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ASSESSMENT AND SELECTION OF VENDOR IN A CONSTRUCTION-BASED ORGANIZATION: A MATHEMATICAL APPROACH

M. MAGENDRAN[1], R. VIKRAMA PRASAD, AND M. VENKATACHALAM

ABSTRACT. Graph theoretic approach has been adopted for evaluation and selection of a builder. The characteristic parameters which affect the builder's quality were identified based on the literature survey of research papers and also followed the factors chosen by different researchers. Based on these factors, a model has been developed for builder selection. During the application of graph theoretic approach, a digraph of characteristics which contributes to quality of builder has been developed further the interdependency of attributes as well as their inheritances has been identified and its representation in matrix form has been used for calculation of numerical index of the builder's quality through variable permanent function. A single numerical index has been developed using graph theoretic approach for assessment and comparison of builder in manufacturing organization.

1. INTRODUCTION

The selection of a good builder is a strategic decision as the assets have a long-lasting effect on the quality of construction. It not only satisfies the customer demands and increases the builder's profit but also satisfies various factors like supplier cost, quality, quantity, less rework, service, etc. Builder selection is one of the major factors which affect the quality and service of assets very strongly. In current scenario, a functioning supplier selection process is essential for the

[1]*corresponding author*

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growth of any civil organization [1]. If a builder performance is of consistently high quality, the customer can decrease or eliminate the expensive incoming inspections and minimize miscellaneous value added to the construction [2]. Builder selection and evaluation are one of the major topics in production and operations management literature, especially in advanced construction environment [3]. Cost of purchase of raw materials and component parts from external builders are also very important. As an example, in civil industry, costs of components and parts purchased from external agencies may total more than 50 costs for high technology firms and this shows the importance of making decisions in the purchasing activity [4]. In general, supply interruption costs at present are higher than ever before [5], necessitating the further investigation to builder development. The gravity of 'builder selection process' is evident from umpteen of researches on the issue. Many researchers reported various factors and applied different approaches to converse the issue and afford a solution for builder selection. The work done by the different researchers has provided immense help to the authors for selection of factors in the present paper. However, the authors observed that the individual and interactive effect of factors have not been taken into account during the course of application of techniques. To predict or compare the builder performance for a manufacturing industry, it is necessary to analyze various factors and their effect. A mandatory mathematical model is applied to evaluate and compare the different factors and sub-factors of builders for different applications. The present work undertakes the application of GTA in the builder selection of manufacturing industry. A mathematical approach [6] can provide a solution to the above problem in the form Graph theoretic approach (GTA) which is a systematic and logical approach that can be applied to various science and technology fields [7]. In addition, a graphic illustration by a matrix offers comfort in computer processing [8]. To support this problem, a mathematical approach is proposed for the study and quantification of various factors, sub-factors affecting the performance of civil work [9]. This would lead to determination of single numerical index, which would be useful in assessing and comparing the quality of builders.

2. Graph theory based literature survey

Graph theoretic approach – history of its use: It is a systematic methodology consisting of 'Digraph representation', 'Matrix representation' and 'Permanent function'. Permanent function leads to Single Numerical Index. Graph theoretic approach is a tool for multiple utility for its application in various fields [10,11]. The conventional methods of representation are not suitable for mathematical modeling and analysis. Graph theoretic approach is suitable for visual analysis and can be computer processed as a mathematical entity [12]. This approach has been used in the determination of performance index of an organization, human or system reliability, determination of Intellectual capital value index, etc.

3. Identification of factors

To apply GTA effectively, it is very important to select the factor properly and for this an intense literature survey is done as mentioned in Table 2. On the basis of these factors, GTA can be applied to assess the best builder. According to literature surveys, the most important factors which affect the builder selection process in a manufacturing organization are as follows with their co-factors:

- Quality – wastage control knowledge (WCK), commitment to quality (CQ), Modernized Process Capability (MPC).
- Cost – unit cost (UC), operating cost (OC), maintenance cost (MC), acquisition cost (AC).
- Service – on time delivery, quick responsiveness (QR), warranty (WR).
- Financial capability – economic performance (EP), financial stability (FS).
- Technical and production capability – manufacturing capability (MC), design capability (DC), capacity utilisation (CU).

Representation of factors in a model tree form.

The factors are general and important in nature and are briefly discussed as under:

3.1. **Quality.**

The term quality has many definitions represented by different researchers from time to time. Here, in the context of builder selection, quality means the good quality material at low cost supplied by the builder within specified time period. The quality of any product solely depends on the raw

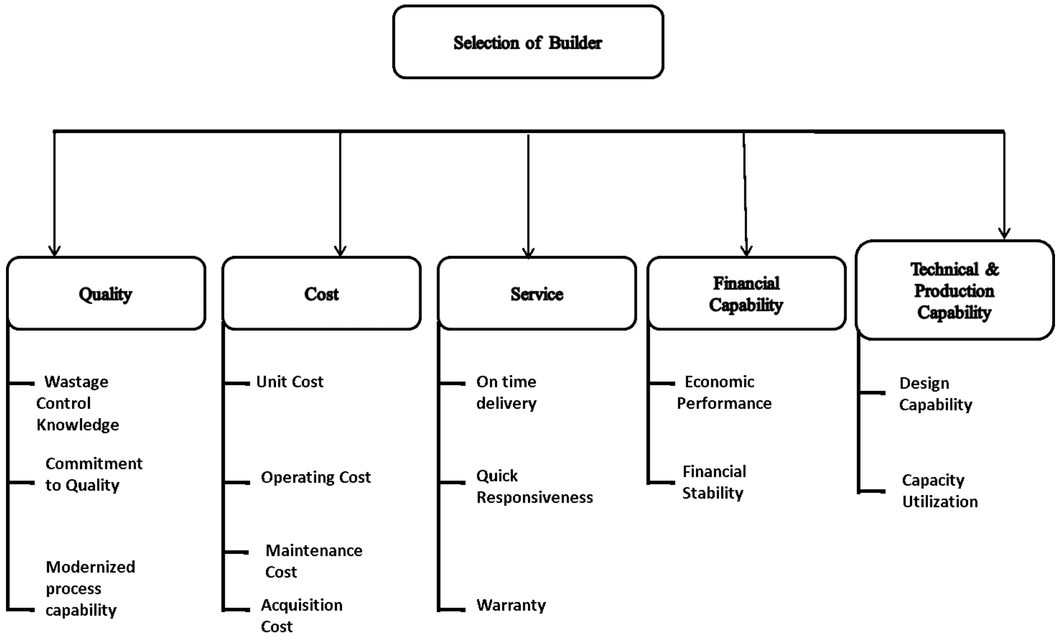

FIGURE 1. Model tree for builder selection

material supplied by the builder because if the raw material does not meet the required level expectations then there is no guarantee for good quality product. So, for this reason, it is necessary to ensure whether the quality of raw material supplied by the builder meets the required expectations or not? For ensuring the quality, it is necessary to measure the co-factors of quality like defect rate, commitment of quality and process capability of the builder. The material supplied by the builder must have minimum defects and the builder must be committed to quality, CQ which is meant for "The builder must be committed to continuously evaluate their systems, processes, resources and organizational structure to ensure that they are aligned to achieve quality result". With all these, it is also necessary to measure the process capability of the builder to ensure that the builder is capable to fulfill ones requirements within the specified period of time properly.

3.2. **Cost.** Cost is one of the major factors which influence the builder selection significantly. In this competitive environment, it becomes awkward for the manufacturing industries to retain their stake in the market and earn profits. New companies are introduced in the market with competitive price. In this scenario, cost of raw material supplied by the builder plays an important role in deciding the cost of the product manufactured by the industry as it is not possible to produce goods at low cost when the raw material supplied by the builder is expensive; hence the raw material supplied by the builder material should also be of low cost. The OC and MC of the material supplied by the builder also increase the cost of the product extensively. Operating cost is meant for "the cost incurred in processing/operating the material" and MC is meant for "the cost incurred in maintenance of any facility, equipment or asset". AC is meant for "costs included for the site preparation, installation and testing".

3.3. **Service.** To choose a builder, it is important to consider the services provided by the builder before selection. The services include on-time delivery, QR and WR of the product. On-time delivery (OTD) stands for delivering the product or services to the industry within the specified time. Quick responsiveness stands for response of builder towards any queries and complaints raised by the purchaser. The builder must take care of material/service during the WR period and should provide an optimum WR period.

3.4. **Financial capability.** It is one of the important factors while choosing a builder. The builder's financial position must be sound enough so that the builder fulfils the order properly without any delay and at optimum cost. The co-factors of financial capability are: EP, FS. Financial performance account for direct commercial value generated and circulated including revenues, OCs, workers compensation, assistances and other community funds, reserved earnings and expenses to capital benefactors and governments. Financial stability stands for ability to facilitate and enhance economic processes, manage risks, and absorb shocks.

3.5. **Technical and production capability.** Before selecting any builder, it is very important to judge the technical and production capability of the builder. After evaluation of technical and production capability, the industry can identify whether the selected builder is good enough to complete your demands or not. The co-factors of technical and production capability are: MC, DC, CU. Manufacturing capability stands for capability of builder to manufacture the product within the specified period of time with the available resources. Design capability stands for capability of the builder to design the product according to the demand and to incorporate latest changes and amendments on time. Capacity utilization can be defined as utilization of all resources, machinery and facilities of builder in a full swing to manufacture the product.

4. Application of GTA

The value of the builder quality index is determined using graph – theoretic approach. The GTA consists of three steps:

- Digraph representation;
- Matrix representation;
- Permanent function representation.

4.1. **Digraph representation.** The builder's quality digraph represents the significance of factors and interdependence between them. The nodes (Pi's) of the digraph represent the builder's quality measures of characteristics and the edges $(P'_{ij}s)$ represent the quality dependence of the characteristics. The four characteristic quality digraph is shown in Figure 2.

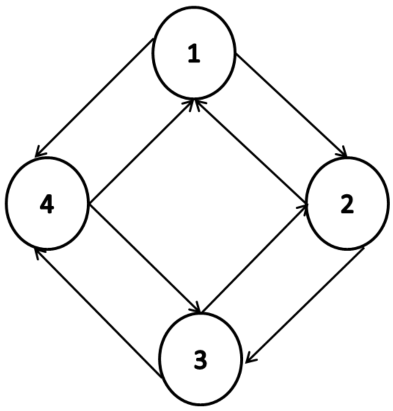

Figure 2. Four characteristic quality digraphs

4.2. **Matrix representation.** The digraph representation provides a visual representation which is helpful to a limited extent. After digraph representation of factors, now a matrix representing factors for builder evaluation is formed. Matrix representation for builder evaluation gives one to one representation. This matrix is known as variable permanent matrix (VPM).

$$\text{Variable Permanent Matrix} = \begin{pmatrix} A_1 & A_{12} & A_{13} & A_{14} \\ A_{21} & A_2 & A_{23} & A_{24} \\ A_{31} & A_{32} & A_3 & A_{34} \\ A_{41} & A_{42} & A_{43} & A_4 \end{pmatrix}$$

In the given matrix the value of A_1, A_2, A_3 and A_4 can be determined by making a digraph of each factor with their co-factors and the value of inter-dependencies like A_{12}, A_{13}, A_{14} etc., can be determined with the help of Table 1.

TABLE 1. Value of interdependency of factors (A_{ij})

S.No.	Quality measure of interdependency	Assigned value
1	Very strong	5
2	Strong	4
3	Medium	3
4	Weak	2
5	Very weak	1

The value of diagonal elements can also be determined by the Table 2

TABLE 2. Value of inheritance of factors (D_i)

S.No.	Quality measure of inheritance	Assigned value
1	Extremely low	1
2	Low	2
3	Below average	3
4	Average	4
5	Above average	5
6	High	6
5	Extremely high	5

4.3. **Permanent function representation.** To determine the numerical index, the permanent of the matrix called as variable permanent quality function of the industry is used here. The permanent function is obtained in a similar manner as its determinant but with all signs positive. This expression is representative of the builder quality and contains all possible quality terms of the builder. The

VPF expression corresponds to the four – characteristic digraph/VPM is given as

$$\begin{aligned} VPF &= A_1A_2A_3A_4 + a_{12}a_{21}A_3A_4 + a_{13}a_{31}A_2A_4 + a_{14}a_{41}A_2A_3 + a_{23}a_{32}A_1A_4 \\ &+ a_{24}a_{42}A_1A_3 + a_{34}a_{43}A_1A_2 + a_{12}a_{23}a_{31}A_4 + a_{13}a_{32}a_{21}A_4 + a_{12}a_{24}a_{41}A_3 \\ &+ a_{14}a_{42}a_{21}A_3 + a_{13}a_{34}a_{41}A_2 + a_{14}a_{43}a_{31}A_2 + a_{23}a_{34}a_{42}A_1 + a_{24}a_{43}a_{32}A_1 \\ &+ a_{12}a_{21}a_{34}a_{43} + a_{13}a_{31}a_{24}a_{42} + a_{14}a_{41}a_{23}a_{32} + a_{12}a_{23}a_{34}a_{41} + a_{14}a_{43}a_{32}a_{21} \\ &+ a_{13}a_{34}a_{42}a_{21} + a_{12}a_{24}a_{43}a_{31} + a_{14}a_{42}a_{23}a_{31} + a_{13}a_{32}a_{24}a_{41}. \end{aligned} \tag{4.1}$$

The variable permanent function i.e. expression (4.1) is a complete expression itself as it considers all factors and all possible relative interdependencies. Each term in the expression is useful and all combinations of inheritance/interdependencies of factors and subfactors are covered. It contains N! terms, where N is number of factors (here N = 4). Moreover, the terms in permanent function are arranged in a systematic way in N + 1 grouping. The first group contains only one term and represents the presence of factors for Builder assessment i.e., $A_1A_2A_3A_4$. The second grouping is absent since there are no self-loops, i.e., this grouping will occur in expression only if a factor is connected to itself. The third grouping contains set of two builder assessment factor interdependence and remaining N-2 (i.e., 2 here) factors. Each term of fourth grouping represents a set of three builder assessment factor interdependence and the remaining N-3 (i.e., 1 here) factors. The fifth grouping contains terms arranged in a two subgrouping. The first subgrouping contains a set of two builder assessment factor interdependence and measure of remaining N-4 factors. The second subgrouping is a set four builder assessment factor interdependence or its pair and measure of remaining N-4 builder assessment factors. Thus, the permanent function of builder assessment matrix (i.e., expression one) is a true representation of measure of builder assessment factors in an organization.

4.4. **Builder's quality digraph.** In particular, the five quality characteristics of the builder form the builder quality digraph. As already mentioned, these quality characteristics are: (1) quality, (2) cost, (3) service, (4) financial capability, (5) technical and production capability. Each node of the digraph represents the quality measure of the corresponding quality characteristic and the edge between the two nodes represents the dependence between them. The builder's quality digraph gives the visual representation of the interdependence between the quality characteristic and shows the complexity of the interdependencies of the characteristics of the builder.

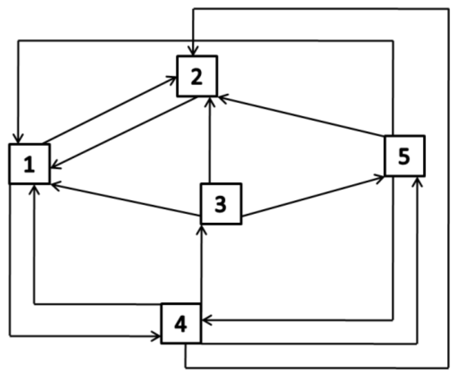

FIGURE 3. Builder quality digraph

4.5. **Builder's quality matrix.** The builder quality matrix according to the builder quality digraph (also known as variable permanent matrix; VPM) is as follows:

$$\text{Variable Permanent Matrix}=\begin{pmatrix} A_1 & A_{12} & A_{13} & A_{14} & A_{15} \\ A_{21} & A_2 & A_{23} & A_{24} & A_{25} \\ A_{31} & A_{32} & A_3 & A_{34} & A_{35} \\ A_{41} & A_{42} & A_{43} & A_4 & A_{45} \\ A_{51} & A_{52} & A_{53} & A_{54} & A_5 \end{pmatrix}.$$

As explained earlier, the diagonal elements represent the quality measure of characteristics and off diagonal elements represent the quality dependence of the characteristics. The value of off diagonal elements can be determined by the Table 1, whereas to determine the value of diagonal elements, the digraph of each quality characteristics with their co-factors is presented and afterwards by making the variable permanent matrix, the value of quality characteristic can be determined.

$$
\begin{aligned}
VPF &= PER - A\\
&= \prod_{1}^{5} Pi + \sum_i\sum_j\sum_k\sum_l\sum_m (a_{ij}.a_{ji})A_kA_lA_m\\
&+ \sum_i\sum_j\sum_k\sum_l\sum_m (a_{jk}.a_{kl} + a_{ik}.a_{kj}.a_{ji})A_lA_m\\
&+ \Bigg(\sum_i\sum_j\sum_k\sum_l\sum_m (a_{ij}.a_{jk})(a_{kl}.a_{lk})A_m\\
&+ \sum_i\sum_j\sum_k\sum_l\sum_m [(a_{ij}.a_{jk}.a_{kl}.a_{li}) + (a_{il}.a_{lk}.a_{kj}.a_{ji})]A_m\Bigg)\\
&+ \Bigg(\sum_i\sum_j\sum_k\sum_l\sum_m (a_{ij}.a_{ji})(a_{kl}.a_{lm}.a_{mk} + a_{kl}.a_{ml}.a_{lk})\\
&+ \sum_i\sum_j\sum_k\sum_l\sum_m [(a_{ij}.a_{jk}.a_{kl}.a_{lm}.a_{mi}) + (a_{im}.a_{ml}.a_{lk}.a_{kj.a_{ji}})]\Bigg).
\end{aligned}
\tag{4.2}
$$

4.6. **Builder permanent function representation.** To determine the numerical index for builder assessment, it is necessary to determine the permanent of builder quality matrix. The permanent of builder quality matrix is a multinomial and a standard matrix function, which has been used and defined in a combinatorial mathematics [13]. The methodology used for deriving the permanent function is similar to determinant calculation but by keeping all the signs positive. The permanent of a matrix can be determined as below: Equation (4.2) contains 5! Terms and these terms are arranged in n + 1 grouping, where n is the number of elements (factors). Here, n = 5, therefore, six grouping are there. The first grouping contains only one term and is a set of effects of five factors i.e., A_1, $A_2 \ldots A_5$. In general, second grouping is absent in absence of self-loops. The third grouping contains set of two factors interdependence, i.e., a_{ij} a_{ji} and measure remaining n-2 (i.e., 3 here) factors. Each term of fourth grouping represents a set of three interdependence a_{ij} a_{jk} a_{ki}or its pair a_{ik} $a_{ki}a_{ji}$ and measure of remaining n-3 (i.e., 2 here) factors. The terms of fifth grouping are arranged in two subgroups. The first sub-grouping is a set of two, 2-factors interdependence, i.e., a_{ij} a_{ji} and $a_{kl}a_{lk}$ and measure of remaining n-4 factors. The second sub-grouping is a set of four factor interdependence, i.e., $a_{ij}a_{jk}$ $a_{kl}a_{li}$

or its pair a_{il} $a_{lk}a_{kj}a_{ji}$ and measure of n-4 factors. The terms of sixth grouping are also arranged in two subgroups. The first subgrouping is a set of two factors interdependence, i.e., a_{ij} a_{ji}, a set of three factor independence, i.e., a_{kl} a_{lm} a_{mk} or its pair a_{km} a_{ml} a_{lk}. The second subgrouping is a set of five factor interdependence, i.e., a_{ij} $a_{jk}a_{kl}a_{lm}a_{mi}$ or its pair a_{im} $a_{ml}a_{lk}$ $a_{kj}a_{ji}$.

4.6.1. **Quality-based digraph**. In the builder quality matrix, the diagonal element A_1represents the Quality characteristic namely 'Quality'. The characteristic quality is having three co-factors namely: LDR, CQ, IPC. The digraph of the characteristic 'Quality' is shown below:

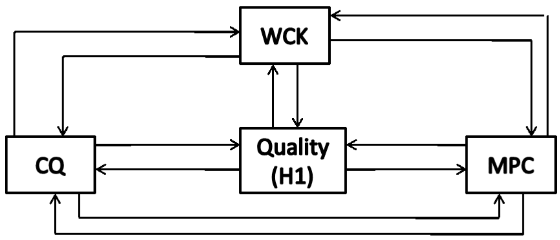

FIGURE 4. Quality-based digraph

On the basis of quality-based digraph, the variable permanent matrix is developed to determine the value of quality characteristics. Similarly, the digraph for other quality characteristic like A_2, A_3, A_4 and A_5 were made and also represented their variable permanent matrices to determine the value of quality characteristics.

$$VPM - A_1 = \begin{pmatrix} D_1 & D_{12} & D_{13} & D_{14} \\ D_{21} & D_2 & D_{23} & D_{24} \\ D_{31} & D_{32} & D_3 & D_{34} \\ D_{41} & D_{42} & D_{43} & D_4 \end{pmatrix}.$$

Now,

$$VPM - A_1 = \begin{pmatrix} 7 & 5 & 5 & 3 \\ 3 & 5 & 4 & 3 \\ 5 & 2 & 5 & 2 \\ 4 & 2 & 2 & 5 \end{pmatrix} = 5263.$$

4.6.2. **Cost-based digraph**: The co-factor of quality characteristic cost is OC, UC, MC, AC Variable permanent matrix for cost

$$\text{VPM-}A_2 = \begin{pmatrix} C_1 & 0 & 0 & 0 & 0 \\ C_{21} & C_2 & 0 & 0 & 0 \\ C_{31} & 0 & C_3 & 0 & 0 \\ C_{41} & 0 & 0 & C_4 & 0 \\ C_{51} & 0 & 0 & 0 & C_5 \end{pmatrix}.$$

Now,

$$VPM - A_2 = \begin{pmatrix} 6 & 0 & 0 & 0 & 0 \\ 5 & 6 & 0 & 0 & 0 \\ 4 & 0 & 4 & 0 & 0 \\ 2 & 0 & 0 & 3 & 0 \\ 2 & 0 & 0 & 0 & 3 \end{pmatrix} = 1296.$$

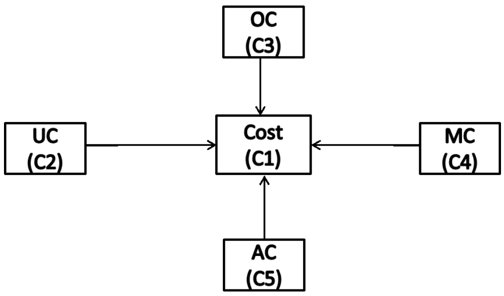

FIGURE 5. Cost-based digraph

4.6.3. **Service-based digraph**: The co-factor of quality characteristic service is OTD, QR, WR Variable permanent matrix for service

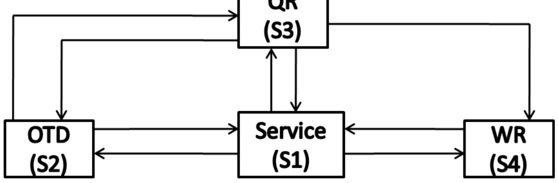

FIGURE 6. Service-based digraph

$$VPM - A_3 = \begin{pmatrix} S_1 & S_{12} & S_{13} & S_{14} \\ S_{21} & S_2 & S_{23} & 0 \\ S_{31} & S_{32} & S_3 & S_{34} \\ S_{41} & 0 & S_{43} & S_4 \end{pmatrix}.$$

Now,

$$VPM - A_3 = \begin{pmatrix} 6 & 4 & 3 & 5 \\ 4 & 5 & 4 & 0 \\ 3 & 5 & 5 & 2 \\ 3 & 0 & 1 & 3 \end{pmatrix} = 2637.$$

4.6.4. **Financial capability-based digraph**:The co-factor of quality characteristic financial capability is EP, FS.

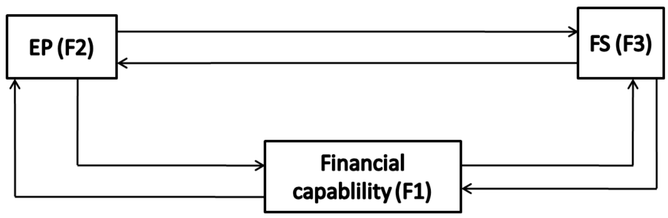

FIGURE 7. Financial capability-based digraph

Variable permanent matrix for financial capability

$$VPM - A_4 = \begin{pmatrix} F_1 & F_{12} & F_{13} \\ F_{21} & F_2 & F_{23} \\ F_{31} & F_{32} & F_3 \end{pmatrix}.$$

Now,

$$VPM - A_4 = \begin{pmatrix} 7 & 5 & 6 \\ 4 & 4 & 3 \\ 5 & 2 & 5 \end{pmatrix} = 525.$$

4.6.5. **Technical and production capability-based digraph**: The co-factor of quality characteristic technical and production capability is (DC, CU)

Variable permanent matrix for technical and production capability

$$VPM - A_5 = \begin{pmatrix} T_1 & 0 & T_{13} \\ T_{21} & T_2 & T_{23} \\ T_{31} & T_{32} & T_3 \end{pmatrix}.$$

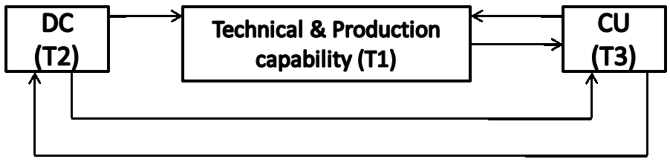

FIGURE 8. Technical and production capability-based digraph

Now,

$$VPM - A_5 = \begin{pmatrix} 4 & 0 & 1 \\ 3 & 6 & 4 \\ 4 & 2 & 4 \end{pmatrix} = 158.$$

After deriving the value of A_1, A_2, A_3, A_4 and A_5, substitute these values in the builder's quality matrix to determine the quality index of builder's quality.

$$VPM - A_3 = \begin{pmatrix} A_1 & A_{12} & 0 & A_{14} & 0 \\ A_{21} & A_2 & 0 & 0 & 0 \\ A_{31} & A_{32} & A_3 & 0 & A_{35} \\ A_{41} & A_{42} & A_{43} & A_4 & A_{45} \\ A_{51} & A_{52} & 0 & A_{54} & A_5 \end{pmatrix} = \begin{pmatrix} 5263 & 4 & 0 & 5 & 0 \\ 3 & 1296 & 0 & 0 & 0 \\ 5 & 3 & 2637 & 0 & 1 \\ 3 & 2 & 2 & 525 & 3 \\ 3 & 1 & 0 & 2 & 158 \end{pmatrix}$$

and $VPM = 1.49209444e + 15$.

5. CONCLUSIONS, LIMITATIONS AND FUTURE WORK

In this paper, a methodology for evaluation of builder's quality is proposed using a digraph and matrix method. It is a very useful tool for rating the builder's performance in terms of numerical index. The highlights of the paper are identification of five quality characteristics which are useful to characterize builder's performance in a manufacturing industry namely quality, cost, service, financial capability, technical & production capability. A model tree is developed indicating factors and co-factors affecting selection of a builder. The theoretical graph methodology consists of the digraph representation, matrix representation and permanent function representation. Digraph is the visual representation of the quality characteristics and their interdependence. Matrix is the mathematical conversion of the digraph to reduce the complexity and permanent function in the mathematical model, which helps in determining the numerical index. Hence, these approaches represented the rating of builder's quality in quantitative terms. Thus, the methodology is helpful in comparing different builders on the basis of their performance. The decision made on the basis of this approach is more precise and chances for wrong selection of builder are reduced. The paper covered a good number of research papers during literature survey so it is beneficial for others to understand the contributions of numerous researchers. As per the literature survey,nearly 37 of companies had indicated that they failed to achieve any increase in revenue after focusing on builder's quality. However, 34 reported an increase of 1–5, 17 reported 5–10 increase, 9 reported 11–20 increase and 3 reported more than 20 increase in revenue. The GTA can also be applied in combination with other approaches like analytic hierarchy process to make the selection process more precise.

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REFERENCES

[1] J. SURARAKSA, K. SUP SHIN: *Comparative Analysis of Factors for Supplier Selection and Monitoring:The Case of the Automotive Industry in Thailand*, Sustainability, **11**(2) (2019), 981-999.

[2] S. E. FAWCETT: *Purchasing: Acquiring the Best Inputs*, In: Swamidass P.M. (eds) Encyclopedia of Production and Manufacturing Management, Springer, Boston, MA, 200..

[3] R. JIN, Y. ZOU, K. GIDADO, P. ASHTON: *Painting, Scientometric analysis of BIM-based research in construction engineering and management*, Engineering, Construction and Architectural Management, **26**(8) (2019), 1750-1776.

[4] P. IVANA, G. PERTA, S. ANDREA, K. MILJAN, G. KREŚIMIR, K. JOŽE: *Analysis of Implementation of Integrated Information Systems in Croatian Wood Processing Industry*, Drvna Industrija, **70** (2019), 129-139.

[5] G. WU, X. ZHAO, J. ZUO, G. ZILLANTE: *Effects of contractual flexibility on conflict and project success in megaprojects*, International Journal of Conflict Management, **29**(2) (2018), 253-278.

[6] N. DEO, P. GUPTA: *Graph-theoretic Web algorithms: An overview*, International Workshop on Innovative Internet Community Systems (Springer, Berlin, Heidelberg), (2001), 91-102.

[7] K. J. BURCH: *Chapter 8 - Chemical applications of graph theory, In Developments in Physical and Theoretical Chemistry*, Mathematical Physics in Theoretical Chemistry. (2019), 261-294.

[8] D. BARBARASH: *Representation stigma: Perceptions of tools and processes for design graphics*, Frontiers of Architectural Research. **5**(4) (2016), 417-488.

[9] S. DEEP, L. SIMON, M. ASIM, A. RAHIMZADEH, S. AL-HAMDANI: *An Analytical Study of Critical Factors Affecting Contractor Efficiency in Construction Projects in Indian Scenario*, Organization, Technology and Management in Construction: An International Journal, **10**(1) (2018), 1794-1802.

[10] T. K. GUPTA, V. SINGH: *A Framework to Measure the Service Quality of Distributor with Fuzzy Graph Theoretic Approach*, Journal of Industrial Engineering, (2016), 1-12.

[11] R. ANGLES, C. GUTIERREZ: *Survey of graph database models*, ACM Computing Surveys (CSUR), **40**(1) (2008), 1-39.

[12] A. BAYKASOGLU: *A review and analysis of Graph theoretical-matrix permanent approach for decision making with practical applications*, Artificial Intelligence Reviews, **42**(4) (2014), 573-605.

[13] C. ZHIXIANG: *Investigation of supplier/buyer coordination performance in Chinese companies*, Gestao and Producao, **11**(3) (2004), 289-298.

DEPARTMENT OF MATHEMATICS
MUTHU MASE ARTS AND SCIENCE COLLEGE
HARUR-636903, TN, INDIA
Email address: mahendranmatphd@gmail.com

DEPARTMENT OF MATHEMATICS
GOVERNMENT ARTS COLLEGE
SALEM-636001, TN, INDIA
Email address: vikramprasad20@gmail.com

DEPARTMENT OF MATHEMATICS
VIVEKANANDHA COLLEGE OF ARTS AND SCIENCE FOR WOMEN
SANKARI-637303, TN, INDIA