems of size 10x10 , 10x15, 20x20. It is observed that 17% is improved for Abz5 problem.

The crossover, mutation probability and population size are estimated by conducting various numerical experiments and obtained as shown in figure 4.

The crossover probability is estimated at 0.65, with mutation probability of 0.08 and population size of 175 with maximum number of generations equal to 1000. The estimated values of crossover probability and mutation probability, population size are tested with measure of similarity and Eucledian distances are measured and observed that re-inserted population with genetic operations are different from initial population. A specified set of jobs are chosen from the given set of orders. 5 jobs are selected and their processing times with routing matrix are given in the table shown below. The genetic parameters are applied to the data obtained for a sample lot1. The figure 4 indicates the non dominant solution set of solutions with minimum flow time of 133 minutes for 5x5 JSSP.

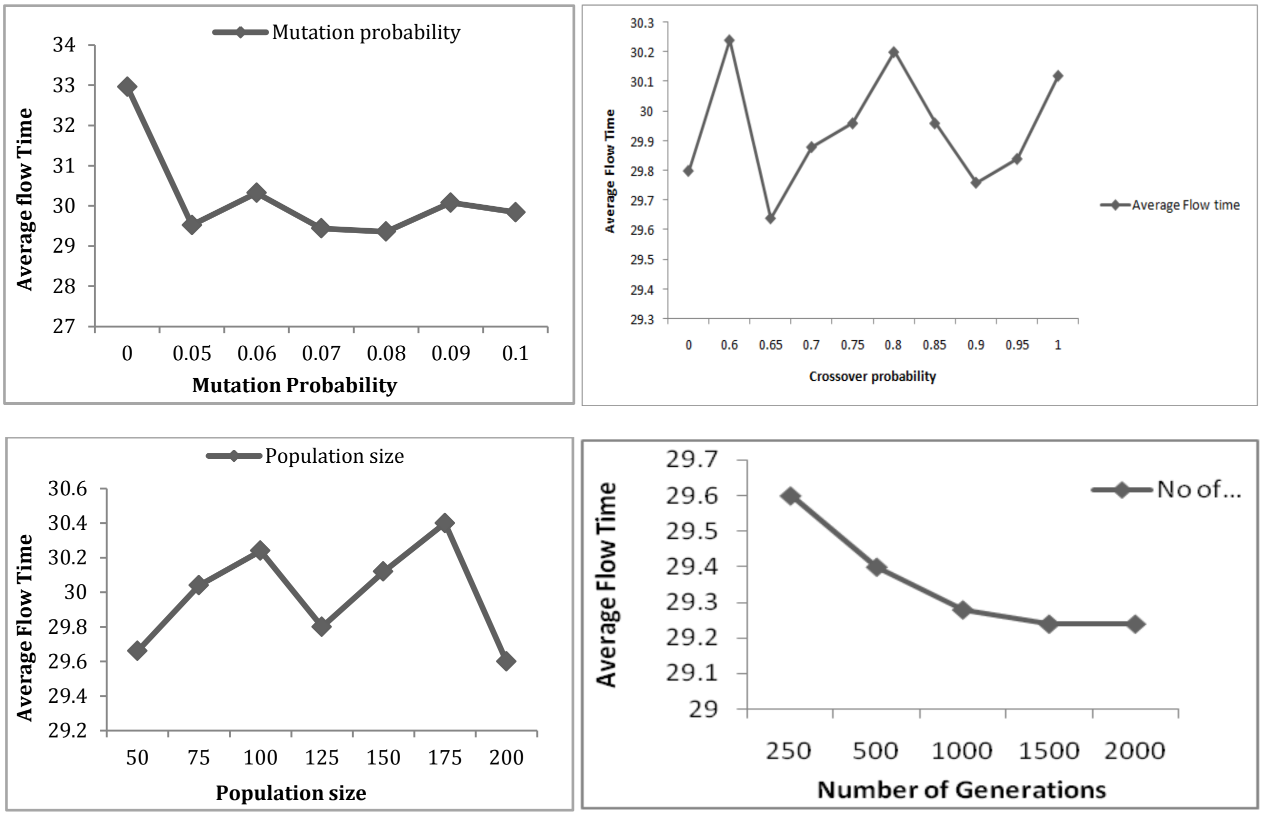


Figure 3: Crossover, mutation probability, Population size and Number of generations

	Processing times (In Minutes)						Routing Matrix				
	ID	O1	O2	O3	O4	O5					
J1	RB119	1	2	3	4	3	M3	M1	M2	M4	M5
J2	RB121	1	2	4	5	4	M3	M1	M2	M4	M5
J3	CH66	1	2	10	4	2	M1	M2	M3	M4	M5
J4	GM-95	1	2	4	3	2	M3	M4	M1	M2	M5
J5	ADP2	2	6	2	3	1	M3	M1	M2	M4	M5

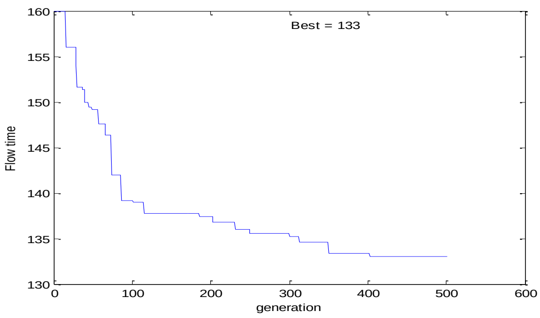


Figure 4: Day 1

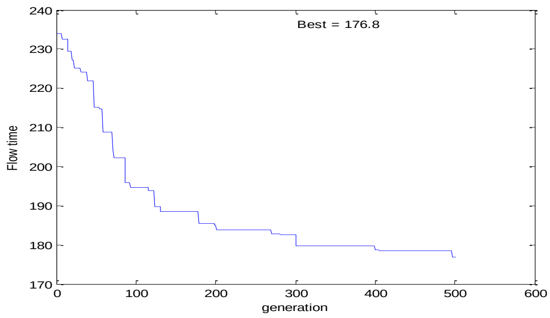


Figure 6: Day 3

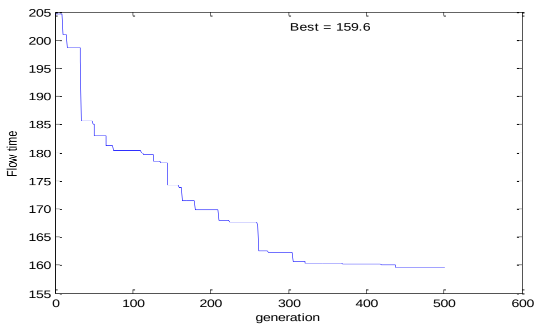


Figure 5: Day 2

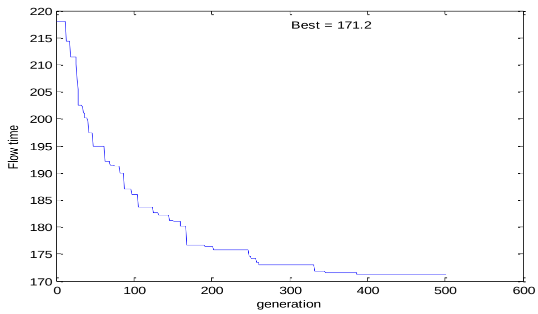


Figure 7: Day 4

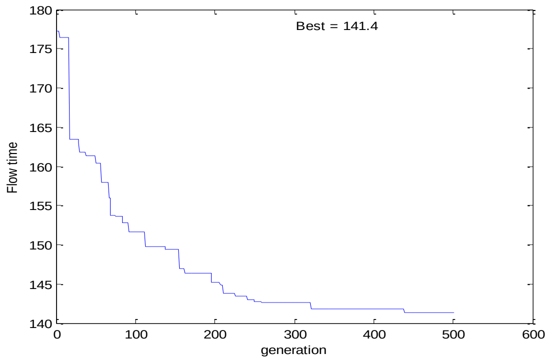


Figure 8: Day 5

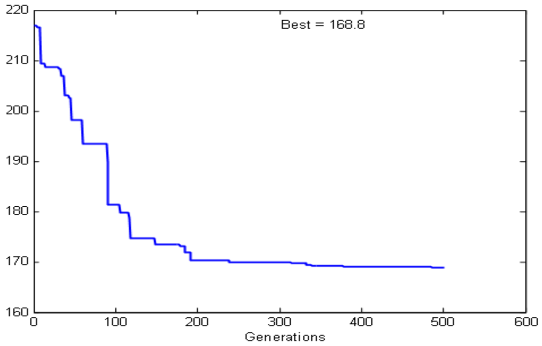
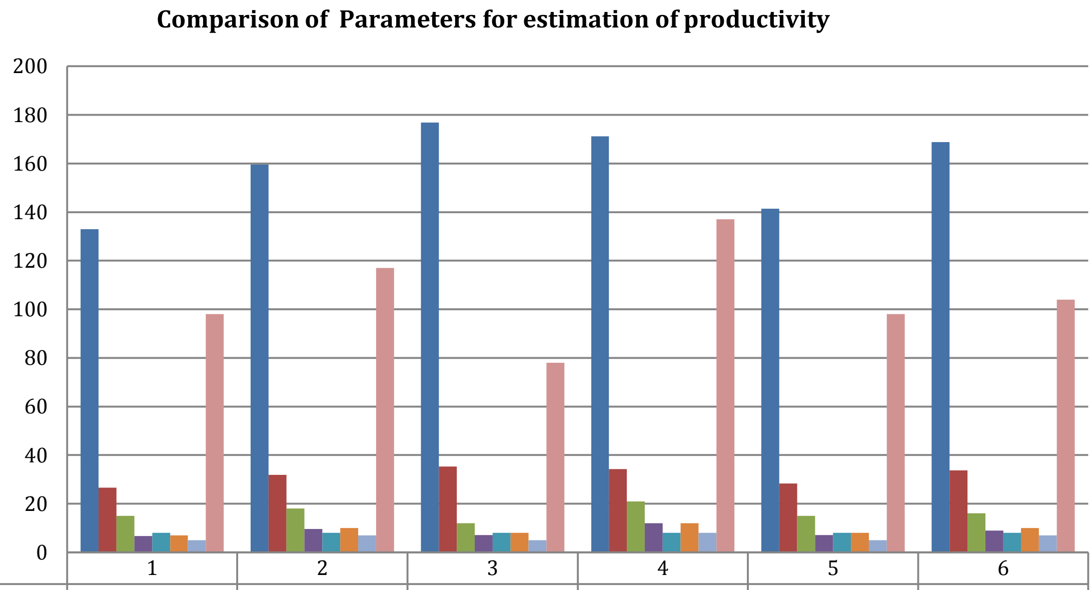


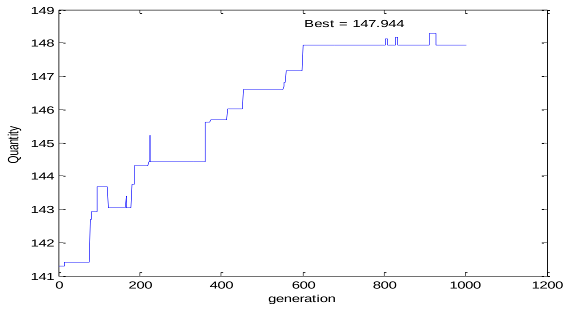
Figure 9: Day 6

Similarly such lots are randomly taken for a week at Glass ware manufacturing unit and average flow time is estimated for the lot of 5 jobs to be processed on 5 machines. The productivity of the jobshop is estimated by finding the minimum flow time for six samples of jobs over a period of 7 days. The glass ware manufacturing involves consumption of LPG (Liquefied Petroleum gas) and electricity for making the components. LPG is used to heat the glassware locally and machine it to the required shape. Hence job completion time gives an estimate of consumption of LPG and electricity. As per the industrial observation made at MLGW Pvt Ltd, Hyderabad, it is observed that total estimate of inputs are raw material cost, electricity consumption in Hrs and machine utilization time and machine idle time, with LPG consumption. It is observed that an industrial correction factor of 2.3 multiplied by total flow time gives an estimate of all overheads in terms of machine- job hours. The Machine -job hours (Capital) is related to man hours (skilled Labour). The Parameters of productivity estimates is indicated in figure.



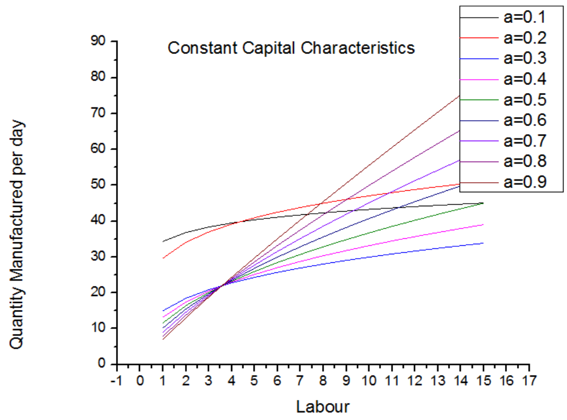
	1	2	3	4	5	6
Flow Time	133	159.6	176.8	171.2	141.4	168.8
AFT	26.6	31.92	35.36	34.24	28.28	33.76
Lots	15	18	12	21	15	16
Total Time	6.65	9.576	7.072	11.984	7.07	9.002666667
Labour	8	8	8	8	8	8
Electricity Consumption	7	10	8	12	8	10
LPG	5	7	5	8	5	7
Raw Material	98	117	78	137	98	104

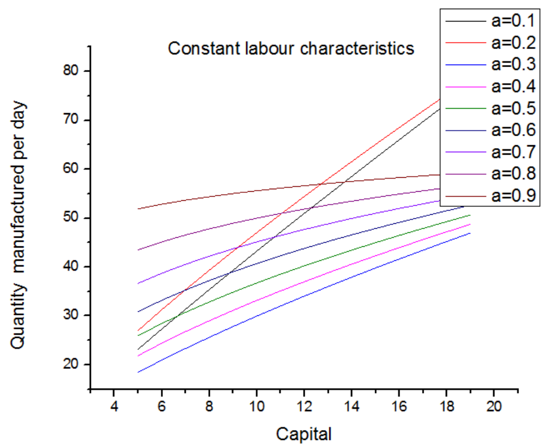
Figure 10: Parameters of production estimates



The genetic algorithm is re-implemented for estimation of productivity with maximization objective. The estimated job completion time is related to capital investment and labour, quantity relation is obtained by cobb-Douglas production function approach. The following production functions are obtained for different indices of capital and labour and presented below. The operating characteristic curves are also indicated.

a	b	Production function
0.1	0.9	$Q=4.328*L^{0.1}*K^{0.9}$.
0.2	0.8	$Q=4.707*L^{0.2}*K^{0.8}$.
0.3	0.7	$Q=2.998*L^{0.3}*K^{0.7}$.
0.4	0.6	$Q=3.318*L^{0.4}*K^{0.6}$.
0.5	0.5	$Q= 3.675*L^{0.5}*K^{0.5}$
0.6	0.4	$Q= 4.073*L^{0.6}*K^{0.4}$
0.7	0.3	$Q=4.515*L^{0.7}*K^{0.3}$
0.8	0.2	$Q=5.00*L^{0.8}*K^{0.2}$
0.9	0.1	$Q=5.562*L^{0.7}*K^{0.3}$





It is observed that for an optimum size of 4 labours, with constant capital, the quantity of goods obtained is same. After a size of 4 workers on floor, and same capital investment the quantity of goods obtained is varied. The minimum size of labour at a constant capital is 4 and to obtain better productivity, the labour quantity should be more than 4. It is observed that for 4 number of labour, with a capital of 10 hours electricity and gas consumption and utilization of machines with skilled labour, the minimum number of quantities that can be produced per day is estimated to be about 24 in number.

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