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Mathematical Modeling of Overall Resource Utilization Factor of Educational Institutes in the Context of Digitalization of Management for Performance Investigation

Aditya Khatri[1], Divya Nigam[2]

[1] is Research Scholar, Dept. of Management, School of Management, SAM Global University, Bhopal-MP
[2] is Assistant Professor, Dept. of Management, School of Management, SAM Global University, Bhopal-MP

Abstract

The affordability and easy accessibility of quality education plays a critically crucial role in socioeconomic development of any nation. India, at the present global geopolitical scenario, is center of interest, as the nation is full of potential and prospects due the multiple natural resource availability, democratic administration system and youth and technically sound young manpower. This signifies the importance of educational institution in the advancement and development of India. The education institutes at present scenario are not less than any professionally managed organization, as these institutions requires technical and managerial skills, strategic planning and professional approach so as to deliver the quality education to make the student of institution compatible to face global competition. In this aspect the performance of institutions became very sensitive factor which is needed to be addressed. The presented research article investigates the key factors which are accountable for the performance of the institute. The investigated and identified factors are defined and mathematically modeled in the context of digitalization of management of education institutes. The identified factors are nominated as faculty utilization factor, staff utilization factor, resource utilization factor and infrastructure utilization factor. An empirical formulation is done to drive the formulation for overall organizational resource utilization factor which is algebraic summation of all these factors. Overall organizational resource utilization factor is the final parameter for performance investigation of institute and can be used for strategic planning and performance improvement projection in different simulation software such as SPSS and DUNDAS-BI.

I. Introduction

The performance of an educational institute refers to its effectiveness and achievements in fulfilling its educational mission, objectives, and goals. It encompasses various aspects of the institute's operations, including teaching, learning, research, student support, community engagement, and overall institutional management. Performance assessment involves evaluating the institute's ability to provide high-quality education, foster student growth and development, contribute to knowledge and innovation, and maintain a positive impact on its students and the broader community. In essence, the performance of an educational institute reflects how well it is meeting its intended outcomes and fulfilling its responsibilities as an educational entity. This evaluation is often based on a combination of quantitative measures (such as academic achievement data, graduation rates, and research output) and qualitative assessments (including student and faculty feedback, program evaluations, and observations). The goal of measuring educational institute performance is to identify strengths, areas for improvement, and opportunities for growth, ultimately enhancing the institute's ability to provide a valuable and impactful educational experience.

The performance of an educational institute is multidimensional, and a combination of quantitative and qualitative measures should be used for a comprehensive assessment. Additionally, the specific factors that are most relevant can vary based on the type of educational institution and its mission. To assess the performance of an educational institute, one needs to consider various factors that contribute to its effectiveness in providing quality education and achieving its goals. These parameters are known as key performance indicators and denoted as KPI's. These are the factors, the performance of an educational institute can be scaled and can be measured.

To assess the performance of an educational institute, you'll need to consider various factors that contribute to its effectiveness in providing quality education and achieving its goals. Here are some key performance indicators (KPIs) and factors needed to be considered to investigate the performance level of the education institution:

1. Academic Excellence: Graduation and Retention Rates: High graduation rates and low dropout rates indicate the institute's ability to keep students engaged and motivated.
2. Student Achievement: Measure student performance on standardized tests, assessments, and projects to gauge their learning outcomes.

3. Academic Honors: Number of students receiving awards, scholarships, and honors for outstanding academic performance.
4. Teaching Quality: Student-Faculty Ratio: A lower ratio usually indicates better opportunities for individualized attention and support.
5. Faculty Qualifications: Assess the qualifications, expertise, and experience of the teaching staff.
6. Teacher Effectiveness: Use student evaluations, peer reviews, and classroom observations to gauge teacher effectiveness.
7. Research and Innovation: Research Output: Evaluate the quantity and quality of research publications, patents, and contributions to the academic field.
8. Innovation and Creativity: Measure the institution's ability to foster innovation and creative thinking among students and faculty.
9. Student Engagement and Satisfaction: Student Surveys: Conduct surveys to gather feedback on various aspects of the educational experience, including teaching quality, support services, facilities, and extracurricular activities.
10. Extracurricular Activities: Assess the availability and diversity of clubs, organizations, and events that enhance students' personal development.
11. Graduate Outcomes: Employment Rates: Monitor the percentage of graduates who find employment in their field of study shortly after graduation.
12. Further Education: Track the number of graduates pursuing advanced degrees or continuing education.
13. Infrastructure and Resources: Facilities: Evaluate the quality of classrooms, labs, libraries, and other facilities that support learning and research.
14. Technology Integration: Assess how well the institute integrates technology into teaching and learning processes.
15. Diversity and Inclusion & Demographic Diversity: Measure the representation of different ethnicities, genders, and socioeconomic backgrounds among students and faculty.
16. Inclusion Initiatives: Evaluate efforts to create an inclusive and welcoming environment for all students and staff.
17. Financial Stability: Budget Management: Monitor the institute's financial health, including revenue sources, expenses, and budget allocations for different departments.
18. Community Engagement: Partnerships: Assess collaborations with local businesses, organizations, and the community to provide practical learning opportunities for students.
19. Social Impact: Measure the institute's contribution to the local community through outreach programs, volunteering, and research.
20. Accreditation and Rankings: Accreditation Status: Confirm if the institute is accredited by relevant educational authorities, which often indicates adherence to quality standards.

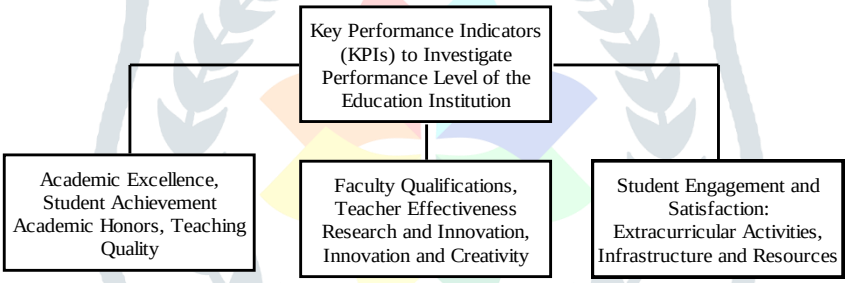

Figure-1. Key Performance Indicators to Investigate Performance Level of Institution

Figure 1, depicts the important factors needed to be considered while investigating the performance level in the context of quality, investment and of the educational institutions. Based upon these factors the performance can be estimated and recommended measure can be taken for the improvement.

II. Literature Survey

This section of the research article presents an investigative review of the technical literature in the stream of digitalization in the context of management prospective. Research article in the field of digitalization are sorted out from different reputed online research journals and are concluded in this section.

Digitalization can also improve intra-firm communication (management and shareholders, management and workers, and management and other stakeholders), saving costs (Zhai et al., 2022). The reduction of internal communication costs allows quicker information processing, lower coordination costs, fewer supervisors required (reduction in labor costs), and easier decision-making processes (Gilchrist et al. 2001; Atrostic et al. 2004; Arvanitis & Loukis 2009; Cardona et al. 2013). It can also prompt additional investments (Colecchia & Schreyer 2002), the introduction of innovations, and the development of new business models.
In the directive process, digitalized firms can build better information exchange channels, speeding up the flow of information, facilitating the communication between different internal areas, and reducing unnecessary delays (Zhai et al., 2022). In short, improved communication can result in cost reductions, better management, and enhanced innovation, and nourish other channel.
Digital tools allow firms to continuously generate, process, and analyze significant volumes of useful information (Heredia et al., 2022), thus creating opportunities for organizations to reap the benefits from analyzing these massive influxes of data (Benitez et al., 2022) and radically improving firm performance (McAfee & Brynjolfsson, 2012). This is facilitated by the strong cost decrease associated with storing, processing, and transmitting Big Data (Gu et al., 2021).

Big Data analytics provide enterprises with the means required to integrate and manage these large volumes of information. It is usually characterized by some specific dimensions such as volume, variety, and velocity (Feijóo et al., 2016).2 The challenge is that adequate skills are needed to successfully interpret data and extract value from it (Benitez et al., 2022). This can lead to the reshaping of business activities, particularly in knowledge-intensive sectors (Loebbecke & Picot 2015; Ribeiro-Navarrete et al., 2021).

Data collected from interactions with suppliers and distributors can be potentially analyzed to improve logistic and value-chain efficiencies. In this respect, Gu et al. (2021) highlight the importance of Big Data for supply chain management, as analytic practices are expected to monitor trends more precisely, to provide more accurate predictive models, and to optimize business processes.

Similarly, data obtained from internal operations can be a powerful tool for firms' optimization. The possibility of collecting, analyzing, integrating, and interpreting high quality, real-time data, fuels automation processes, predictive and forecasting tools, artificial intelligence, and robotics in many industrial sectors (Abou-foul et al., 2020). An adequate use of data can help to reduce the costs of firms, optimize resources and assets utilization, and to redesign processes (Abou-foul et al., 2020; Heredia et al., 2022).

Digital technologies provide the potential for firms to monitor production processes, locations, conditions, or uses, as well as to improve product quality (Bouwman et al., 2018; Martín-Peña et al., 2019). Big Data can also be a relevant tool for preventive maintenance, helping companies to avoid losing time and achieve smoother operations (Abou-foul et al., 2020). Human resources management is another source of internal optimization generated by data analytics (Zhou et al., 2021). As a result of all the above, internal data can promote intra-firm performance, which triggers the operational transformations depicted in channel.

Digital technologies enable the development of new production processes and practices (Mack & Faggian 2013; Zhai et al., 2022). Automatization is a key transformation in this respect (Martín-Peña et al., 2019). It can make internal processes more flexible, rational, and efficient. Agility improvements are a crucial gain derived from the incorporation of such technological advances (Škare & Soriano, 2021; Benitez et al., 2022; Orji et al., 2022). Consequently, firms can introduce standardized processes, increasing reliability, decreasing operational costs, and improving the quality of their outputs (Benitez et al., 2022).

Digital transformation contributes to improve the allocation of resources and to reduce costs (Ribeiro-Navarrete et al., 2021; Heredia et al., 2022; Zhai et al., 2022). This happens because of a better use of resources and a reduction of capital requirements, thanks to better equipment utilization and reduced inventories. From an internal perspective, digital transformation allows firms to achieve more efficient delivery and output, organization, and docking, as well as to avoid unnecessary waste of time, manpower and resources (Zhai et al., 2022). AI reduces repetitive processes in the supply chain (Abou-foul et al., 2020). Martín-Peña et al. (2019) highlight the ability of robots, flexible systems, and numerical control systems to simultaneously standardize and customize process.

Table-1. Research Gap in the Field of Digital Management Issues of Institution in India

Article Title	Outcome	Gap in the Research
Article-1 Chengqi Xia, Xinge Li, Shixiong Cao	The research investigates about a lack of scientific innovation, a widening poverty gap in terms of access to higher education, and a mismatch between supply and demand in the labor market. Practical aspects are covered n the research. Industrial expectations and skill set mismatch is mainly focused.	Only china's prospective is discussed and interpreted a global vision in totally absent from the research article. Research covers only labors class skill set at ground zero and other prospective are not addressed. Further Investigation is required.
Article-2 Luis Filipe Rodrigues, Abilio Oliveira	The research article is investigate the latest & recent developments in sustainability in higher education, seeking to understand what is happening in the areas of Management and Accounting. Article contributes to development of research area on sustainability in higher education as well as having potential implications for educators as it is useful for educational purposes.	The article did not cover professional education system and technical education system limitations and system vulnerabilities. Article is not a complete study and total investigation. Further investigation is required to address multiple domain and multi-vertical aspect of the professional education system.
Article-3 by M. Belen Calavia, Teresa Blanco, Roberto Casas	Article about presents 'Think-Create-Teach' technique (TCT) methodology to assist teachers to create instructional materials guided by DT. TCT applied and assessed through quantitative methods in a project-based learning subject with teachers.	More advance technique in the field of the education delivery among technical teachers is not covers. State of mind of teachers of professional institution is not been covers. Further research is required to address the other aspects.

III. Key Performance Indicators of Educational Institution

The performance of the educational institute or organization is depends upon the individual performance of the stack holders of organization. The collaborative performance is the overall performance of the organization. There will be significant improvement in the overall performance of the organization if the individual performance will be improved. In the present case the stack holder or process participant are as listed below upon which the overall performance will be depends:

1. Students Studying in the Institute or in the University

2. Faculty Members of the Institute or in the University
3. Staff Members of the Institute or in the University
4. Management Individuals of the Institute or in the University

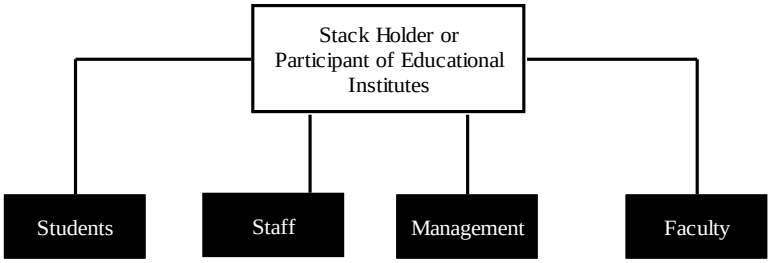

Figure-2. Stack Holders or Participant of Educational Institution contributing in performance

The management of educational institutions, including administrators, department heads, and other leadership roles, have their own set of expectations when it comes to digitalization. These expectations are enhancing operational efficiency, improving decision-making, and providing a high-quality learning experience for students. By addressing these expectations, educational management can effectively navigate the challenges and opportunities of digitalization, leading to a more efficient, adaptive, and student-centered institution.

Here are some key factors that educational management needed to consider for improving the performance and efficiency of the organization. These key performance factors are as listed below:

1. **Improved Administrative Processes:** Management expects digitalization to streamline administrative tasks such as enrollment, registration, grading, scheduling, and resource allocation. This leads to increased efficiency and reduced administrative burdens.
2. **Data-Driven Decision-Making:** Management anticipates using digital tools to collect and analyze data related to student performance, enrollment trends, faculty workload, and financial metrics. This data informs strategic decision-making and helps identify areas for improvement.
3. **Enhanced Communication:** Digitalization enables better communication within the institution, including among different departments, faculty, staff, and students. Management expects improved communication platforms to foster collaboration and transparency.
4. **Efficient Resource Allocation:** Digital systems can help management optimize resource allocation by analyzing data on classroom usage, facility maintenance, and staff deployment.
5. **Strategic Planning and Forecasting:** Management expects digital tools to aid in long-term planning and forecasting, helping to anticipate changes in student demographics, industry trends, and educational demands.
6. **Financial Management:** Management expects digital financial systems to facilitate budgeting, expense tracking, and financial reporting, leading to better financial management and accountability.
7. **Adapting to Industry Trends**: Management anticipates leveraging digitalization to keep up with industry trends in education, ensuring that the institution remains competitive and relevant.
8. **Online Learning Opportunities:** Management expects to offer a range of online courses and programs to attract a diverse student body, accommodate different learning preferences, and tap into new markets.
9. **Alumni Engagement and Fundraising:** Management expects digital platforms to help foster alumni engagement and facilitate fundraising efforts through targeted outreach and communication.
10. **Quality Assurance and Accreditation**: Management anticipates using digital systems to track and maintain compliance with quality assurance standards and accreditation requirements.
11. **Efficient Student Services:** Management expects digitalization to improve student services, including online registration, access to academic advising, counseling, and career services.
12. **Risk Management and Security:** Management anticipates implementing digital security measures to protect student and institutional data from breaches and cyber threats.
13. **Faculty and Staff Development:** Management expects digital platforms to support faculty and staff development initiatives, including online training, workshops, and opportunities for skill enhancement.
14. **Parent and Guardian Communication:** For schools, management expects digital tools to enhance communication with parents and guardians, providing them with timely updates on student progress and events.
15. **Innovation and Differentiation:** Management expects digitalization to enable the institution to innovate in its teaching methods, curriculum design, and student engagement strategies, leading to a unique and valuable educational experience.
16. **Adaptive Learning:** Management expects digital tools to enable adaptive learning, personalized education paths, and analytics-driven interventions to address individual student needs.

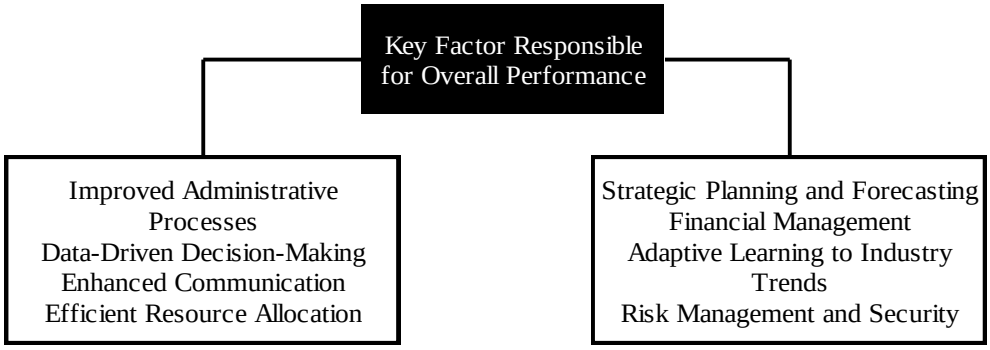

Figure-3. Key Factors contributing in performance of an Educational Institute

IV. Mathematical Modeling of Utilization Factor

The general the term "resource utilization factor" typically refers to a metric used to quantify the efficiency or utilization of a particular resource within a system or process. This factor is often used in various industries, such as manufacturing, energy, and technology, to assess how effectively a resource is being used in comparison to its maximum potential.
Resource utilization factor is calculated by dividing the actual utilization of the resource by its maximum possible utilization and expressing the result as a percentage or a decimal fraction. In mathematical terms:

$$\textbf{Resource Utilization Factor} = \left(\frac{\textbf{Actual Utilization of Available Resources}}{\textbf{Maximum Possible Utilization of Available Resource}}\right)$$

Here's a breakdown of the key components:

Actual Utilization
This refers to the real-world usage or consumption of the resource in the system or process during a given period. It could be the amount of energy consumed, the time a machine is operational, the memory used by a computer system, or any other relevant measurement.

Maximum Possible Utilization
This represents the theoretical or ideal utilization of the resource under optimal conditions. It's the highest level of utilization that the resource could achieve without any constraints or limitations.

Result
The calculated utilization factor is usually expressed as a percentage (multiplied by 100) or a decimal fraction. A utilization factor of 1 (or 100%) indicates that the resource is being used to its maximum potential, while a factor lower than 1 indicates that there is room for improvement in resource utilization.

In practical terms, understanding resource utilization factors can help businesses and organizations identify inefficiencies, optimize processes, and allocate resources more effectively. For example, a manufacturing plant might calculate the resource utilization factor for its production line to identify bottlenecks and improve overall productivity. Similarly, data centers might monitor the resource utilization factor of their servers to ensure optimal performance and energy efficiency.

In the context of the presented research article the utilization factor can be estimated by including all the available resources of the educational institution or educational organization. The available resources of the institution are as listed below:

1. Faculty Utilization Factor – FUTF

Faculty members are the main participant of the institutional organizations. The salary package of the high quality faculty staff is very high; in the context optimal utilization of the faculties of the organization is the factor which can improve the performance of the organization. The faculty member utilization factor can be estimated as below:

$$\textbf{FUTF} = \textbf{Faculty Utilization Factor} = \left(\frac{\textbf{Actual Work Load on Faculty Mambers}}{\textbf{Maximum Possible Work Load on Faculty Members}}\right)$$

2. Staff Utilization Factor – SUTF

Numbers of the staff is working in different department of the educational organization. Optimal utilization of the available staff member is mandatory for financial management of performance enhancement. This factor can be calculated as below:

$$\textbf{SUTF} = \textbf{Staff Utilization Factor} = \left(\frac{\textbf{Actual Work Load on Staff Mambers}}{\textbf{Maximum Possible Work Load on Staff Members}}\right)$$

3. Infrastructure Resources Utilization Factor – INFUTF

Infrastructures of the educational organizations are generally very big a huge amount of investment is required for the same. But this is noted that most of the Infrastructures resource is only utilized when in institute is in working slot during class conduction, else most of the other time this is not in use, management is needed to use the same infrastructure with maximum possible exploitations. This can

be calculated as below:

$$\text{INFUTF} = \text{Infrastructure Resource Utilization Factor} = \left(\frac{\text{Actual Utilization of Infrastructure}}{\text{Maximum Possible Utilization of Infrastructure}}\right)$$

4. Associated Resources Utilization Factor- ASFUTF

Each Educational Organization has numbers of associated infrastructure such as computer labs, conference hall, seminar hall and others. These resources are most of the time ideal, as an approximation 90% these resources are in ideal condition. This aspect needed to be addressed by management so that the utilization can improved and hence the overall performance of the organization.

$$\text{ASFUTF} = \text{Faculty Utilization Factor} = \left(\frac{\text{Actual Utilization of Associated Infrastructure}}{\text{Maximum Possible Utilization of Associated Infrastructure}}\right)$$

V. Mathematical Formulation of Overall Utilization Factor

The overall utilization factor will be the algebraic summation of all the above defined and formulated utilization factor.
This is denoted as OUTFACT in the presented article.
Mathematically this can be formulated as below:

Overall Utilization Factor is equal to Algebraic Summation of Faculty Member of the Institution, Staff Member of the Institution, Infrastructure Resources of Institution, Associated Resources of Institution and the resut is divided by 4.

Mathematical Formulation is done in the next paragraph.

$$\text{Overall Utilization Factor} = \text{OUTFACT} = \frac{(\text{FUT} + \text{SUT} + \text{INFUT} + \text{ASFUT})}{4}$$

VI. Conclusion

The presented research article the importance of resources utilization factor of any organization for optimal and efficient performance of the organization. The article mainly focus about resources utilization factor of an educational institutions, which are not less than any professionally managed organization in any respect to make student compatible to face global competition. A systematic review of literature concerning to the title of the article is presented and research gaps in the respective filed is preciously detected and tabulated with proper highly cited research articles from reputed online journals. Utilization factor is discussed, defined and formulated in the context of common organization. Factors accountable for efficient utilization factor had been detected in the context of educational organization. Individual utilization factor that is Faculty Member of the Institution (FUT), Staff Member of the Institution (SUT), Infrastructure Resources of Institution (INFUT) and Associated Resources of Institution (ASFUT) is defined and formulated. The overall utilization factor is defined and formulated. The outcome of the research article is of great importance to scale the performance of any educational organization on a standard pointer.

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Aditya Khatri is a distinguished and highly-regarded educationist in Central India. He graduated in the year 2011-12 from a Government University with a degree in the Science stream. Subsequently, he pursued postgraduate studies in the field of Management from a prestigious professional university in Central India. During his management studies; his research was focused on the enhancement of educational quality and management of educational organization. For nearly the past decade, Mr. Aditya Khatri has been actively contributing to the field of professional education in Central India, demonstrating unwavering dedication to the betterment of Indian society. Currently, he holds the position of Doctoral Research Scholar at SAM Global University, located in Raisen, Madhya Pradesh. His ongoing doctoral research investigates the pivotal role of digitalization in the operation and management of educational institutions, with a specific emphasis on the Indore Region. At present he is deputy director of Guru Vashishtha Education College, Dewas (M.P.)-India.