SHAMOON COLLEGE OF ENGINEERING

Industrial Engineering and Management Department

Applied IEM Workshop 2026

September 2

Book of Abstracts

Welcome Address

We welcome you to SCE- Shamoon College of Engineering Campus Beer Sheva for the Applied IEM Workshop 2026. We are pleased to host the workshop this year after the successful previous one in 2023. The applied IEM Workshop is a gathering of academics and practitioners covering a wide range of applied research in Industrial Engineering and Management. We have attempted to arrange a wide range of talks during the workshop day that covers the fields of Operation Research, Information Systems, and Economics.
A complete list of the abstracts of the papers to be presented at the conference can be found in this book.
We hope that you will enjoy the meeting.

Yizhaq Minchuk, Elroi Hadad and Alisa Voslinsky
The Organizing Committee

Keynote

Dvir Shabtay **(BGU) -** **Fairness in Repetitive Scheduling Problems**

Recent research found that fairness plays a key role in customer satisfaction. Therefore, many manufacturing and services industries have become aware of the need to treat customers fairly. Still, there is a huge lack of models that enable industries to make operational decisions fairly, such as a fair scheduling of the customers' jobs. Our main aim in this research is to provide a unified framework to enable schedulers to make fair decisions in repetitive scheduling environments. For doing so, we consider a set of repetitive scheduling problems involving a set of n clients. In each out of q consecutive operational periods (e.g., days), each one of the customers submits a job for processing by an operational system. The scheduler's aim is to provide a schedule for each of the q periods such that the quality of service (QoS) received by each of the clients will meet a certain predefined threshold. The QoS of a client may take several different forms, e.g., the number of days that the customer receives his job later than a given due date, the number of times the customer receives his preferred time slot for service, or the sum of waiting times for service. We analyze the single machine variant of the problem for several different definitions of QoS and classify the complexity of the corresponding problems using the theories of classical and parameterized complexity. We also study the price of fairness, i.e., the loss in the system's efficiency that results from the need to provide fair solutions.

Session 1 - Competition and Regulation

Regulating sabotage
Doron Klunover **(SCE) -** **Regulating sabotage**

We consider a contest between two principals who can exert both productive and destructive effort. They also have the option of delegating the destructive effort to a delegee and sharing the prize with him in the case of a win. We characterize the subgame perfect equilibria of the game and show that destructive effort is maximized when both principals choose to delegate. Therefore, regulating only the principals is inefficient because either they delegate in the first place or will do so as a result of the regulation. Policy applications are discussed.

Yizhaq Minchuk **(SCE),** ***Aner Sela*** **(BGU) - Moderate Externalities in All-Pay Contests**

We study all-pay contests with incomplete information. We assume that, in addition to the winner's prize, there are externalities with a loss function that result in agents receiving non-positive payoffs based on their performance and the contest results. We primarily focus on moderate externalities in which, despite the possibility of loss, all agents participate and stay in the contest. We characterize symmetric equilibrium strategies for various types of externalities and investigate how they affect agents' equilibrium effort. Moderate externalities are easier to analyze than other levels of externalities, and they typically provide the best indication of whether any type of externality has a positive effect on the agents' total effort in the contest.

Limor Hatzor **(JCT) - Green antitrust conundrum: Collusion with social goals**

Recent green antitrust policies in several countries have introduced exemptions from competition regulation to advance environmental objectives. However, under asymmetric information, firms may exploit such exemptions to exercise their market power beyond the permitted scope. To examine these challenges, we introduce a model of green antitrust policy and analyse two key decisions: (1) whether to grant an exemption, and, if granted, (2) whether to commission a costly investigation into potential non-compliance or breach of exemption requirements. Our results suggest

that under high uncertainty, ex post investigations play a critical role in the successful implementation of the policies. When investigative institutions are effective in deterring non-compliance ex post, the authorities are more likely to grant firms an exemption ex ante. In these circumstances, if investigation costs are sufficiently high, a commitment policy is preferable to a discretionary investigation policy.

Session 1 - Applied Artificial Intelligence

Brad Morantz **(Vice Chair IEEE Phoenix AZ Computer Society) - An Agentic Computing System for Cognitive Decision-Making**

Decision-making is a task that an average person does about 300 to 400 times a day. Most decisions are minor but there are some that are of great importance, where the decision can have great impact. The Butterly Effect states that a small action in one part of the world can cause a great effect in another part of the world at some later time. [Lorenz]

Decision Support Systems (DSS) were designed to assist a human being in making a decision. Decisions are required in almost every aspect of a commercial enterprise, including sales, engineering, manufacturing, and management. The Ghartner Group estimates that by 2028 33% of enterprise applications will include agentic AI, and that this will enable 15% of daily work decisions to be made autonomously, without human intervention. [Ghartner] This can be fueled by a combination of shortage of capable humans, an increase in the cost of human involvement, and greater AI accuracy and performance.

This realm of agentic AI should be started on a narrow realm of application, and with knowledge, experience, and success, it can be expanded. Human cognitive function is an integral part of this function that we try to recreate in the machine environment. Some example situations are included to help demonstrate the problem.

This paper explains some of the types of decision-making and how they are performed. The paper then discusses how this process, modeled after how an intelligent human, would perform the task. This discussion combines computer science, decision sciences, psychology, and mathematics/statistics.

Adi Katz **(SCE),** ***Dov Te'eni*** **(Tel Aviv University) - Beyond the Hype of Vibe Coding: Technical Breakdowns, Emotional Strain, and the Struggle for Shared Context**

We examine communication and trust breakdowns in "vibe coding," a development paradigm in which developers use natural language to direct AI agents in code generation and debugging. While this approach promises to democratize and accelerate software development, it often leads to functional errors and coordination failures. Our ongoing research comprises two phases. First, we conducted a qualitative field study of 163 developer–AI interaction episodes, identifying recurring dynamics of context gaps, asymmetrical learning, trust erosion, and error expansion. Second, we extended the investigation to 104,616 posts and comments from nine developer communities, adding emotional and social dimensions. This phase examined eight codes: error occurrence, substantive errors, coordination errors, implementation errors, emotional experience, social legitimacy, psychological ownership, and negative humor as an indirect expression of frustration. Integrating both phases, we propose a model of interacting feedback loops and highlight contingent contextualization as key to sustaining reliable human–AI collaboration.

Ronit Shmallo **(SCE),** ***Lior Aronshtam*** **(SCE),** ***Gali Naveh*** **(SCE) - The Impact of AI Usage Approach on Student Learning Perception and Performance**

The emergence of ChatGPT in late 2022 marked a significant turning point in higher education, accelerating the adoption of generative artificial intelligence (Gen-AI) and consequently reshaping teaching, learning, and assessment. Students' use of Gen-AI is frequent and diverse but the approach they employ in their learning is

predominantly not guided. To explore students' perceptions and performances with a specific approach of Gen-AI use, an experiment in a database course was conducted. The students were given an in-class quiz, two similar assignments (assignment A and B) and were asked to employ different approaches using Gen-AI tool/s to complete each one. The class was divided into two groups randomly. Half of the students were first given assignment A and then assignment B, while the other half were given the assignments in the reverse order (i.e., assignment B first and then assignment A).

Students' learning was examined based on their performance (i.e., grades) and by asking them about their learning perception using a questionnaire they were asked to complete after each assignment. The analysis of the data gathered indicates students felt statistically significantly higher perceived learning after employing approach A compared to their perception after employing approach B. They also felt statistically significantly higher perceived learning after performing the second assignment, compared to their perception after the first assignment. Additionally, students' performances on their second assignment were statistically different compared to their performances in their first assignment. Due to the research's case study nature, the applicability of these findings to various disciplines, courses and assignment types should be explored in future research.

Session 2 - Market Game Dynamics

Artyom Jelnov **(Ariel University) - Too many details**

There are two experts, each seeking to persuade a consumer to accept a treatment. An expert can provide a detailed argument, from which the consumer may be able, with some probability, to infer which treatment is appropriate. However, with the complementary probability, the detailed argument is difficult to process and therefore uninformative. An alternative is to offer a facile argument—one that the consumer can easily understand but that may be less accurate. In the theoretical

model, I show that an equilibrium in which at least one expert employs facile arguments is beneficial for consumers.

Yizhaq Minchuk **(SCE),** ***Baruch Keren*** **(SCE) - Free walking tours: A game theoretical approach**

Free guided walking tours are becoming increasingly common in cities that are popular tourist destinations. We use game theoretical tools to model and analyze the competition between several tour operators competing in one destination. The model consists of two stages: In the first, each operator decides on the level of effort to invest in order to attract tourists to its free tour and decides on the level of effort to invest in the walking tour itself to make it an enjoyable experience for the participants. In the second stage, based only on the effort invested in the tour itself, the participants decide how much to tip. The model generates several theoretical and practical insights into the organization of free tours.

Session 2 - Data Analytics Systems

Mali Sher **(HIT) - Academia–Industry–Government Collaboration for Data-Driven Micromobility Safety: A Decision-Support Framework for E-Scooter Risk Management in Tel Aviv**

Electric scooters (ES) have become an important component of urban micromobility, offering flexible, low-emission, and efficient transportation in dense metropolitan areas. At the same time, their rapid adoption has created new safety, regulatory, operational, and infrastructure-management challenges. ES riders are vulnerable road users, and their interaction with pedestrians, cyclists, motor vehicles, and urban infrastructure requires coordinated action by municipalities, government agencies, technology providers, shared-mobility operators, and academic researchers. This challenge is especially relevant in Tel Aviv–Jaffa (TAJ), Israel's primary hotspot for ES crashes, where ES incidents represent a substantial and growing share of micromobility-related crashes.

This study presents an applied decision-support framework for improving urban micromobility safety through collaboration between academia, industry, the TAJ Municipality, and relevant government bodies. The research is grounded in the Safe System Approach, which views road safety as a shared responsibility and emphasizes the prevention of fatal and serious injuries through integrated interventions involving road users, vehicles, infrastructure, speed management, regulation, and post-crash response. Within this framework, the study focuses on the development of a Business Intelligence (BI) and Artificial Intelligent (AI) analytical system that transforms crash, infrastructure, and operational data into actionable insights for decision-makers. The project therefore contributes both to applied Industrial Engineering and Management and to practical road-safety management. The main objective is to support evidence-based decision-making for reducing ES crashes and injury severity in urban environments. The proposed framework reflects a multi-stakeholder ecosystem. Academic partners contribute methodological expertise in data analytics, spatial analysis, statistical modeling, and decision-support design. Municipal partners contribute local infrastructure knowledge, planning priorities, and operational constraints. Government agencies contribute regulatory context, national safety objectives, and access to official crash and enforcement data. Industry and technology stakeholders contribute practical understanding of micromobility operations, user behavior, digital platforms, and scalable implementation requirements. This structure enables the research to move beyond descriptive analysis toward a practical decision-support tool that can guide intervention planning, monitoring, and policy design.

The BI system integrates police-reported injury crash data from 2013 to mid-2025, obtained from the Israeli Central Bureau of Statistics (CBS), with municipal infrastructure layers from TAJ, including quarters and street network data. The crash database includes linked information on accident records, persons involved, and vehicles involved. Spatial processing was conducted for assign crashes to municipal quarters and matching of crash locations to street segments. Data-quality issues were

addressed throughout the process to improve the reliability of spatial and relational integration.

The analytical framework distinguishes between crash volume and crash severity. Crash volume is measured using absolute counts, proportional shares, and normalized measures by geographic units such as municipal quarters and street segments. Severity is measured both at the person level, based on individual injury outcomes, and at the crash level, based on accident severity. This distinction is critical for decision-making because locations with many crashes are not necessarily the same locations where the probability of severe injury is highest. The framework therefore supports a more nuanced prioritization process, separating high-frequency crash areas from high-severity risk environments.

The BI system was designed to answer operational questions that are directly relevant to municipal and governmental decision-making: where ES crashes occur, who is involved, when crashes happen, and how they occur. Interactive dashboards allow users to explore crash patterns by location, road environment, user role, gender, age group, time of day, day of week, season, crash type, and severity. In addition, advanced capabilities of AI were incorporated, including Decomposition Trees for hierarchical exploration of crash patterns, natural-language Q&A visualizations for non-expert users, and Key Influencers analysis for identifying factors associated with severe injury outcomes. These features are intended to make the system usable by researchers, practitioners in municipalities, ministries, and operational organizations.

The results reveal important demographic and behavioral patterns. Like findings reported internationally, injured ES riders in TAJ are mainly young adults, and males constitute the majority of injured riders. However, the local data show that the highest severity rates are not necessarily concentrated among the most frequently involved groups. For example, children and older adults may show higher severity rates despite lower overall involvement. This distinction is important for government and municipal safety policy, because effective intervention design must

account not only for the number of crashes, but also for vulnerability and expected injury consequences.

The practical contribution of the study is a replicable framework for academia–industry–government collaboration in road-safety analytics. For municipalities, the system provides a tool for prioritizing infrastructure interventions, traffic-calming measures, enforcement locations, and public-safety campaigns. For government agencies, it supports evidence-based regulation and monitoring of ES risk. For industry and ES operators, it provides a structured basis for improving operational practices, rider guidance, fleet management, and cooperation with public authorities. For academia, the project demonstrates how Industrial Engineering and Management methods can be translated into usable decision-support systems for complex public-sector problems.

The study contributes to several applied areas of Industrial Engineering and Management, including BI, AI, process optimization, decision-support systems, spatial analytics, operations research, and public-sector performance management. It demonstrates how academic research can be embedded in a real operational ecosystem involving municipal, governmental, and industrial actors. Future work may extend the framework by incorporating exposure measures, shared-ES usage data, near-miss detection from video analytics, predictive risk modeling, and simulation of interactions between ES, pedestrians, cyclists, and vehicles. Such extensions would strengthen the transition from retrospective crash analysis to proactive safety management.

Elroi Hadad **(SCE) -** **Climate Risk Sentiment and Bank Credit Pricing: Evidence from European CDS Markets**

We examine whether sentiment-driven physical and transition climate risks are priced into European banking credit risk alongside macro-financial and behavioral factors. Using text-based measures of climate risk sentiment and daily CDS spread returns from 2019–2023, we examine how climate-related shocks transmit to bank

credit risk across market conditions. Employing a quantile regression framework, we show that transition risk sentiment is consistently priced, widening CDS spreads across the distribution, with stronger effects at higher quantiles. By contrast, physical risk sentiment exhibits asymmetric effects, increasing spreads at lower quantiles but compressing them at the upper tail, consistent with the information-resolution mechanism of Kölbel et al. (2024). Behavioral factors also display significant asymmetric effects, whereas traditional macroeconomic and geopolitical uncertainty measures contribute comparatively less explanatory power. Overall, the results indicate that climate sentiment is incorporated into European banking CDS markets through distinct transition- and physical-risk channels, highlighting the importance of expectation-driven climate-risk pricing. These findings have important implications for investors, risk managers, prudential supervision, and financial stability monitoring.

Session 3 - Social Optimization Models

Lior Aronshtam **(SCE),** ***Hadassa Daltrophe*** **(SCE) - Who Should Be Fired? Towards a Complexity Analysis of High-Cohesion Group Selection**

Introduction

In many real-world scenarios, institutions are required to select a subset of individuals from a larger population while preserving social cohesion within the chosen group. For example, an academic institution may wish to assemble a delegation of outstanding students to represent it, whereas a large organization facing workforce reductions due to the growing availability of AI agents may seek to retain employees while preserving existing social ties. In both settings, the individuals are assumed to be highly qualified; therefore, the selection process places particular emphasis on interpersonal relationships, aiming to ensure that each selected individual remains alongside at least one person they identify as their preferred companion.

We consider a setting involving n individuals, where each individual specifies a set of preferred peers and desires to be grouped with at least one member from that set. Given these preferences, our goal is to select a subgroup of size k that ensures social cohesion, measured by the number of satisfied individuals - those who are selected together with at least one person they identified as their preferred companion.
The problem can naturally be modeled by a directed graph G = (V,E), whose vertices correspond to individuals and whose edges encode social preferences. Specifically, a directed edge (u,v) ∈ E signifies that individual u has selected v as a preferred companion. The problem is naturally modeled by a directed graph G = (V,E), whose vertices correspond to individuals and whose edges encode social preferences. Specifically, a directed edge (u,v) ∈ E signifies that individual u has selected v as a preferred companion.
Selecting a subset of individuals based on their relationships has been extensively studied from various perspectives. From a graph-theoretic standpoint, our setting is closely related to the Densest k-Subgraph problem [3], which seeks a k-vertex induced subgraph maximizing internal edges. However, our metric focuses on vertex satisfaction (an out-degree of at least 1 within the subgroup), aligning closely with peer-selection variants of the Approval Chamberlin-Courant voting rule [2] and social welfare maximization in Boolean Hedonic Games [1]. Optimizing these preferences is computationally intractable; because it generalizes the classic k-Clique problem (seeking a complete directed subgraph), identifying the optimal k-sized subgroup is strongly NP-hard [5].To circumvent this hardness, literature often explores structural relaxations. One relevant framework is the directed (k,l)-core [4], defined as a maximal subgraph where every vertex maintains an in-degree of at least k and an out-degree of at least l within the group. While decomposing a network to find a maximal (k,l)-core can be done in polynomial time and effectively captures mutual collaboration, imposing a strict subset size constraint (exactly k individuals) on such cohesive structures reintroduces severe computational intractability.
Results

The first natural problem seeks to find a set of k agents such that all agents are satisfied:

Problem 1 (Social Preference All Satisfied Problem). Instance: A set of n agents A, where each agent ai ∈ A is associated with a set of preferred agents pi ⊆ A, and an integer k.

Question: Does there exist a subset S ⊆ A of cardinality k such that, for every agent ai ∈ S, we have pi ∩ S≠ ∅?

For the case in which each agent has exactly one preferred agent, we develop a polynomial-time dynamic programming algorithm.

The computational complexity of the problem for higher preference degrees remains open. Moreover, in the general case, a feasible solution does not always exist; that is, there may be no subset in which every agent is satisfied. This observation motivates a relaxed variant of the problem, in which all but at most one agent in the selected subset are required to be satisfied:

Problem 2 (Social Preference Almost All Satisfied Problem). Instance: A set of n agents A, where each agent ai ∈ A is associated with a set of preferred agents pi ⊆ A, and an integer k.

Question: Does there exist a subset S ⊆ A of cardinality k such that at most one agent in S has no preferred agent within S? Formally, does there exist aj ∈ S satisfying ∀ai ∈ S \{aj},pi ∩ S≠ ∅?

We show that every instance of Problem 2 admits a positive answer, and a corresponding subset can be constructed in polynomial time.

Albert Yirmiyahu **(Sapir Academic College)** **- The Differential Impact of the National Program for Increasing Skilled Workforce for the High-Tech Industry: A Case Study of Peripheral Regions in the Israeli Labor Market.**

Many studies assessing national educational reforms focus on the likelihood of acquiring advanced education and the associated labor market returns. This study investigates the impact of the 'National Program for Increasing Skilled High-Tech Personnel,' a policy aimed at promoting higher education in STEM fields (science,

technology, engineering, and mathematics) across all segments of the Israeli population.

The findings reveal that the reform contributed considerably more to making STEM higher education accessible to residents of the periphery than to the rest of the population. However, this impact is not fully reflected in the earning capacity of these residents. This gap may stem from variations in the quality of education provided by different Israeli academic colleges, as well as the specific fields of study chosen by students.

Utilizing data from the Israel Central Bureau of Statistics (ICBS) and applying advanced econometric models, this study highlights the challenges of STEM education reforms. It underscores that while access has improved, disparities in institutional quality remain a significant barrier to achieving labor market equality.

Elad Shufan **(SCE),** ***Hagai Ilani*** **(SCE),** ***Lior Aronshtam*** **(SCE) -** **One-Sided Assignment Problem with Priorities**

Introduction

The preference-based one-sided assignment problem is a classical problem in matching theory [8]. Given a set of agents and a set of indivisible items, each agent specifies a preference ordering over the available items. The aim is to match items with agents to achieve some declared goal. Applications include house allocation, school choice, student-project allocation, and other resource allocation settings [4, 2, 7, 3].

An assignment is usually expected to be Pareto optimal, (i.e., no agent can be made better off without making another agent worse of). A simple mechanism to obtain a Pareto optimal assignment is Serial Dictatorship (SD), in which agents choose items sequentially according to a predetermined order [1]. The resulting assignment strongly depends on the chosen ordering and can result in a poor assignment, for example, in terms of the number of agents receiving highly-preferred items. Assignments are evaluated through their profile, namely the distribution of assigned ranks. Two known profile-based mechanisms are Rank-Maximal Matching (RMM)

and Generous Matching (GM) [5, 6, 9]. RMM lexicographically maximizes the profile from the best ranks downward. GM lexicographically minimizes the profile from the worst ranks upward. These mechanisms represent different notions of social welfare.

Usually in a one-sided matching problem, all agents are of equal importance. In this work, we consider a different setting, where agents possess externally defined priority levels. Our goal is to combine the preferences over items and the agents' priority levels within a single optimization framework.

Motivation

Our work is motivated by a real-life problem obtained during the reconstruction of a kibbutz severely affected by the October 7, 2023 attacks. Families who chose to remain members of the kibbutz were invited to return and receive residential plots on which their new homes would be built. The community leadership considered seniority as a dominant principle, and therefore initially considered an SD in which families would choose plots according to decreasing seniority. Although such a mechanism fully respects the seniority, it can significantly reduce the overall quality of the resulting allocation in terms of the obtained profile. We propose an allocation mechanism that preserves the importance of seniority while simultaneously considering the preferences of all participating families.

Our Model

We consider a set of families (the agents) and a set of plots (the items). Each family submits a ranked list of acceptable plots. In addition, every family is associated with a seniority score representing its tenure within the community. The objective is to compute an allocation that balances the families preferences and the role of seniority.

1

We formulate the allocation problem as a binary integer program. Each feasible assignment receives a weight determined by two independent components: (i) the rank of the assigned plot in the family's preference list; (ii) the family's seniority. Different choices of these weights generate different allocation mechanisms. On one

end of the spectrum, seniority is ignored yielding a standard preference-based mechanisms (e.g, RMM or GM). At the other extreme lies a seniority-based SD (i.e., SD with an order explicitly determined by the seniority score). Intermediate weighting schemes interpolate between these two extremes, allowing decision makers to determine the desired balance between seniority and preference satisfaction.

The proposed framework provides a unified view of several seemingly different allocation policies. Rather than selecting among independent algorithms, one chooses a weighting scheme within a single optimization model. Unlike classical one-sided matching models, our framework explicitly incorporates heterogeneous agent priorities while preserving preference-based optimization. We present a unified optimization framework in which seniority-based SD, RMM, GM, and a continuum of intermediate mechanisms arise as different choices of a single weighting scheme. Beyond the motivating application, we believe that this framework defines a broader class of priority-aware onesided matching problems that may arise whenever socially accepted priorities coexist with individual preferences.

Session 3 - Engineering Operations Methodology

Alon Sela **(Agricultural Research Organization - Volcani Institute, Israel) - Applying Weak Correlation Networks in Industrial Engineering and Beyond**

Correlations below 0.20 or 0.30 are often described as small, but a weak correlation can still represent a real and repeatable connection in a noisy system. The important question is not only whether a correlation is large, but whether it is stronger than correlations produced by chance under comparable conditions. The Havlin-Ashkenazy climate-network approach answers this by comparing the real link with links obtained after realistic shuffling [1-7]. This idea is useful whenever many time series describe a complex system and we seek weak but significant connections, delayed effects, or paths by which change spreads. We explain the method through

climate studies and the reported association between air pollution and age-related macular degeneration (AMD) [8], and propose applications in Industrial Engineering (IE).

Eliran Sherzer **(Ariel University) - Learning-Based Analysis of Feed-Forward Queueing Networks with General Non-Markovian Arrival Processes**

Queueing networks with general inter-arrival and service-time distributions arise in manufacturing, healthcare, logistics, communication systems, and transportation. Although these models accurately describe real-world systems, they are notoriously difficult to analyze because departure processes become non-renewal and superposition operations destroy the tractable stochastic structure that exists in Markovian models. Consequently, practitioners typically rely either on computationally intensive discrete-event simulation or on approximation methods that provide only coarse first-order performance measures.

This extended abstract summarizes two complementary studies that together establish a unified machine-learning framework for the analysis of feed-forward queueing networks with general non-Markovian arrival processes. The first develops neural-network modules for learning departure processes and steady-state queue-length distributions in tandem queueing systems. Rather than representing stochastic processes using only the mean and squared coefficient of variation, each arrival and departure process is characterized through its first five moments together with short-range polynomial autocorrelation descriptors. Three neural networks cooperate to approximate departure processes from GI/GI/1 queues, departure processes from G/GI/1 queues, and stationary queue-length distributions at downstream stations. Extensive computational experiments demonstrate that these compact descriptors preserve nearly all information required for accurate queue-length prediction while substantially outperforming existing decomposition-based approximation methods.

The second study extends this framework beyond tandem systems by addressing one of the remaining fundamental challenges in queueing theory: the superposition of multiple non-renewal arrival streams. Instead of attempting to derive analytical

expressions for the merged process, a neural superposition operator is trained to directly predict the statistical descriptors of the superposed stream. Training data are generated using exact superposition of Markovian Arrival Processes, while inference requires only low-dimensional statistical descriptors and no explicit stochastic-process representation.

Combining the learning-based superposition operator with the previously developed departure-process and steady-state modules produces a modular recursive framework capable of analyzing arbitrary feed-forward queueing networks with merging flows. Each neural component performs a single queueing operation, allowing increasingly complex networks to be analyzed through repeated composition while avoiding the state-space explosion that characterizes traditional analytical approaches.

Experimental results reported in the two studies demonstrate prediction errors typically on the order of only a few percent across broad utilization, variability, and dependence regimes. In contrast, classical approximation methods frequently incur substantially larger errors, particularly under highly variable and strongly correlated traffic. The proposed framework therefore bridges the gap between computationally intensive simulation and classical queueing approximations, providing a scalable methodology for accurately estimating complete stationary queue-length distributions in realistic non-Markovian queueing networks.

Dimitry Bykhovsky **(SCE) - The Transition from Traditional Hardware to Interpretable Soft Sensor Measurement Systems**

Traditional vs. Modern Measurement Paradigms

Traditional sensor-based measurement systems rely on a direct translation of a measurand into a numerical quantity. In these architectures, a physical sensor produces an output, typically an electrical signal, which is calibrated, often linearly, to a specific physical quantity.

Modern measurement systems increasingly behave as soft sensors. In this case, the physical sensor is followed by a machine learning (ML) or deep learning (DL) model that estimates a measurand or decision variable from the raw digitized sensor output signal.

The Soft Sensor Trade-Off

The performance of a soft sensor using advanced learning algorithms provides two potential design objectives:

1. Hardware Simplification: Learning software can overcome the limitations of low-grade physical sensors to allow for more straightforward hardware design, reducing cost and complexity while maintaining the performance equivalent of a higher-grade physical sensor.
2. Performance Improvement: Learning software can overcome even the limitations of higher-grade physical sensors.

Explainable vs. Black-Box Learning

Because the measurand is typically related to a physical quantity, a clear physics-induced traceable relation is expected, particularly during the initial design stages. This approach is termed explainable learning. It stands in contrast to typical black-box algorithms, which often lack traceability.

Classification and Fusion Strategies

Soft sensors enable combining multiple measurements to further reduce estimation or decision uncertainty. For example, for decision-related sensors, a soft sensor pipeline can be designed to produce calibrated probabilities rather than simple binary outputs. In these cases, multiple observations can be aggregated using advanced fusion techniques, such as majority voting or log-likelihood-ratio (LLR) combining. These techniques can significantly reduce error compared to a single measurement decision.

Applications and Case Studies

The presentation of these concepts will be supported by recent research case studies involving diverse physical measurands, such as acoustic measurements [1], medical

applications of infrared spectrometry [2] and enhanced-accuracy gamma-radiation spectrometry [3].

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