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Quantifying the Various Factors for Automation of Foundry Technology in Indian Casting Industry

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ABSTRACT: Foundry plays an important part in the manufacturing industry, where metal is casted into a definite shape and in the required quantities as per the customer schedule received. So the manufacturer has to supply the products on time and of correct quantity and in sufficient amounts to retain the customers. The Indian Foundries are developing in a progressive manner where a lot many manufacturers are aiming for advanced manufacturing systems in their foundries which will enable them to satisfy the customers while more increasingly gaining market shares. The objective here is to determine a single numerical index which takes into account different factors of foundry by considering their inheritances and interactions, and access their effect on the automation of foundry in the Indian environment. This can be done by developing a mathematical model using graphs theoretic approach, which studies the interactions among the various factors that affect the automation for a foundry. These factors have their own influencing sub-factors which interact with each other and have an overall affect on the automation. To signify the automation factors at system and sub-system level, an index has been characterized which shows the extent of automation factors for the foundry. This procedure may yield fruitful results in the self-analysis and standardizing among the organisations. The paper takes into account various general factors, which may change depending upon different organisation views (mission & vision). Hence the variation in the factors can be studied upon and used through the useful methodology for the organisation to assess the factors & improve on. The methodology for the step-wise application of the proposed model is shown with example.

Keywords: Foundry, Casting, Numerical index, Graph theoretic approach

I. INTRODUCTION

The scope of this project is to identify the requirements for automation in an Indian casting industry and understand the benefits from the reconfigured production system. A production system has a direct impact on the productivity and quality, which helps the casting manufacturer to determine the cost of the product along with the retention of customer satisfaction. This also helps them to maintain a competitive approach in the market among the number of other manufacturers. And for the improvement of the productivity (on volume & quality) the foundry has to invest in upgraded technology for faster quality production in the equivalent time. Here has the exploitation of an automated manufacturing system as the foundry has varied processes and different kinds of products lie under its manufacturing line.

Also the foundry manufacturing process is time-consuming operation and tedious task due to the high volume and reoccurrence of all the processes that has to be performed on the product.

Traditional operation involves the mould preparation (hand moulding) in a vast area and getting the melt (in Cupola furnace) ready in the mean time. Once the melt prepared, its transferred to the pouring ladle and poured respectively in the prepared moulds. After the complete extraction and pouring of the metal from the furnace into the moulds, the moulds are broken (knock-out), after solidification/cooling time and sent for the cleaning and grinding (fettling operations) of the prepared castings. This process doesn’t yield in high productivity under the case of diverse product requirement in a short period of notice.

This limits the manufacturer into the manufacturing of only one or similar products only and to a sole customer, thus reducing the market share. Hence an initiative for implementation of an automated system is prepared by the casting manufacturer for gaining a competitive edge in the market for gaining more market share to increase their reach in different product range rather than being retained in the production of just a single component.

Mostly study were being conducted based on the Returns on Investment or Internal Rate of Returns that are supposed to be receiving but this method doesn't usually yield into a good profiteering company as this lacks in encapsulating the other variables which affect their customers directly. The automation for the foundries in India is a new area of research and the references had been taken based on the implementation of the (FMS) flexible manufacturing systems as there are different processes that are being performed inside the casting industry which can be automated.

An automated manufacturing system (FMS) is designed to combine the efficiency of a mass-production line and the flexibility of a job shop to produce a variety of work pieces on group of machines. In FMS - automated systems, the manufacturing of different products is possible since the machines are promptly flexible in manufacturing, to the required changes along with the competence of varying level of production volumes. Lately, many foundries are opting for an investment in automation. But, it's has also been seen that many automated foundries had to be closed because of the various factors that weren't considered at the time of implementation. Hence it's sometimes suggested for the implementation of automation as a gradual development of an existing foundry, considering the cost factors in the Indian foundry industry. Spending for an automated foundry is a multi-attribute decision and includes various quantitative and qualitative attributes. Some of the attributes include skilled employment requirement with expertise, work in process, varied production in flexibility and volumes, quality requirements, lead times, floor space requirements, etc.

II. LITERATURE REVIEW

Various researches had been conducted on FMS selection based on the financial analysis methods like Net Present Value (NPV) method, Return On Investment (ROI) method, Internal Rate of Return (IRR). The insufficiency of the traditional financial analysis and measures lies on their non-stochastic nature. Nelson introduced a scoring model for FMS project selection by complementing the traditional capital budgeting procedures with the treatment of project interdependence and non-economic criteria. Wabalickis developed a justified methodology based on the AHP to evaluate many tangible and intangible benefits of an investment on FMS. In addition, Bayazit presented an AHP approach for selecting a FMS. Stam and Kuula developed a two-phase decision procedure that uses the AHP method and multi-objective mathematical programming to select an FMS. Boucher et al. argued that AHP is often criticized for the way the criteria weights are elicited, rank reversal problem, inappropriateness of the crisp ratio representation, and problems faced in the comparison process when the number of criteria and/or the number of alternatives increase. In addition, Karsak and Kuzgunkaya presented a fuzzy approach with multi-objective programming for selection of a flexible manufacturing system. Data envelopment analysis (DEA) has been used severally as a tool for evaluation of manufacturing technologies and FMSs. Shang and Sueyoshi proposed a selection framework of a FMS using AHP, simulation, and data envelopment analysis. They integrated AHP and simulation to generate "input" data and used computing techniques to provide "output" data for analysis using DEA. Sarkis applied DEA technique for evaluating FMSs. He presented a number of DEA models to aid in the investment and adoption decision process. Shiang integrated Fuzzy Data Envelopment analysis (FDEA) and Assurance Region (AR) approach for selection of FMSs when the input and output data is represented as crisp and fuzzy data. He compared twelve FMS alternatives (DMUs) by considering two inputs and four outputs. Capital and operating costs were considered, and floor space requirement as input factors and improvements in qualitative factor, work-in-process (WIP), numbers of tardy jobs, and yield as output factors.

III. PROBLEM FORMULATION

In this paper, the interdependences and the overall impact of the automation factors are discussed using a mathematical model by applying graphs theoretic approach. Graph theory which is a logical and systematic approach and moreover graph/digraph model representations have proved to be useful for modelling and analyzing various kinds of systems and problems in numerous fields of science and technology. An equivalent matrix of the graph/digraph model can be defined. Graph theory and the matrix approach help in identifying attributes, and offer a better visual appraisal of the attributes and their interrelations. This approach is capable of handling the inherent errors, and can deal with any number of qualitative and quantitative attributes simultaneously. The method has axiomatic foundation, involves less computation, provides great emphasis on decision-making methodology, and offers a more objective, simple and consistent decision-making approach. In addition, identification and comparison of alternatives in terms of their similarity/ dissimilarity can be carried out.

The application of graph theory and the matrix approach as a decision-making tool in manufacturing situations is relatively new. The method of quantification looks at the factors that affect the automation from an aspect of Indian manufacturing industry such that an improvement can be practised over the present situation. The main advantage of this method is that it gives a better view of the inter dependencies between the factors that account for the automation factors, which is very efficient in our scenario as there is an interactive complexity that leads to the Automation for a foundry. All the factors have been studied by representing them in numerical indices.

A. Automation Attributes Digraph

Automation in simple words can be defined as the use of different systems which leads into the change in the existing working procedures such that the new procedure yields into a higher productivity and better quality products in a manufacturing unit. To incorporate the automation in a foundry, there can be two methods: one in a totally new plant& the other in existing functioning plant. The first situation is highly risky as lot of funds are to be contributed and the results of the plant are yet far to be seen. But in case, the contribution for the automation can be diverted from the returns from the existing run-up of the plant. Also the improvements are to be seen in the regular practise as the automated section is to be directly linked up in the production system, which gives the manufacturer a surety for the goodwill on returns. So majority of the casting manufacturers prefer this scenario for implementing automation in the plant.

Factors affecting the automation vary for each foundry according to their mission, vision & goals. This yields the input to understand the competitiveness aimed by the manufacturer, the aim of organisation about globalisation, target of market share aimed and the value given to the customer.

For a foundry to be competitive in market, the company should offer the best price for the product to the customer which should also incorporate the operating costs involved for the casting manufacturer. These operating costs vary from the traditional casting methodology and from that incurred in the automated or advanced casting manufacturing methodology. The manufacturer can also bargain with the customer on the product price based on the volume of production received since this has a direct impact on the operating cost for that particular customer's product. The achieved rated capacity of the manufacturing system of the foundry is also a stimulant for undertaking the volume of production, work in process to be kept. For better competition, every manufacturer aims for a continuous production which is not possible to be seen without having any down-time for the machinery repair & maintenance; which has a direct impact on the implementation of automation. These factors lead to the point of increasing the productivity which is of no gain if quality is not drawn off the system. By having an automated plant, target is to have a better control on process parameters, which increases the quality of products. This is greatly acceptable by the customers as they ask for the manufacturing system to be System Oriented rather than Person Oriented. To gain customers confidence, it is also required to have good operating skills personals and proper trainings to be imparted to the operators of all levels as this helps in better production lead times, better equipment & service support for the machinery. The goal of getting globalized for the company gets affected by its product quality & reliability, company's flexibility over changeovers of the production items with least possible setup times required, company's aim towards the direct online delivery system. These, award the company in its image and technological leadership in the market. With increase in globalisation, competition and customer expectation, to sustain & improve in the market share is a great deal of pressure. This has a direct impact from the rejection levels maintained, their returns on investment, skilled labour requirements, floor space availability, services provided & ease in by-product handling.

To achieve the desired goals of the organisation through automation, it is necessary to understand, analyse and evaluate the contribution of critical factors & sub-factors. This is achieved through quantification of effect and interdependency among these factors discussed in the next section.

B. Development of Graph Theoretic Model

Graph theoretic and matrix model consists of digraph representation, matrix representation and permanent representation. Digraph representation is useful for visual analysis. Matrix model is useful for computer processing. Permanent multinomial function characterizes abstract Automation uniquely. Permanent value of multinomial represents the effect of different factors on environment uniquely by a single number/index, which is useful for comparison, ranking and optimum selection.

C. Behavioural Digraph

A Behavioural digraph is prepared to represent the behavioural factors of the Automation environment in terms of nodes and edges. Let nodes represent behavioural factors and edges represent their interactions. The four behavioural factors: competitiveness (B1), globalisation (B2), market share sustainability (B3), customer expectation (B4) and interactions amongst them are shown in Fig. 1.

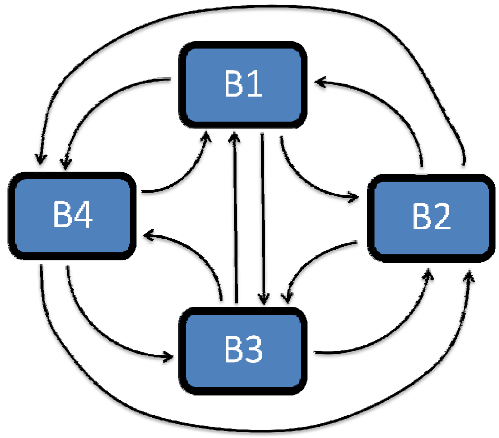

Fig. 1. Behavioural Digraph.

D. Behavioural Matrix

Since, digraph is a visual representation; it helps in analysis to a limited extent only. To establish an expression for behavioural effect, the digraph is represented in matrix form, which is convenient in computer processing also. The behavioural matrix representing the digraph shown in Fig. 1 is written as:

$$\begin{array}{c} \\ A = \end{array} \begin{array}{c} \begin{array}{cccc} 1 & 2 & 3 & 4 \end{array} \\ \begin{bmatrix} 0 & 1 & 1 & 1 \\ 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 \end{bmatrix} \end{array} \begin{array}{c} \text{FACTOR} \\ 1 \\ 2 \\ 3 \\ 4 \end{array} \quad \ldots(1)$$

Off diagonal elements with value 0 or 1 represent the interdependency of behavioural factors. The diagonal elements are 0 since effect of behavioural factors is not taken into consideration. To consider this, another matrix, behavioural characteristic matrix is defined.

E. Behavioural Characteristic Matrix (CM-B)

The characteristic matrix already used in mathematics is used to characterize behavioural factors affecting Automation. Considering I as an identity matrix and B as the variable representing behavioural factors, behavioural characteristic matrix is written as C = [BI - A]

$$\begin{array}{c} \\ C = \end{array} \begin{array}{c} \begin{array}{cccc} 1 & 2 & 3 & 4 \end{array} \\ \begin{bmatrix} B & -1 & -1 & -1 \\ -1 & B & -1 & -1 \\ -1 & -1 & B & -1 \\ -1 & -1 & -1 & B \end{bmatrix} \end{array} \begin{array}{c} \text{FACTOR} \\ 1 \\ 2 \\ 3 \\ 4 \end{array} \quad \ldots(2)$$

In the above matrix the value of all diagonal elements is same, i.e. behavioural factors have been assigned same value which is not true practically, since all behavioural factors have different values (effects) depending on various parameters affecting them. Moreover, interdependencies have been assigned value depending on it is there or not. To consider the effect of behavioural factors and their interdependencies, another matrix, behavioural variable characteristic matrix (VCM) is considered.

F. Behavioural Variable Characteristic Matrix (VCM-B)

It is proposed to characterize the Automation by various behavioural factors and their effects through VCM. For this let us consider digraph in Figure 2 for defining VCM-B. Consider a matrix D with off-diagonal elements b_{ij} 's representing interactions between behavioural factors, i.e. instead of 1 (as in matrix 1). Consider another matrix E with diagonal elements B_i, i = 1, 2, . . . 6, where B_i represent behavioural effect of various factor, i.e. instead of B only (as in matrix 2). Considering matrices D and E, the VCM-B is written as H = [E - D]

$$\begin{array}{c} \\ H = \end{array} \begin{array}{c} \begin{array}{cccc} 1 & 2 & 3 & 4 \end{array} \\ \begin{bmatrix} B_1 & -b_{12} & -b_{13} & -b_{14} \\ -b_{21} & B_2 & -b_{23} & -b_{24} \\ -b_{31} & -b_{32} & B_3 & -b_{34} \\ -b_{41} & -b_{42} & -b_{43} & B_4 \end{bmatrix} \end{array} \begin{array}{c} \text{FACTOR} \\ 1 \\ 2 \\ 3 \\ 4 \end{array} \quad \ldots(3)$$

The matrix provides a powerful tool through its determinant called variable characteristic behavioural multinomial (VCBM). This is a characteristic of the system and represents the behavioural effect of the system consisting of behavioural effect of factors and their interactions. Determinant of matrix equation (3), i.e. VCBM carries positive and negative signs with some of its co-efficient. Hence, complete information on behavioural effect will not be obtained as some will be lost due to addition and subtraction of numerical values of diagonal and off diagonal elements (i.e. B_i's and b_{ij}'s).

Thus, the determinant of VCM – behavioural, i.e. matrix equation (3) does not provide complete information concerning behavioural effect. For this, another matrix, behavioural variable permanent matrix (VPM-B) is introduced.

G. Behavioural Variable Permanent Matrix

Overall behavioural effect is max when the behavioural effect of all the factors is max. Since, total quantitative information is not obtained in VCM-B, VPM-B is defined for the system in general (assuming interactions among all factors) as B = [E + D]

$$\begin{array}{c} \\ H = \end{array} \begin{array}{c} \begin{array}{cccc} 1 & 2 & 3 & 4 \end{array} \\ \begin{bmatrix} B_1 & b_{12} & b_{13} & b_{14} \\ b_{21} & B_2 & b_{23} & b_{24} \\ b_{31} & b_{32} & B_3 & b_{34} \\ b_{41} & b_{42} & b_{43} & B_4 \end{bmatrix} \end{array} \begin{array}{c} \text{FACTOR} \\ 1 \\ 2 \\ 3 \\ 4 \end{array} \quad \ldots(4)$$

Where E and D have meaning as in matrix equation (3). The permanent of matrix equation (4) is multinomial and is called variable permanent behavioural function (VPF-B), also known as permanent of B (per B). The permanent for matrix equation (4) in general form is written as:

Per B = B1.B2.B3.B4 –b12.b21.B3.B4 –b34.b43.B1.B2 +b12.b21.b34.b43 + b12.b23.b31.B4 – b13.b31.B2.B4 - b12.b23.b34.b41 + b13.b34.b41.B2 + b13.b2.b31.b42 – b14.b23.b31.b42 – b13.b24.b32.b41 + b13.b21.b32.B4 – b23.b32.B1.B4 – b13.b21.b34.b42 – b23.b42.B1.B2 + b14.b21.b42.B3 + b14.b31.b43.B2 – b12.b24.b31.b43 – b14.b41.B2.B3 + b12.b24.b41.B3 …(5)

The permanent function defined above, i.e. equation (5) is the complete expression for behavioural effect as it considers presence of all attributes and their interdependencies.

Quantification of B_i's and b_{ij}'s

Quantification of human factors (i.e. B_i's) is carried out on the lines of per B (equation (5)). Each factor is identified as a subsystem and graph theoretic approach is applied in each subsystem. Behavioural subsystem permanent characteristic matrix (similar to equation (5)) is evaluated for permanent function considering various factors affecting the subsystem. The various factors affecting subsystems are identified in Figure 1. The dependencies of factors at subsystem level are visualized through digraphs. These digraphs lead to the inheritance of factors at system level through matrix and measures. The corresponding variable permanent matrices are then derived for each subsystem (ss) and permanent function of each VPM (ss) is evaluated. The permanent functions of these matrices (similar to equation (5)) will lead to inheritance of behavioural factors. Thus, graph theoretic approach may be applied at every level. In order to avoid complexity, suitable scale may be used to assign value at subsystem level or sub subsystem. If all the factors are not equally important to an organization, suitable weights may be assigned. Table I suggests assignment of numerical values to factors. To get the complete value of multinomial (equation (5)), the off diagonal elements in VPM-B (equation (4)) are to be assigned numerical values. As already discussed, these off diagonal elements represent interdependencies among the factors for Automation. However, this dependence among factors at system level (or subsystem level) cannot be measured directly and values can be assigned only after proper interpretation through a team of experts. It is suggested to use Table II for value of interdependencies.

The index is a means for the manufacturing unit to see upon the impact of the various factors on the implementation of Automation. The higher the index value more beneficial is the environment for the Automation. This index value can also be used for self-analyses of the organisation and any improvements can be judged for.

Table 1: Quantification of Factors.

S. No.	Qulitative Measure of Automation Factors	Assigned Value of Factors
1	EXCEPTIONALLY LOW	1
2	VERY LOW	2
3	LOW	3
4	BELOW AVERAGE	4
5	AVERAGE	5
6	ABOVE AVERAGE	6
7	HIGH	7
8	VERY HIGH	8
9	EXCEPTIONALLY HIGH	9

Table 2: Quantification of factor interdependencies.

S.No.	Qualitative Measurement of Interdependencies	B_{ij}
1	VERY STRONG	5
2	STRONG	4
3	MEDIUM	3
4	WEAK	2
5	VERY WEAK	1

IV. METHODOLOGY USED TO EVALUATE THE AUTOMATION INDEX

(i) The various factors affecting the automation of a foundry in Indian environment have been identified in Figure 1.
(ii) The sub-factors affecting the automation are listed in Table III.
(iii) The dependencies of factors at subsystem level are understood by the digraphs shown in Figures 3-8. Superscript denotes the subsystem and subscript indicates the factors affecting the subsystem.
(iv) Variable permanent matrix for digraph for each subsystem is written. At subsystem level, variable permanent matrix for digraph for subsystem 1 (Figure 3) in general form is considered. VPM-B_1 is given by

$$B_{ss1} = \begin{bmatrix} 1 & 2 & 3 & 4 & 5 & 6 \\ B_1^1 & b_{12}^1 & b_{13}^1 & b_{14}^1 & b_{15}^1 & b_{16}^1 \\ b_{21}^1 & B_2^1 & b_{23}^1 & b_{24}^1 & b_{25}^1 & b_{26}^1 \\ b_{31}^1 & b_{32}^1 & B_3^1 & b_{34}^1 & b_{35}^1 & b_{36}^1 \\ b_{41}^1 & b_{42}^1 & b_{43}^1 & B_4^1 & b_{45}^1 & b_{46}^1 \\ b_{51}^1 & b_{52}^1 & b_{53}^1 & b_{54}^1 & B_5^1 & b_{56}^1 \\ b_{61}^1 & b_{62}^1 & b_{63}^1 & b_{64}^1 & b_{65}^1 & B_6^1 \end{bmatrix} \begin{matrix} \text{FACTOR} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \end{matrix} \quad \ldots (6)$$

Similar to equation (6) variable permanent matrix for each subsystem are written.
(v) At the sub subsystem level Tables I and II are used to determine numerical values for inheritance of attributes and their interactions. The variable permanent matrices for different subsystems (based on their digraphs) are written through equations (7.1)-(7.6).

$$\text{VPM } B_1 = \begin{bmatrix} 1 & 2 & 3 & 4 & 5 & 6 \\ 7 & 4 & 3 & 4 & 2 & 5 \\ 0 & 5 & 2 & 4 & 4 & 4 \\ 0 & 0 & 7 & 3 & 4 & 4 \\ 2 & 4 & 4 & 5 & 3 & 5 \\ 0 & 0 & 0 & 0 & 6 & 4 \\ 0 & 0 & 0 & 4 & 0 & 8 \end{bmatrix} \begin{matrix} \text{SUB-FACTOR} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \end{matrix} \qquad (7.1)$$

Similarly, variable permanent matrices for other subsystems are written as,

$$\text{VPM } B_2 = \begin{matrix} 1 & 2 & 3 & 4 & 5 & 6 \end{matrix} \begin{bmatrix} 7 & 0 & 3 & 0 & 0 & 4 \\ 4 & 8 & 3 & 0 & 0 & 5 \\ 3 & 5 & 6 & 4 & 0 & 4 \\ 3 & 4 & 3 & 5 & 0 & 4 \\ 3 & 4 & 3 & 3 & 5 & 3 \\ 0 & 0 & 3 & 0 & 0 & 7 \end{bmatrix} \begin{matrix} \text{SUB-FACTOR} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \end{matrix} \qquad (7.2)$$

$$\text{VPM } B_3 = \begin{array}{c} \\ \\ \end{array}\begin{bmatrix} 1 & 2 & 3 & 4 & 5 & 6 \\ 9 & 3 & 3 & 0 & 5 & 0 \\ 3 & 5 & 3 & 0 & 0 & 0 \\ 3 & 3 & 7 & 3 & 5 & 4 \\ 4 & 0 & 3 & 5 & 0 & 0 \\ 0 & 3 & 3 & 0 & 8 & 4 \\ 3 & 3 & 4 & 3 & 0 & 5 \end{bmatrix} \begin{array}{c} \text{SUB-FACTOR} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \end{array} \quad (7.3)$$

$$\text{VPM } B_4 = \begin{bmatrix} 1 & 2 & 3 & 4 & 5 & 6 \\ 6 & 3 & 0 & 3 & 3 & 0 \\ 3 & 7 & 4 & 3 & 0 & 5 \\ 4 & 0 & 6 & 3 & 0 & 0 \\ 0 & 0 & 3 & 8 & 0 & 4 \\ 3 & 0 & 4 & 3 & 5 & 4 \\ 4 & 4 & 3 & 4 & 0 & 9 \end{bmatrix} \begin{array}{c} \text{SUB-FACTOR} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \end{array} \quad (7.4)$$

(vi) The permanent of matrix (6) – Per B_{ss1}, which will lead to inheritance of behavioral factor 1, is evaluated on the lines of equation (5). The complete expression for the Per Bss1 is given as:

The value of permanent function for ss1 leads to the inheritance of behavioral factor B_1. Substituting the values from equation (7.1)

Per Bss1 = 286312

(vii) Similarly the value of permanent functions of different subsystems are evaluated from the variable permanent matrices in equations (7.1)-(7.6) and are written as under:

Per Bss1 = 286312
Per Bss2 = 226920
Per Bss3 = 427833
Per Bss4 = 485322

(viii) Behavioral factor digraph is shown in Figure 2 and behavioral matrix at system level is developed through equations (1)-(4). Variable permanent matrix for this example is written in symbolic form as:

$$\text{VPM - B} = \begin{bmatrix} 1 & 2 & 3 & 4 \\ B_1 & b_{12} & b_{13} & b_{14} \\ b_{21} & B_2 & b_{23} & b_{24} \\ b_{31} & b_{32} & B_3 & b_{34} \\ b_{41} & b_{42} & b_{43} & B_4 \end{bmatrix} \begin{array}{c} \text{FACTOR} \\ 1 \\ 2 \\ 3 \\ 4 \end{array} \quad \ldots (9)$$

The values of the diagonals are to be taken from step 7 and the values of off diagonal elements are taken from Table II.

(ix) After substituting the values in step 8, the variable permanent matrix behavioral becomes:

$$\text{VPM - B} = \begin{bmatrix} 1 & 2 & 3 & 4 \\ 286312 & 2 & 2 & 4 \\ 2 & 226920 & 2 & 3 \\ 3 & 2 & 427833 & 3 \\ 4 & 3 & 4 & 485322 \end{bmatrix} \begin{array}{c} \text{FACTOR} \\ 1 \\ 2 \\ 3 \\ 4 \end{array} \quad \ldots (10)$$

(x) Value of permanent function for the system is evaluated as per equation (5).

The value of permanent of above matrix (equation (10)) is 1.34901 X 10^{22}, which indicates the index for the case considered. By carrying out similar analysis indices for different foundries can be obtained. As suggested, this will help an organization to assess itself and improve. It is also suggested to find hypothetical best and hypothetical worst value of index. Automation index is at its best when the inheritance of all its factors is at its best. Since, inheritance of factors is evaluated considering sub factors and applying graph theoretic approach at the subsystem level, it is evident that index is at its best when inheritance of sub factors is at its best. Since, Table I is used at subsystem level, maximum value of Per B1 is obtained when inheritance of all the sub factors is maximum, i.e. value taken from Table I is 9. Thus, equation (7.1) may be rewritten for the maximum value of Per B1 as

$$\text{VPM } B_1 = \begin{bmatrix} 1 & 2 & 3 & 4 & 5 & 6 \\ 9 & 4 & 3 & 4 & 2 & 5 \\ 0 & 9 & 2 & 4 & 4 & 4 \\ 0 & 0 & 9 & 3 & 4 & 4 \\ 2 & 4 & 4 & 9 & 3 & 5 \\ 0 & 0 & 0 & 0 & 9 & 4 \\ 0 & 0 & 0 & 4 & 0 & 9 \end{bmatrix} \begin{array}{c} \text{SUB-FACTOR} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \end{array} \quad (11)$$

The value of the permanent of the above function is 1.20532×10^6, i.e. max. Per $B_{ss1} = 1.20532 \times 10^6$.
Similarly index is at its worst when the inheritance of all its factors and sub factors is at its worst.

This is the case when inheritance of all the sub factors is minimum, i.e. value taken from Table I is 1. Thus, equation (7.1) may be rewritten for the minimum value of Per B1 as

$$\text{VPM } B_1 = \begin{array}{c} \\ \\ \\ \\ \\ \\ \end{array} \begin{array}{cccccc} 1 & 2 & 3 & 4 & 5 & 6 \\ \end{array} \quad \text{SUB-FACTOR}$$

$$\text{VPM } B_1 = \begin{bmatrix} 1 & 4 & 3 & 4 & 2 & 5 \\ 0 & 1 & 2 & 4 & 4 & 4 \\ 0 & 0 & 1 & 3 & 4 & 4 \\ 2 & 4 & 4 & 1 & 3 & 5 \\ 0 & 0 & 0 & 0 & 1 & 4 \\ 0 & 0 & 0 & 4 & 0 & 1 \end{bmatrix} \begin{array}{c} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \end{array} \qquad (12)$$

The value of the permanent of the above function is 4011, i.e. min. Per $B_{ss1} = 4011$.
Similarly maximum and minimum values for each subsystem are evaluated and different values of permanent of subsystem matrices are summarized in Table IV. Maximum value of index at system level is evaluated by considering maximum values of all subsystems and minimum value of index at system level is evaluated by considering minimum values of all subsystems. The value of per B indicates the value of index. Thus, the maximum and minimum value of automation index indicates the range with in which it can vary. Experts can use this range to decide a threshold value for a given set of similar industries.

Table 4: Values For Maximum/Minimum Automation Index.

System/Subsystem	**Current Value**	**Maximum Value**	**Minimum Value**
Per B1	286312	1.20532×10^6	4011
Per B2	226920	1.14026×10^6	1936
Per B3	427833	1.65243 X 106	29035
Per B4	485322	1.50899×10^6	28114
Per B	1.34901×10^{22}	3.42701×10^{24}	6.33874×10^{15}

V. CONCLUSION

A casting industry is a combination of different processes through which the manufacturer aims for higher benefits and implementing automation inside the plant is of much interest in the present day scenario. This project proposes a model for the implementation for the automation inside a foundry in Indian industry, which is based on the study of different attributes of goals and targets of the industry affected by external and internal parameters.
The case study gave an outline on some of the factors that affect the automation implementation which may vary for different casting industries.

VI. FUTURE SCOPE

The project is the framework for the identification of the attributes that affect the implementation of the automation in the foundry in Indian casting industry. Further study can be improved upon for the calculation of the efficiency of the implemented automation of the foundry. Also the timeline for the implementation of the automation can be dealt in detail for the future work.

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