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Performance improvement through automation: A case of Indian brick industry

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***Abstract**:*

Indian brick industry, the second largest brick industry in world generating an annual turnover of about Rs.140 billion is running as an unorganized small sector throughout the country and is the only industry where modernization has not taken place. Numerous efforts have been taken up to improve the kiln design for increasing the productivity but efforts to mechanize the system as a whole as a mean to increase the productivity has been scarce. This paper aims at studying the effect of lack of automation of the entire brick manufacturing system on the productivity of the system. The study is based on data collected from 4 different firms located in Bihar and which are typical in structure as being mostly followed all over the country. The data collected regarding various aspects of the system has been used to study the effect of lack of automation on total loss incurred and establish a mathematical relation between the total loss and loss due to lack of automation using statistical tools. The result indicates that automating even few of selected processes of brick manufacturing can bring about considerable decrease in total cost of manufacturing and also increase the efficiency and decrease seasonal dependency of the industry. .

Keywords

Brick Manufacturing, Statistical Tools, Automation

1. Introduction

Expanding construction industry and increasing demand for quality and strength of constructions the need to enhance the quality and quantity of bricks produced by each manufacturing unit has also arise. The brick manufacturing process followed in India still uses many obsolete practices. Hence the need is not to increase the size or number of the manufacturing units but to remove the malpractices in brick industry and reduce the ineffectiveness and wastages in the process [1],[3].

Many efforts have been taken to improve the design of the kiln in order to reduce the losses due to improper heating of the green brick but, losses due to manual operations and lack of automation, an equally inefficient aspect causing even higher losses than the losses in the kiln itself has always been neglected. This study is aimed at establishing a mathematical

proof to the fact that a greater emphasis on mechanizing the processes of brick manufacturing system can reduce the total losses and total cost of production by a fat count.

Several problems exist in the most widely used brick manufacturing system in India which can be attributed to flaws in manual operations or in other words to lack of automation. The study highlights the contribution of such obsolete practices to the losses and wastages occurring in the process and establishes a relation between the two for a clear visualization. It also draws significant conclusion about what minimal sub processes of the system should be automated to bring an appreciable improvement in the efficiency of entire system.

The paper is organized as follows. In section 2 a review of previous work and existing brick manufacturing system is presented. Section 3 describes the data collection and organization methods as employed for study. Section 4 represents the statistical analysis of the data collected. Section 5 discusses the results of statistical analysis. Conclusions are given in section 6.

2. Literature review

It is estimated that presently there are at least 1,50,000 brick fields in India, each field manufacturing between 100,000 and 20 million bricks per year. The industry employs low-technology, manual and inefficient methods like hand-molding, sun-drying and open clamp burning. The industry is not 'organized' and very few fields have officially registered themselves as small-scale industrial units. On the national level, All India Brick & Tile Manufacturers Federation, New Delhi, looks after interests of the industry in general, and its member units in particular [1]. Brick fields are normally set up on leased-out lands near clay sources. Simple tools like pickaxes, shovels, baskets, etc.; hand carts, screens, moulds, arrangement for storage / pumping of water and workers' makeshift sheds constitute the only fixed investment of a brickfield. Owing to their temporary, low technology and polluting nature, and total absence of professional management (including quality control), these units do not enjoy much respect in the eyes of people and consequently, bricks are not thought of as an 'industrial' product by the common man. Only in South India (and at a few places in the North also), where roof tile plants are very common, similar technology is used for making wire-cut bricks, which command reasonable consumer respect. Silt deposited by rivers, dams, percolation tanks, etc. and / or surface soil excavated

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from barren / uncultivated / hilly lands form the main sources of supply of clay. Coal, coal ash (i.e. coal cinder), wood and many agricultural wastes are used as fuels in the open clamp, where the extent of under / over burnt bricks varies up to 20 %. Barring few mechanized / semi-mechanized units in North and South India, all other units employ piece-rate contract labor to carry out the clay winning / preparation, molding, drying, firing and material handling operations. Molders perform all operations from clay winning / preparation to drying, while 'Firemen' or 'Kiln Contractors' take care of the balance jobs. For this work, molders are paid up to Rs. 150/- per 1000 bricks and firemen up to Rs. 125/- per 1000 full-size bricks. A molder family of 3 to 4 persons - husband, wife and 1 or 2 helping hands - can mould up to 3000 'full size' bricks in a day. However, molder productivity of 1,200 to 1,500 bricks per day is most common. Before the beginning of every season, molders and firemen are 'booked' by paying them hefty advances. As it is evident, the brick industry in India is still very primitive in nature. It is still untouched by the technological developments taking place in and around the world .Due to this the overall output of brick industry is very low, with minimal productivity, accompanied with a lot of wastages. The major cause of ancientness of this industry is 'mechanization phobia', which has arisen due to the techno-commercial failures of a large number of semi-mechanized / mechanized brick plants set up so far. Still the major emphasis of researchers as well as the government is on the kiln design, for instance the recent 'Brick Regulation '96' of the Ministry of Environment & Forests is forcing them to convert their existing clamps / moving chimney kilns into cleaner and more fuel-efficient kilns. The most widely accepted brick manufacturing system in India can be divided into following stages:

1. Preparation of Clay: It is the first phase of the manufacturing process. In this process all the non clay substances like grasses, stones and rocks are first separated from raw material. To make good quality of bricks, the dry lumpy soil has to become smooth i.e. soft moist mixture containing no hard lumps or stone particles. For this the soil is treated in two steps:

Tempering: It is the process of adding adequate quantity of water to clay and allowing it to stand undisturbed for a few days before mixing starts.

Mixing: Here manual mixing takes place in such a way that the mass becomes ready to take any shape we want to give it.

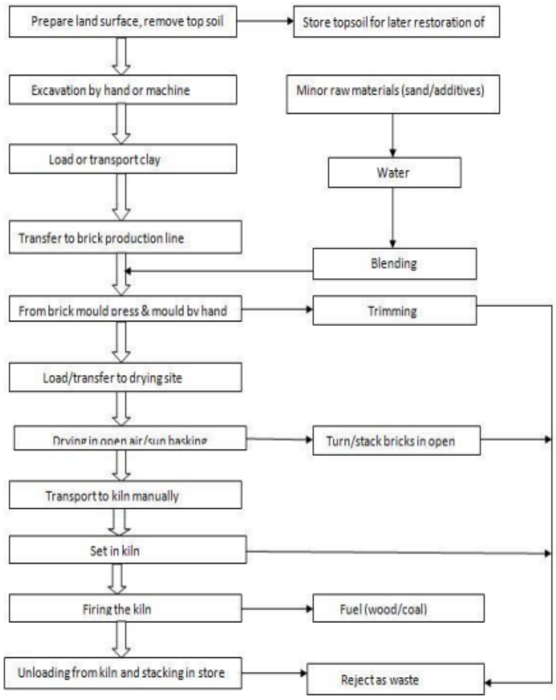

Figure 1. Process Chart (Source – Self)

2.Moulding of Green Bricks: It is mainly done by throwing the ball into sand laced wood mould. The excess raw material is removed with the help of wire to give it an accurate shape. The mould is bumped and dumped by hand to loosen the brick from wooden mould.

3.Drying of Green Bricks: The green bricks are kept in pit for natural drying in open sunlight for 2-3 days depending upon sun's heat. After this they are carried to kiln for firing.

4. Packing (Loading Inside) kiln: The next step is to carry the sun dried brick to green brick storage area and stacking of bricks in required fashion inside the kiln.

5. Firing: It is one of the important process, because after firing only clay mass turns into a hard durable stuff is obtained.

6. Cooling: The hot clay mass is cooled.

7. Unpacking the kiln: The kiln is finally unloaded after the requisite numbers of bricks are baked.

Brick industry plays a pivotal role in both state and national level economy on the basis of its contribution towards developmental work, generation of employment. However, it is still not considered as an 'Organized Sector' of the economy due to following loopholes:

1. *Seasonal dependence*: The heat required for drying of bricks is only provided by the sun's heat. So the whole process becomes too intermittent.

2. *Less eco-friendly*: The huge amount of smoke liberated from the kilns degrades the environment to a huge extent. Also the areas where the kiln or the bhattis are set up tend to increase degradation of land.

3. *Deplorable working condition*: The working conditions are too unhygienic for the workers which reduce their efficiency. Also discrimination based on caste and sex occurs as the female and lower class people are made to do meagre work like carrying materials from one place to other while men and upper class workers do all the technical work irrespective of their expertise.

4. *Much Manual Input*: Due to lack of mechanization in this sector, a lot more human input is required, and as a result the output is not up to the mark.

5. *Outdated Kiln Technology*: The kilns which are used presently not only put pressure on existing raw materials like coal and clay etc. but also contribute a lot to pollution due to inefficient ventilation.

6. *Lot more wastage*: During the process of moulding, a lot of bricks are wasted due to which the whole cost of investment is not realized.

7. *Inefficient Material Handling*: A lot more wastage occurs in taking the raw material from one location to other manually.

8. *Lengthy moulding process*: As it is done manually, so it not only takes a lot of time but also much wastage occurs as the wet sand is too fragile to hold.

9. *Inefficient Binders*: In absence of suitable and strong binders, the chances of unbaked clay mass to get dismantled increases as they are too fragile. Due to this losses occur to this industry.

3. Industrial Survey and Data Collection

To identify the main processes that cause maximum loss in a brick manufacturing system that will form the basis of the project, an industrial survey was conducted. Based on elementary interaction with the workforce of brick manufacturing firm a detailed questionnaire is structured and the feedback of the same as obtained by the workers provided the quantitative data about various aspects of the system. The entire process is divided into eight stages and the losses and cost incurred at each stage is attributed to various factors as shown in the Tables 2 to 9 (Appendix-1). The notations used in organizing the data and statistical analysis are shown in the Table 1 below.

Table 1. Notations

Notation	Meaning
Ci or ΔC	Cost incurred at particular sub process/1000 brick
Li or ΔL	Loss incurred at a particular sub process/1000 brick
C	Total cost of producing 1000 bricks i.e. ΣCi
L or Xi	Total loss incurred in production of 1000 bricks i.e. ΣLi
Yi	Total losses due to lack of automation/flaws in manual operations
σ_X	Standard deviation of x
σ_y	Standard deviation of y
X_{mean} Y_{mean}	Mean value of X Mean value of Y

4. Statistical Analysis

By this stage it was obvious from the data collected that manual operations and lack of automation was the major cause of losses in the brick industry. To establish a mathematical proof for the same and to identify any other factor that was being missed by the individuals' observations but contributed to the losses considerably, following statistical tools were used to accomplish the task.

4.1 Graphical Tool: Various stages are plotted against four parameters individually in order to visualize and identify the major area of losses and maximum inefficiency stages with maximum cost optimization opportunity.

The first graph (Figure 2) between sub stages against ΔC/C is plotted this graph indicates the processes with their relative share in the total expenditure. Higher the value of ΔC/C higher is the contribution to total expenditure. Even slight reduction in the cost of the processes with higher value ofΔC/C can reduce the total cost by considerable amount. The processes in increasing order of the same are as follows.

Drying, clay preparation, digging, storage, arranging, transportation to kiln, framing, firing as evident from the graph that reduction in cost of framing, transportation to kiln and storage can bring about greater reduction in the cost of production.

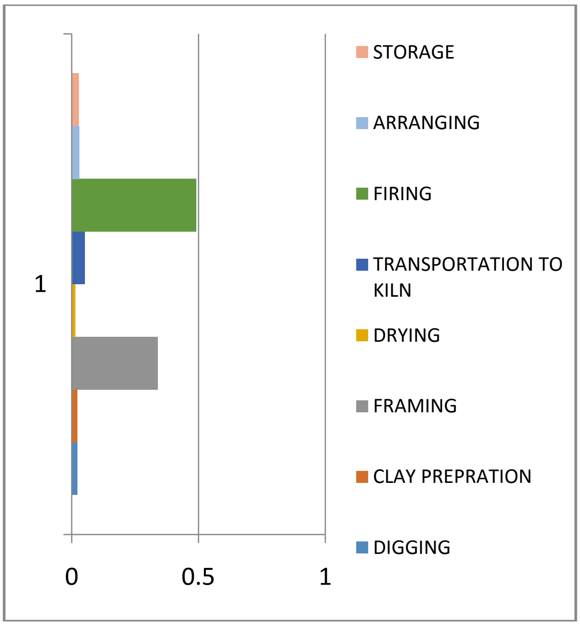

Figure 2. Sub stages vs. ΔC/C (Source-Self)

The second graph (Figure 3) is plotted for sub stages against ΔL/L. This graph is the tool to recognize the areas of maximum loss. It depicts the contribution of each stage to the total loss incurred in the manufacturing process as a whole. Higher the ΔL/L value more is the contribution towards total loss incurred. The process in increasing order of their contribution are as follows- transportation to kiln, framing, drying, storage, firing, arranging.As obvious from the graph (Figure 3) the major portion of loss occurs in arranging process followed by firing process. Since the losses in firing is due to temperature setting which is the design feature of kiln and not automation hence this process will be excluded in the later discussions.

The third graph (Figure 4) is plotted for sub stages against ΔL/ΔC. This graph represents the relative efficiency of each stage. Higher the value of ΔL/ΔC, higher the ineffectiveness of the process i.e. These processes should be replaced by alternative methods as the loss incurred with the given method is considerably high and in some cases even higher as compared to the process cost.

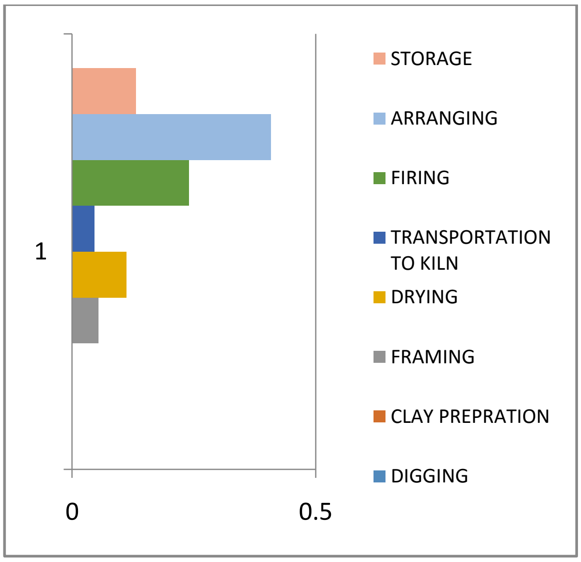

Figure 3. Sub stages vs. ΔL/L (Source-Self)

As observed from the graph (Figure 4) we find the processes with highest inefficiency in increasing order of the same are transportation to kiln, storage, drying, arranging the above mentioned processes have very high inefficiency. The most economic method to minimize these inefficiencies will be to imply other alternatives with which reduction in loss incurred at each stage is comparatively very high as compared to the cost of the process.

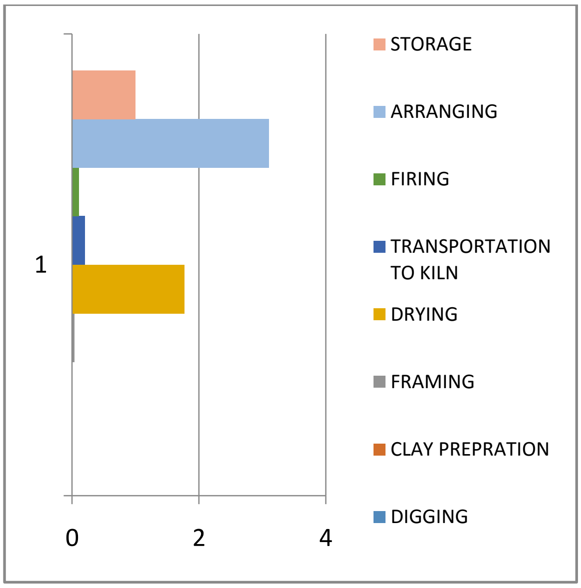

Figure 4. Sub stages vs. ΔL/ΔC (Source-Self)

The fourth graph (Figure 5) is plotted for sub stages against ΔL/C. this graph is the tool to identify the area/process with the highest opportunity of cost minimization. This graph depicts the amount of total expenditure wasted in a process in other words the amount that can be reduced from the expenditure in each step. Higher the ΔL/C value higher is the opportunity of cost reduction. The processes in increasing order of the same are as follows transportation to kiln, framing, drying, storage, firing, arranging identifying the key causes that causes losses in respective processes and eliminating the same can reduce the losses incurred in the manufacturing process.

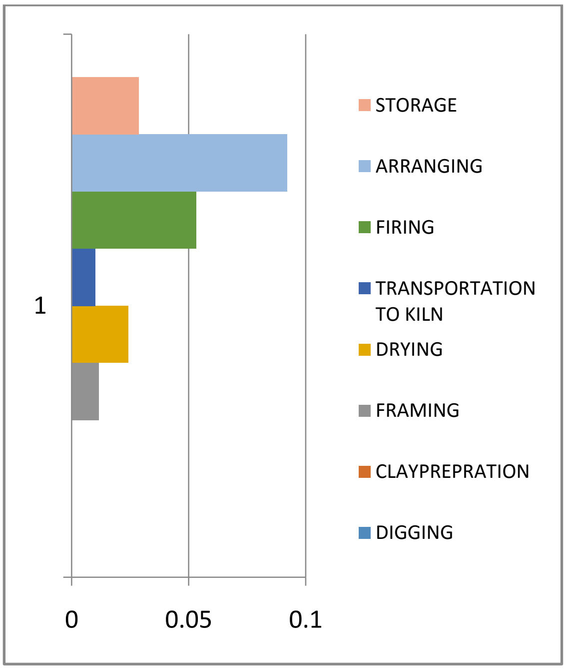

Figure 5. Sub stages vs. ΔL/C (Source-Self)

4.2 Measure of Relationship: With the help of graphical tools, it can be visualized that major portion of losses occur at stages with lack of automation and high manual operation. To understand the nature of relationship between total loss incurred and losses due to lack of operation Karl Pearson's coefficient of correlation is used [2]. Karl Pearson's coefficient of correlation (r) is also known as the product moment correlation coefficient. The value of 'r' lies between ±1. Positive values of r indicate positive correlation between the two variables (i.e., changes in both variables take place in the statement direction), whereas negative values of 'r' indicate negative correlation i.e., changes in the two variables taking place in the opposite directions. A zero value of 'r' indicates that there is no association between the two variables.

$$r = \Sigma\,(X_i\text{-}X_{mean})(Y_i\text{-}Y_{mean})/n\sigma X\sigma Y$$

To work out the correlation factor data was extracted and calculated from the data obtained in earlier stage. The data used to obtain this factor and elementary calculations done are shown in Table 10&11.

Table 10. Standard Deviation

Total Loss (Xi)	Xi^2	Framing	Drying	Arranging	Storage
424.99	180616.5001	22.65	47.22	151.36	38.92
456.83	208693.6489	27.09	46.89	176.8	50.62
474.83	225463.5289	29.23	46.79	192.4	59.55
403.73	162997.9129	22.08	45.1	136.29	62.12
403.2072	162576.0461	26.892	51.34	127.38	69.72
402.8956	162324.8645	22.308	47.18	175.374	50.09
447.418	200182.8667	22.537	44.722	237.24	40.58
445.1525	198160.7483	22.835	51.078	204.43	50.5
412.1676	169882.1305	24.8	46.701	161.376	62.37
404.4734	163598.7313	26.162	50.889	141.806	64.7218
501.3	251301.69	15.96	57.98	229.74	68.94
579.69	336040.4961	28.23	68.64	250.46	71.49
513.26	263435.8276	34	54.37	245.34	74.04
553.19	306019.1761	23.2	53.32	215.1	84.46
610.71	372966.7041	34.77	74.12	286.13	66.02
68.62414697 (Standard Deviation)	**3364260.872 (Sum)**				
468.9229533 (Mean)					

Table 11. Data Calculations

Y_i	Y_i^2	$X_i.Y_i$	X_i-X_{mean}	Y_i-Y_{mean}	A*B
260.15	67678.0225	110561.1	-43.933	-74.146	3257.456218
301.4	90841.96	137688.6	-56.023	-32.896	1842.932608
327.97	107564.3209	155730	5.907	-6.3268	-37.3724076
265.59	70538.0481	107226.7	-65.716	-68.706	4515.083496
275.332	75807.71022	111015.8	65.52	-58.964	-3863.32128
294.952	86996.6823	118834.9	-66.028	39.344	-2597.805632
345.079	119079.5162	154394.6	-21.505	10.782	-231.86691
328.843	108137.7186	146385.3	-23.7705	-5.453	129.6205365
295.247	87170.79101	121691.2	-56.766	-39.049	2216.655534
283.5788	80416.93581	114700.1	-64.45	-50.717	3268.71065
372.62	138845.6644	186794.4	32.377	38.324	1240.816148
418.82	175410.1924	242785.8	110.767	84.524	9362.469908
407.75	166260.0625	209281.8	44.337	73.454	3256.729998
376.08	141436.1664	208043.7	84.267	41.784	3521.012328
461.04	212557.8816	281561.7	141.247	126.744	17902.20977
61.194391	**1728741.673**	**2406696**			**43783.33096**

Now, putting the values from the tables the value of '*r*' comes out to be 0.695.Which implies a positive correlation between the total loss incurred and the losses due to manual operations a high value of the coefficient also indicates a higher degree of correlation between the two.

4.3 Simple Regression Analysis: It is used to establish statistical relationship between total loss incurred and losses due to automation. The generally used method to find the 'best' fit that a straight line of this kind can give is the least-square method.The basic relationship between X and Y is given as below:

$$Y = a + bX$$

Where the symbol Y denotes the estimated value of Y for a given value of X. the formulae used to obtain this relation are as follows:

$$\Sigma(x_i^2)=\Sigma(X_i^2) - n(X_{mean}^2)$$

$$\Sigma(yi^2)=\Sigma(Y_i^2)-n(Y_{mean}^2)$$

$$\Sigma(x_i y_i)=\Sigma(X_i y_i)- n(X_{mean}Y_{mean})$$

$$b= \Sigma(x_i y_i)/ \Sigma(x_i^2)$$

$$a= Y_{mean- b}X_{mean}$$

Where, X_i= total loss, Yi= total manual losses in framing-drying, arranging, storage.
X_{mean}= mean value of X, Y_{mean}= mean value of Y, Now, putting the data obtained from previous tables, the relationship is given as below,

$$x_i^2 =3357227.155$$

$$\Sigma x_i y_i =55304.1248$$

$$b = 0.016$$

$$a = 326.793$$

$$\boldsymbol{Y=326.793 + .016X}$$

5. Results of Statistical Analysis

Using the graphical tools it can be easily visualized thatframing, drying, arrangement of bricks in kiln, storage are major areas of losses. Firing is another major process that contributes to the wastage considerably, since the losses in the kiln is not due to lack of automation this process is beyond the area of interest of the paper. From the study of the various processes involved in brick manufacturing it is evident that above mentioned process are manually done and the losses/wastage during these process can be attributed to lack of automation or manual material handling.Summing up the ΔL/L values of the processes namely framing, drying, arrangement of bricks in kiln, storage from various tables, $(\Delta L/L)_{net}$ comes out to be 0.605406, which implies 60.5% of losses can be omitted if these processes are automated.
Summing up the ΔL/C values of the processes namely framing, drying, arrangement of bricks in kiln, storage from various tables, $(\Delta L/C)_{net}$ comes out to be 0.15686, which implies 15.686% of the total cost can be minimized just by automating above mentioned processes.
The value of Karl Pearson's coefficient of correlation came out to be 0.695 which indicates indicate positive correlation between the two variables (i.e., changes in both variables take place in the statement direction). Regression analysis indicates that an approximate linear relation exists between the total loss and the losses due to lack of automation. This linear relation has been approximated as$Y=326.793 + 0.016X$.

6. Conclusion

The study clearly indicates that the existing brick manufacturing system suffers from a number of loop holes that needs to be rectified but are still not given due consideration. Automation is the solution to these problems and needs to be incorporated in the manufacturing system.The minimal processes which should be automated for bringing large reduction in production cost and wastages are framing, drying, setting the bricks in kiln and intra plant material handling.The study shows substantial motivation to go for automation but, as India is a developing economy, the entrepreneurs will not be willing to invest more in any newly innovated, high cost automation techniques unlike other developed economies. Hence emphasis should be on entrepreneurs to consider immediate adoption of affordable, cost-effective, dependable and simple automation technologies. With application of automated technology bricks with higher strength, accuracy, consistent size and sharp corners can be obtained which is likely to reduce the mortar consumption by 30% in constructions.An automated system can increase the working season by 100-120 days as raining season or bad weather will no longer be a constraint on working condition.An automated brick manufacturing system will likely reduce the requirement of land by three fourths for setting up a brick manufacturing plant.A huge reduction in process inventory can be obtained which will reduce material handling hence the chances of damage or breakage.

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