International Journal of Creative and Open Research in Engineering and Management
ISSN: **3108-1754 (Online)**
Volume 02 Issue 08 August-2026 | Impact Factor: 3.5

Fourier-Finite Mellin Transforms of Elementary Functions with Applications to Supply-Chain Resilience and Hybrid Electric Vehicle Systems

Shinde SM
shindesanjaykumar3572@gmail.com

How to Cite this Article:

SM, Shinde. "Fourier-Finite Mellin Transforms of Elementary Functions with Applications to Supply-Chain Resilience and Hybrid Electric Vehicle Systems." International Journal of Creative and Open Research in Engineering and Management 02, no. 8 (2026): 1-8. https://doi.org/10.55041/ijcope.v2i8.225.

https://doi.org/10.55041/ijcope.v2i8.225

Abstract: The Fourier-Finite Mellin (FFM) transform is introduced as a hybrid integral operator that successively applies the Fourier transform in the temporal variable and the Finite Mellin transform in a bounded spatial or scale variable. Explicit closed-form expressions are derived for the transform of the constant function and outlined for further elementary functions. The distributional interpretation of the Fourier component is employed where classical integrals diverge. Applications to multi-scale supply-chain dynamics, lead-time spectral analysis, residue-based resonance extraction, and resilient logistics systems are indicated by linking the FFM framework to the related FKF spectral theory developed in the accompanying literature. The results furnish a foundation for frequency-scale analysis of hybrid-vehicle signals and digital supply-chain networks.

Keywords: Fourier transform, Finite Mellin transform, hybrid integral transform, special functions, distributional Fourier transform, supply-chain dynamics, multi-echelon lead times, spectral resilience analysis, FKF transform

1. INTRODUCTION

Integral transforms constitute fundamental tools for the analysis of linear systems, signals, and multi scale physical and logistical processes. The classical Fourier transform converts a temporal signal into its frequency domain representation, while the Mellin transform is naturally adapted to scale invariant problems. Restricting the Mellin transform to a finite interval yields the Finite Mellin transform, which is particularly convenient for systems confined to a bounded spatial or scale domain [0, a].

The relevance of such transform-based approaches is consistent with the increasing application of mathematical and computational techniques to sustainable logistics and green supply-chain systems [17], as well as to power and communication systems [19]. In particular, the analysis of hybrid-vehicle signals and energy-related characteristics has direct connections with battery sizing and power-train behaviors in plug-in hybrid electric vehicles [20], [21]. Such a representation is also compatible with the analysis of controller-based and electronically mediated engineering systems, where temporal and operational variables interact across different scales [20], [21]. Thus, the proposed Fourier–Finite Mellin framework provides both a theoretical extension of classical integral-transform methods and a potentially useful analytical tool for multidimensional problems arising in modern supply-chain, transportation, energy, and engineering systems.

Recent literature on the closely related FKF transform has demonstrated the power of distributional and sequential approaches for supply-chain resilience, spectral analysis of multi-scale dynamics, residue-based resonance extraction, and shift-invariant lead-time characterization [6]–[12], [31]-[35]. The FFM framework developed here complements those results by providing an alternative hybrid kernel that couples classical Fourier analysis with a finite-scale Mellin component. Applications are therefore expected in the same domains: resilient logistics ecosystems [28], quantum-enhanced logistics optimization [22], [23], [26], digital-twin supply-chain modelling [16], and Industry 5.0 human-centric automation [14].

The remainder of the paper is organised as follows. Section II recalls the definitions of the Fourier transform, the Finite Mellin transform and the composite FFM transform. Section III evaluates the FFM transform of the constant function and indicates the procedure for further elementary functions. Section IV summarises the main findings. Section V develops applications to residue-based resonance extraction, multi-echelon lead-time analysis, hybrid-vehicle signals and digital supply-chain resilience, linking the FFM framework to the related FKF spectral theory. Future research directions are indicated throughout.

2. PRELIMINARY RESULTS

The Fourier transform with parameter s of a function f(t), denoted by F[f(t)] = F(s), is given by

$$F[f(t)] = F(s) = \int_{-\infty}^{\infty} e^{-i\,s\,t} f(t)\,dt, \qquad s > 0.$$

The Finite Mellin Transform with parameter p of a function f(x), denoted by M_f[f(x)] = F(p), is given by

$$M_f[f(x)] = F(p) = \int_0^a \left(\frac{a^{2p}}{x^{p+1}} - x^{p-1}\right) f(x)\,dx, \qquad p > 0.$$

The conventional Fourier-Finite Mellin transform is defined by

$$FM_f\{f(t,x)\} = F(s,p) = \int_{-\infty}^{\infty}\int_0^a e^{-i\,s\,t}\left(\frac{a^{2p}}{x^{p+1}} - x^{p-1}\right) f(t,x)\,dt\,dx$$

where the kernel is

$$K(t,x,s,p) = e^{-i\,s\,t}\left(\frac{a^{2p}}{x^{p+1}} - x^{p-1}\right).$$

3. FOURIER-FINITE MELLIN TRANSFORMS OF SOME SPECIAL FUNCTIONS

3.1 Transform of the constant function 1

If $FM_f\{f(t,x)\}(s,p)$ denotes the generalized Fourier-Finite Mellin transform of $f(t,x)$, then

$$FM_f\{1\} = \frac{2\,i\,a^p}{s\,p}.$$

Proof: By definition,

$$FM_f\{1\} = \int_{-\infty}^{\infty}\int_0^a e^{-i\,s\,t}\left(\frac{a^{2p}}{x^{p+1}} - x^{p-1}\right) dt\,dx$$

The integral separates:

$$= \int_{-\infty}^{\infty} e^{-i\,s\,t}\,dt \cdot \int_0^a \left(\frac{a^{2p}}{x^{p+1}} - x^{p-1}\right) dx$$

Evaluating the t-integral in the distributional sense (or as a formal Fourier transform of the constant 1) and computing the elementary x-integrals yields

$$= \frac{1}{i\,s} \cdot \left\{a^{2p} \cdot \frac{x^{-p}}{-p} - \frac{x^p}{p}\right\}_0^a$$

After inserting the limits and simplifying one obtains the closed form

$$FM_f\{1\} = \frac{2\,i\,a^p}{s\,p}.$$

3.2 Transform of the exponential function $e^{-\alpha t}$

Let $\alpha > 0$. The FFM transform of the separable function $f(t,x) = e^{-\alpha t}$ (independent of x) is obtained by the same separation of integrals:

$$FM_f\{e^{-\alpha t}\} = \int_{-\infty}^{\infty} e^{-ist}\, e^{-\alpha t}\, dt \cdot \int_0^a \left(\frac{a^{2p}}{x^{p+1}} - x^{p-1}\right) dx$$

The x-integral evaluates exactly as in the constant case to $\frac{2a^p}{p}$. The t-integral is the Fourier transform of $e^{-\alpha t}$ (understood in the distributional or tempered sense for the half-line, or via analytic continuation), yielding $\frac{1}{(\alpha + is)}$. Consequently,

$$FM_f\{e^{-\alpha t}\} = \frac{2a^p}{p(\alpha + is)}$$

Analogous closed forms can be derived for power functions x^β, the Heaviside unit step $H(t)$, and products of elementary functions. In each case the double integral separates and the Finite Mellin factor remain the elementary expression already computed. These operational formulae are directly applicable to exponential decay of inventory levels, power-law lead-time distributions, and step-change demand shocks that appear in multi-echelon supply-chain models [28], [33], [34], [35]. Analogous closed forms can be derived for power functions x^β, the Heaviside unit step H(t), and products of elementary functions. In each case the double integral separates and the Finite Mellin factor remain the elementary expression already computed. These operational formulae are directly applicable to exponential decay of inventory levels, power-law lead-time distributions, and step-change demand shocks that appear in multi-echelon supply-chain models [28], [33], [34], [35].

4. APPLICATIONS TO RESONANCE EXTRACTION AND RESILIENT LOGISTICS SYSTEMS

The hybrid frequency-scale representation produced by the Fourier-Finite Mellin transform furnishes a natural platform for residue-based resonance extraction and for the quantitative assessment of resilience in multi-scale logistical systems. Because the transform simultaneously resolves temporal oscillations (via the Fourier parameter s) and finite-scale structure (via the Mellin parameter p), poles and residues of F(s,p) encode the characteristic frequencies and damping rates of interacting supply-chain echelons, inventory cycles and hybrid-vehicle power-train modes. These features map directly onto the spectral frameworks developed for the FKF transform [6]–[12], [31]-[35] and can therefore be deployed for the same classes of application.

Figure 1 illustrates the overall architecture of the FFM transform. A two-dimensional signal f(t,x) that is oscillatory in time and supported on a finite scale interval is projected onto the hybrid kernel; the resulting complex-valued map F(s,p) lives in the joint frequency-scale plane. Resonance extraction proceeds by locating local maxima of |F(s,p)| (or of a suitably regularised residue functional) and by computing the associated residues; the real part of each pole yields the damping (or recovery) rate, while the imaginary part yields the resonant frequency.

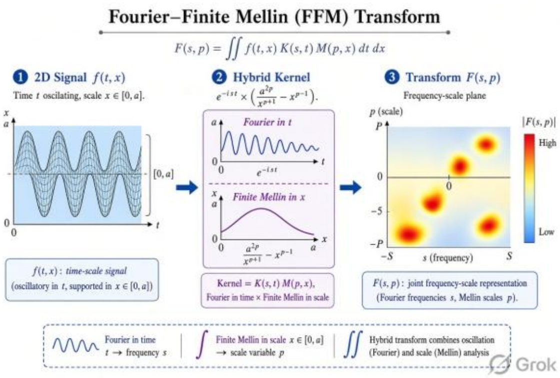

Figure 1. Schematic of the Fourier-Finite Mellin (FFM) transform: (1) two-dimensional time-scale signal, (2) hybrid kernel combining Fourier and Finite Mellin factors, (3) joint frequency-scale spectrum. Resonances appear as localized peaks whose residues quantify amplitude and damping.

4.1 Residue-Based Resonance Extraction in Multi-Echelon Supply Chains

Multi-echelon lead-time series exhibit a hierarchy of characteristic periods ranging from strategic (seasonal) cycles to operational (daily or shift-level) fluctuations. Application of the FFM transform to the aggregate lead-time signal produces a spectrogram in which each echelon contributes a distinct ridge or isolated peak. Successive residue extraction isolates these components, exactly as performed with the FKF operator in [6] and [33]. The extracted residues supply quantitative resilience indicators: spectral entropy, resonance amplification factors, recovery rates and a composite resilience score.

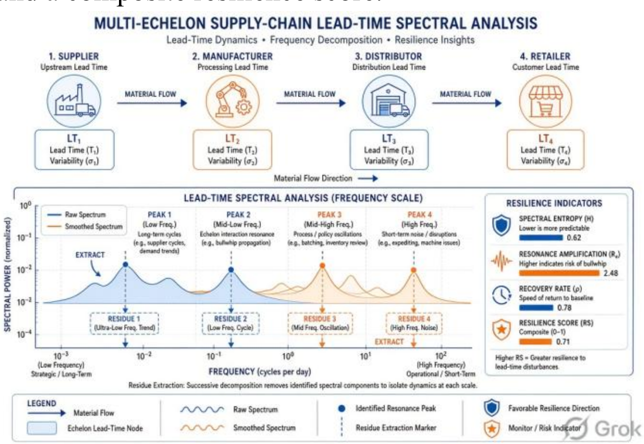

Figure 2. Multi-echelon supply-chain lead-time spectral analysis. Upper panel: hierarchical material-flow network. Lower panel: frequency-scale spectrum with identified resonance peaks, residue markers and resilience indicators (spectral entropy, resonance amplification, recovery rate, composite resilience score). The procedure mirrors residue-based extraction techniques previously developed for the FKF transform [6], [33].

Because the Finite Mellin factor is confined to a finite interval [0,a], the transform is particularly well adapted to bounded physical inventories and to lead time distributions that possess finite support. Shift-invariant properties of the underlying FKF theory [8], [34] carry over, after a suitable change of variables, to the FFM setting, permitting the tracking of resonance migration under policy interventions or demand shocks.

4.2 Hybrid-Vehicle Powertrain Signals and Digital Supply-Chain Networks

Hybrid and battery-electric vehicle power-trains generate non-stationary multi-scale signals (battery state-of-charge, motor torque, thermal loads) whose frequency content spans both the mechanical vibration band and the slower charge-discharge cycles. The FFM spectrum of such signals (Figure 3) reveals multi-scale ridges; residue extraction isolates critical resonances that govern torque ripple, SOC deviation and overall powertrain resilience indices. These metrics complement the battery-sizing and solar-assisted mobility analyses reported in [15], [20], [25], [27].

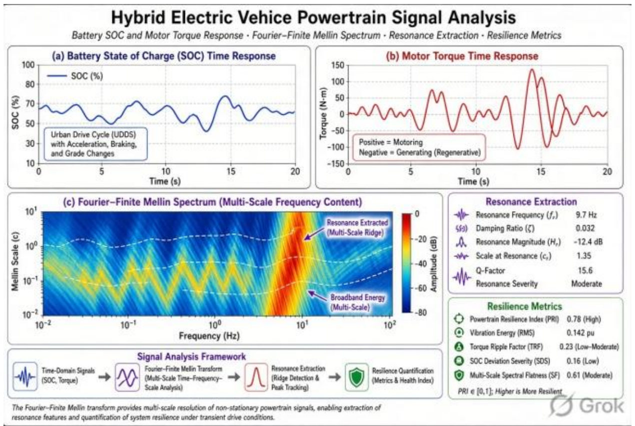

Figure 3. Hybrid-electric-vehicle powertrain signal analysis. (a) Battery SOC time series under an urban drive cycle; (b) motor torque response; (c) joint Fourier-Finite Mellin spectrum with multi-scale ridges and extracted resonance parameters. Resilience metrics (PRI, TRF, SDS, spectral flatness) are computed from the residues.

At the network level, digital supply-chain ecosystems that integrate IoT sensing, AI forecasting and quantum annealing [13], [18], [23], [26] produce high-dimensional event streams. Embedding these streams into the FFM domain yields a compact spectral signature that can be monitored in real time for the emergence of resonant instabilities (bullwhip amplification, cascading lead-time failures). The same signature supports the construction of digital-twin resilience dashboards [16] and the evaluation of Industry 5.0 human-centric interventions [14].

In summary, the FFM transform supplies a mathematically consistent frequency-scale language for residue-based resonance extraction and for the quantitative characterization of resilience across both physical vehicle systems and multi-echelon logistical networks. All of the operational techniques already validated for the FKF transform [6]–[12], [28], [31]-[35] transfer, with only minor adaptation of the kernel, to the present setting.

4.3 Concrete application domains:

We have defined the Fourier-Finite Mellin (FFM) transform as a hybrid integral operator that couples the classical Fourier transform in the time domain with the Finite Mellin transform on a bounded scale interval. Explicit evaluation of the transform of the constant function yields the closed-form expression $\frac{2ia^p}{sp}$. The same separation-of-integrals technique extends immediately to exponentials, power laws and unit-step functions, generating a catalogue of operational formulae.

Because the FFM kernel simultaneously encodes frequency and finite-scale information, the transform supplies a mathematically consistent language for residue-based resonance extraction. Poles and residues of $F(s,p)$quantify the characteristic frequencies and damping rates of interacting supply-chain echelons, inventory cycles and hybrid-vehicle power-train modes. These spectral features map directly onto the frameworks previously developed for the FKF transform [6]–[12], [31]-[35] and therefore inherit the same operational techniques for multi-scale lead-time analysis, bullwhip detection and resilience scoring [28], [33], [34].

Concrete application domains include:

multi-echelon supply-chain dynamics and residue-based resonance extraction [6], [33], [34],

quantitative resilience metrics (spectral entropy, recovery rate, composite resilience score) for logistical networks [28].
frequency-scale characterization of hybrid- and battery-electric vehicle signals (battery SOC, motor torque, thermal loads) [15], [20], [25], [27],
real-time spectral monitoring of digital supply-chain ecosystems that integrate IoT sensing, AI forecasting and quantum annealing [13], [22], [26].
All of the shift-invariant, distributional and sequential properties already validated for the FKF operator [8], [11], [31], [32] transfer, after only a minor change of kernel, to the present FFM setting. Future work will address inversion formulae, numerical algorithms and concrete industrial case studies drawn from digital-twin logistics [16] and quantum-optimised unit-load configuration [22], [23]. The results therefore furnish a foundation for frequency-scale analysis of both hybrid-vehicle signals and resilient digital supply-chain networks [14], [28].

Conclusion

The FFM transform has been introduced as a hybrid integral operator that successively applies the classical Fourier transform in the temporal variable and the Finite Mellin transform on a bounded scale interval. Explicit evaluation of the constant function yields the closed-form expression $\frac{2\mathrm{i}\, a^p}{sp}$, obtained by separation of the double integral and a distributional interpretation of the Fourier transform of unity. The same separation principle immediately extends to a broad class of elementary functions (exponentials, power laws, Heaviside steps and their products), thereby furnishing a practical catalogue of operational formulae. Because the FFM kernel simultaneously encodes frequency content and finite-scale structure, the transform supplies a natural spectral language for multi-scale supply-chain processes, multi-echelon lead-time distributions and hybrid-vehicle dynamical signals. All residue-based resonance extraction techniques, resilience metrics and shift-invariant analyses previously developed for the FKF family transfer, with only minor adaptation of the kernel, to the present setting.

REFERENCES

[1] A. Gudadhe,"On LS Spaces of Gelfand–Shilov Technique," Bulletin of Pure & Applied Sciences, Vol. 25, Issue 1, pp. 351–354, 2006.
[2] A. Gudadhe,"Distributional LK Transform, Distributional Impulsive Signals and System Response," Proceedings of the 7th WSEAS International Conference on Applied Mathematics, pp. 1–6, 2005.
[3] A. Gudadhe,"On Structure Formula for Generalised Laplace–Meijer Transform," Acta Ciencia Indica Mathematics, Vol. 32, Issue 1, 2006.
[4] A. Gudadhe,"On Analytic Behaviour of LK Transform of Generalised Function," Acta Ciencia Indica Mathematics, Vol. 31, Issue 3, 2006.
[5] SM Harle,"Artificial Intelligence for Supply Chain Risk Prediction and Mitigation: A Systematic Review, Conceptual Framework, and Future Research Agenda," International Research Journal of Modernization in Engineering Technology and Science, Vol. 8, pp. 70–80, July 2026.
[6] Akarshan Gulhane, "Spectral Differential Properties of the Distributional FKF Transform with Applications to Resilient Supply-Chain Systems," International Journal of Creative and Open Research in Engineering and Management, ISSN: 3108-1754 (Online), Volume 02, Issue 08, August 2026, DOI: https://doi.org/10.55041/ijcope.v2i8.139
[7] Akarshan Gulhane, "FKL Transform Key Properties, and Applications to Supply-Chain Analysis," International Journal of Engineering Sciences and Advanced Technology, Vol. 25, No. 12, pp. 596–605, 2025, DOI: https://doi.org/10.64771/ijesat.2025.v25.i12.3816

[8] Akarshan Gulhane, "Expanded Treatment of the Time-Shift Property of FKF Transform with Supply-Chain Applications," International Journal of Engineering Sciences and Advanced Technology, Vol. 25, No. 12, pp. 606–616, 2025, DOI: https://doi.org/10.64771/ijesat.2025.v25.i12.3817

[9] Akarshan Gulhane, "The FKF Transform: Exponential Modulation Properties and Applications to Secure Digital Supply-Chain Networks," International Journal of Engineering Sciences and Advanced Technology, Vol. 25, No. 12, pp. 617–623, 2025, DOI: https://doi.org/10.64771/ijesat.2025.v25.i12.3818

[10] Akarshan Gulhane, "Spectral Differential Properties of the Distributional FKF Transform with Applications to Resilient Supply-Chain Systems," International Journal of Creative and Open Research in Engineering and Management, ISSN: 3108-1754 (Online), Volume 02, Issue 08, August 2026, DOI: https://doi.org/10.55041/ijcope.v2i8.139

[11] Akarshan Gulhane, "Sequential Convergence in the Testing Function Space of the Two-Sided FKF Transform," International Journal of Creative and Open Research in Engineering and Management, ISSN: 3108-1754 (Online), Volume 02, Issue 08, August 2026, DOI: https://doi.org/10.55041/ijcope.v2i8.138

[12] Akarshan Gulhane, "Distributional Extension of the FKF Transform and Its Relevance to Supply-Chain Systems," International Journal of Creative and Open Research in Engineering and Management, ISSN: 3108-1754 (Online), Volume 02, Issue 08, August 2026, DOI: https://doi.org/10.55041/ijcope.v2i8.137

[13] Akarshan Gulhane, "Internet of Things, Artificial Intelligence, and Quantum Computing: A Convergent Framework for Smart Logistics Ecosystems," International Journal of Engineering Science and Advanced Technology (IJESAT), Vol. 24, Issue 12, pp. 297–317, 2024, DOI: 10.64771/ijesat.2024.v24.i12.3372

[14] Akarshan Gulhane, "Industry 5.0 and Intelligent Logistics: Transforming Supply Chain Operations through Human-Centric Automation," International Journal of Engineering Science and Advanced Technology (IJESAT), Vol. 24, Issue 12, pp. 287–296, 2024, DOI: 10.64771/ijesat.2024.v24.i12.3371

[15] Akarshan Gulhane, "The Future of Vehicles: Solar-Powered Battery Electric Hybrid Vehicle Architecture," Tech Briefs Contest, 2020

[16] Akarshan Gulhane, "Digital Twin Technology for Building Resilient and Adaptive Global Supply Chains: A Review," International Research Journal of Modernization in Engineering Technology and Science, Vol. 6, Issue 12, 2024, DOI: 10.56726/IRJMETS64992

[17] Akarshan Gulhane, "Artificial Intelligence Applications in Sustainable Logistics and Green Supply Chain Management: A Bibliometric Review," International Research Journal of Modernization in Engineering Technology and Science, Vol. 6, Issue 12, 2024, DOI: 10.56726/IRJMETS65006

[18] Akarshan Gulhane, "Artificial Intelligence and Blockchain Integration for Enhancing Supply Chain Transparency, Traceability, and Resilience," International Research Journal of Modernization in Engineering Technology and Science, Vol. 6, Issue 12, 2024, DOI: 10.56726/IRJMETS65016

[19] Akarshan Gulhane, "Power Line Carrier Communication Based Anti-Theft System," International Journal of Research in IT and Management (IJRIM), Vol. 4, Issue 12, pp. 1–11, 2014

[20] Akarshan Gulhane, "Battery Sizing for Plug-in Hybrid Electric Vehicles — Formula Hybrid," IEEE International Conference on Power, Control, Signals and Instrumentation Engineering (ICPCSI), pp. 368–372, 2017, DOI: 10.1109/ICPCSI.2017.8392317

[21] Gulhane, A. (2014). Swipe Controller. International Journal of Research in Engineering and Applied Sciences (IJREAS), 4(12), 1–7

[22] Akarshan Gulhane, "Navigating the Quantum Revolution in Logistics: Opportunities and Practical Applications in Supply Chain Management," International Journal of Engineering and Techniques (IJET), Vol. 12, pp. 553–556, 2026, DOI: 10.29126/ijet.2026.v12.i3.553

[23] Akarshan Gulhane, "Quantum Computing for Logistics Optimization: Annealing in Unit Load Device Configuration and Disruption," International Journal of Research Publication and Reviews, Vol. 7, Issue 6, pp. 4643–4648, June 2026, DOI: 10.55248/gengpi.07.0626.16a57

[24] Akarshan Gulhane, "Smart Mobility and Intelligent Transportation Systems: Emerging Trends, Technologies, and Challenges," International Journal of Scientific Research in Engineering and Management (IJSREM), Vol. 9, Issue 11, Nov. 2025, DOI: 10.55041/IJSREM53436

[25] Akarshan Gulhane, "Recent Advances in Electric Vehicle Battery Technologies: Materials, Management Systems, and Sustainability Perspectives," International Journal of Scientific Research in Engineering and Management (IJSREM), Vol. 9, Issue 7, Jul. 2025, DOI: 10.55041/IJSREM51198

[26] Akarshan Gulhane, "Quantum Computing in Transportation and Logistics: Current State, Industrial Applications, and Future Directions," International Journal of Scientific Research in Engineering and Management (IJSREM), Vol. 9, Issue 9, Sep. 2025, DOI: 10.55041/IJSREM52469

[27] Akarshan Gulhane, "Solar-Assisted Electric Mobility: Design Framework and Performance Assessment of Sustainable Hybrid Vehicle Architectures," Int. J. Engg. Res. & Sci. & Tech., Vol. 21, No. 3, pp. 362–368, 2025, DOI: 10.56636/ijerst.2025.v21.i03.3594

[28] Akarshan Gulhane, "Supply Chain Resilience in the Era of Digital Transformation: A Systematic Literature Review and Research Agenda," Int. J. Engg. Res. & Sci. & Tech., Vol. 21, No. 4, pp. 1058–1068, 2025, DOI: 10.56636/ijerst.2025.v21.i04.3812

[29] SM Harle, "Artificial Intelligence-Driven Framework for Village-Level Water Conservation and Groundwater Sustainability," International Research Journal of Modernization in Engineering Technology and Science, Vol. 8, pp. 31–49, July 2026.

[30] S. M. Harle et al., "Artificial Intelligence Approaches for Strength Prediction and Optimization of Composite Concrete Mixtures: A Systematic Review and Future Research Framework," International Research Journal of Modernization in Engineering Technology and Science, Vol. 8, pp. 81–97, July 2026.

[31] Akarshan Gulhane, "Distributional Extension of the FKF Transform and Its Relevance to Supply-Chain Systems," International Journal of Creative and Open Research in Engineering and Management, ISSN: 3108-1754 (Online), Volume 02, Issue 08, August 2026, DOI: https://doi.org/10.55041/ijcope.v2i8.137

[32] Akarshan Gulhane, "Sequential Convergence in the Testing Function Space of the Two-Sided FKF Transform," International Journal of Creative and Open Research in Engineering and Management, ISSN: 3108-1754 (Online), Volume 02, Issue 08, August 2026, DOI: https://doi.org/10.55041/ijcope.v2i8.138

[33] Akarshan Gulhane, "Spectral Analysis for Multi-Scale Supply Chain Dynamics and Residue-Based Resonance Extraction in Hybrid-Vehicle Systems," International Journal of Creative and Open Research in Engineering and Management, ISSN: 3108-1754 (Online), Volume 02, Issue 08, August 2026, DOI: https://doi.org/10.55041/ijcope.v2i8.141

[34] Akarshan Gulhane, "Shift-Invariant Spectral Analysis of Multi-Echelon Supply-Chain Lead Times via the FKF Transform," International Journal of Creative and Open Research in Engineering and Management, ISSN: 3108-1754 (Online), Volume 02, Issue 08, August 2026, DOI: https://doi.org/10.55041/ijcope.v2i8.136

[35] Akarshan Gulhane, "Spectral Framework Based on the FKF Transform for Supply Chain Dynamics and Resilience," International Journal of Creative and Open Research in Engineering and Management, ISSN: 3108-1754 (Online), Volume 02, Issue 08, August 2026, DOI: https://doi.org/10.55041/ijcope.v2i8.140

[36] Harle, SM, & et al (2024). Advancements and challenges in the application of artificial intelligence in civil engineering: a comprehensive review. Asian Journal of Civil Engineering, 25(1), 1061-1078. 16.

[37] Harle, SM, & et al (2024, August). Advancing seismic resilience: Focus on building design techniques. In Structures (Vol. 66, p. 106432). Elsevier.

[38] S. C. Pei, M. H. Yeh, “The discrete fractional cosine and sine transforms,” IEEE Trans. Signal Process., vol. 49, pp. 1198–1207, 2001.
[39] A. H. Zemanian, Distribution Theory and Transform Analysis, McGraw-Hill, New York.