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International Conference on Data Analytics in Public Procurement and Supply Chain 2022

(ICDAPS)

Selected Abstracts of the Proceedings

10th June – 11th June 2022

मनुष्यवती भूमिरर्थः

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Contents

1. Customer Order Prioritisation in Indian Automotive Industry

Authors: Uttej Reddy Gaddam, S P Sarmah and Sayan Chakraborty

Abstract

Fierce competition, fluctuating market demand and rising customers' demands for high-quality, quick service at a reasonable price pose a significant challenge to organisations today. To provide superior service to all the customer orders is neither practical nor profitable because of financial terms, availability and compatibility of the products. In this case, order prioritisation is a critical and crucial issue. In order to prioritise the orders in an automotive industry, related criteria and sub-criteria are determined based on the literature survey and confirmations of decision makers. As there are several criteria lacking a basis of comparison and causing conflicts, a multi-criteria decision-making process is required. In this study, a Neutrosophic based Analytic Hierarchy Process (NAHP) is used for prioritisation of customer orders in the automobile industry. We have determined fifteen criteria and thirty-eight sub-criteria for this work. Among them, customer influence in the locality, customer financial stability, relationship with customer and scope of future orders from customer are revealed as the most important. The proposed approach of NAHP on the prioritisations of customer orders, is implemented on the organisation data of nine hundred forty-six orders. These orders are prioritised and recommended to the organisation to execute them based on their priorities.

2. Demand Forecasting Of Freight Commodities with Partial Information Revealed By Shippers - A Case Study in Indian Railways

Authors: Ayush Sharma, K Kalaivani and Raja Gopalakrishnan

Abstract

Indian Railways is a major freight transporter in India with a significant share particularly in commodities such as coal, ores, food grains etc. In 2019- 20, Indian Railways transported nearly 1,220 million tonnes of freight contributing a significant proportion of its annual revenues (Indian Railway). Just-in-Time (JIT) inventory management is a philosophy that has been successfully adopted by companies to reduce their inventory carrying costs. However, JIT transfers the demand uncertainty to the transportation links in the supply chain, including those on bulk transporters such as Indian Railways. While aggregate monthly estimates for transportation demand are shared by the shippers with Indian Railways, there are substantial fluctuations in daily/weekly demands. Therefore, unlike passenger trains, freight trains do not operate on a fixed schedule and are chartered by the shippers as and when required. Dynamic generation of freight transportation schedules requires access to the resources such as rail wagons, crew, track etc. Currently, rail fleet managers make daily decisions for assigning empty rakes (set of wagons) to different demand locations. A sub-optimal assignment of rakes results in higher operating costs and dissatisfied customers due to longer waiting times. Often, fleet managers, at the time of assigning rakes to different loading locations, do not have full information of future demand. Shippers routinely place firm demands only 24 to 48 hours before the rakes are required. In contrast, the travel time of an empty rake from its unloading location to the next loading location can be over 72 hours. Assignment decisions can be more efficient if reliable predictions of short-term spatial distribution of commodity demands are available. Accurate forecasts can improve the rake availability, increase freight throughput, and lower the operating costs for Indian Railways while reducing the waiting time for the shippers. Econometric models have been traditionally used in forecasting demand (Talluri & Ryzin) ARIMA assumes that the nature of given data is linear (Adhikari & Agrawal). Also, the lag-variables do not allow the partial information of the future that is revealed by the shippers. Long short term memory (LSTM) cell models (Hochreiter & Schmidhuber), a class within the Recurrent Neural Networks, allows incorporating the partial information of demand in the prediction algorithms. LSTM captures nonlinear patterns and dependencies between data that cannot be modelled by econometric models or an Artificial Neural Network. Ramdhani et al. use ARIMA and ANN approach for passenger forecasting in airlines. Abbasimehr & Shabani model the product demand of a furniture company incorporating both long short term memory cells and seasonality. In this study, we develop an LSTM for predicting the spatial distribution of commodity demand for a rolling horizon of five days. The LSTM model incorporates features such as the partial demand information, monthly estimates of demand provided by the shippers, historical maximum and minimum demand trends, and other commodity-specific criteria to predict the Origin-Destination matrix for a future date. We find that LSTM models improve the RMSE scores by 25 % when compared to other econometric models. Accurate demand estimates will help in the efficient allocation of empty rakes, thereby reducing the unit cost of transportation

3. Modelling Duopoly Competition between Ride-Hailing Platforms to Determine the Dynamic Pricing Strategy of the Platforms

Authors: Lalit Jain and Rofin T.M.

Abstract

This study focuses on modelling competition between two ride hailing platforms to determine the prices they should charge to their customers to maximise their revenue. Since dynamic pricing is used in ride hailing platforms, we will use machine learning algorithm to determine the prices. We will model mainly for ride-hailing platforms, but this model can be easily extended for other sectors.

4. A Reverse Logistics Model Development for Waste Plastic Recycling

Authors: Sachin Kumar and Sanjeev Sinha

Abstract

Plastic waste recycling is becoming a critical issue for countries across the world. An essential approach for recovering plastic waste is recycling. Plastic waste management in developing countries is extremely poor as compared to developed countries. In developed countries very less quantity goes to landfill and incineration and on the contrary like in Africa (57%), Asia (40%) and Latin America (32%) the waste plastic is not even collected. Materials that can be recycled does not always travel backwards through the same channel. Instead, a new channel has evolved to collect, transport and process waste to remanufacture it into a recycled product termed as reverse logistics. It is the process of planning, implementing and controlling an efficient cost-effective movement of raw materials, in process inventory, finished goods and related information from the point of consumption to the point of origin in order to reclaim value or dispose it properly. Reverse logistics has dual benefits both environmentally and economically. Reverse logistics of waste plastics involves different activities like collection, transportation, sorting, processing and remanufacturing. These activities have cost associated with it like collection cost, transportation cost, sorting cost, processing cost etc. out of which transportation cost is the maximum cost incurred in reverse logistics of waste plastics that needs to be minimised. The objective of the study aims to develop a mathematical model based on mixed integer linear programming so as to minimise the total cost that incurs in reverse logistics of waste plastics and also to find the optimal number of recycling plants that needs to be located. The data collection for developing the model is done by field survey of a waste plastic recycling plant. The transportation cost associated with waste plastic is the highest which accounts for around 25% of the overall cost in recycling of waste plastics followed by fixed cost, sorting cost, processing cost and disposal cost. Fixed cost accounts for the cost of land setup and initial machinery of plastic recycling. Sorting cost includes the cost incurred in separating recyclable waste materials from one another like aluminium, paper, steel etc. Processing cost includes the cost that incurs in processing of the sorted and shredded plastic waste materials for converting it to carbon black waste plastic granules that can be further used in manufacturing of new plastic products. Processing cost also includes the electricity cost. Disposal cost is the lowest cost that incurs in waste plastic recycling that includes landfill tax and environment tax. Different drivers and barriers associated with waste plastic recycling has also been analysed. The major challenges associated with waste plastic recycling is to maintain the quantity and quality of recycled materials. The different barriers that greatly impacts the actual recycling rate of plastic wastes are contamination technology limitations and the availability of markets for recycled products. The developed MILP model can be solved by different optimisation techniques like genetic algorithm, particle swarm optimisation, ant colony optimisation etc. Reverse logistics is used as a strategic tool by manufacturing industries to tackle government legislation, customers, market, and competitors. It is different from waste management as it emphasises waste disposal and its recapturing value. It is very much concerned with reuse, recycle, refurbish and remanufacture.

5. A Mixed Integer Linear Programming Modelling for Optimal Fleet Planning for Freight Transportation by Rail

Authors: Gaurav Kumar, Oqais Tanvir and Akhilesh Kumar

Abstract

The need to handle fleet planning issues in transportation networks has grown in recent years and financial viability is determined by the freight transportation fundamentals. The classic freight solution of the road is no longer viable due to globalisation. So, rail freight plays an important part in any country's economic development by offering reliable and profitable freight services. Since, managing rail freight involves many decisions, each one has a substantial impact on profitability. Planning and operating rail freight transportation networks is tough due to the inherent combinatorial complexity of discrete optimisation problems. Researchers and industry professionals are interested in using mathematical optimisation techniques to solve fleet planning issues. To learn more about optimisation models and methodologies used in rail freight transportation, we recommend Baykasoglu et al. (2019), SteadieSeifi et al. (2014, Gorman et al. (2014), Crainic & Laporte et al. (1997), Cordeau et al. (1998) and Dejax & Crainic et al. (1987). Planners of rail freight operators have issues due to the lack of Decision Support Models (DSS). Using the Analytics and Optimisation model, they must develop Decision Support Models for the rail transportation of manufactured goods from diverse manufacturing plants to market destinations. The objectives of this study are an optimal plant-customer pair selection (most profitable routes), optimal number of trips between plant-customer pair, and optimal quantity to be transferred. The MILP mathematical model as a DSS based on optimisation achieves these aims. The MILP model is solved using exact approach. Optimal rail freight operator's planning ensures efficient, competitive, and safe rail freight services.

6. Solving Vehicle Routing Problems under Dynamic Demands using Branch & Cut and Deep Reinforcement Learning

Authors: Uma Chilukuri, Debabrata Das and Priyanka Verma

Abstract

The complexity with Combinatorial Optimisation makes it heavily time consuming and solving it through exact methods is a step above it. Specially the Vehicle Routing whose complexity increases by depots, customers, vehicles, demand, customer distributions require a very accurate and quick analysis. These two factors have resulted in addressing the vehicle routing problems with Branch and Cut (An exact Method) and Deep Reinforcement Learning. Exact Methods are the solutions which can give the optimal solutions where the heuristics and meta heuristics give the near optimal solutions. Branch and Cut is the exact method, chosen to solve the dynamic multi product and multi vehicle environment followed by the application of reinforcement learning.

The methodology adopted is initially by mathematical formulation of the routing problem then using the python coding with minimum number of customers. Solving the increased number of customers with the exact method starts consuming the time, then the initial Branch and Cut must be combined with the Deep Reinforcement(Q) Learning which helps in accelerating the cutting plane selection thus providing the optimum routing in terms of distance and showing it in graphical way at the optimum time.

The initial program code is run with 9 customers on python which has optimum runtime and accurate graphical representation, but when the customers is increased to 100, deep learning must be imposed to run at the optimum time. Python language is chosen as it makes branch and cut adaptable to the deep reinforcement algorithm.

Implications

The major implications are the decreased computation time of combinatorial optimisation by application of deep learning techniques which helps in solving further problems of combined distribution and inventory optimisations. Exact methods rather than heuristics like genetic algorithm makes solution optimal rather than closer to optimal solutions.

7. Discrete Particle Swarm Optimisation for Warehouse Location Problem

Authors: Challa Sai Ajay Narendra, Dr.Debabrata Das & Dr.Priyanka Verma

Extended Abstract

Application of meta-heuristic techniques to solve np-hard problems is the current active research area. Particle Swarm Optimisation (PSO) is a one of its kind metaheuristic techniques with population-based search algorithm similar to the genetic algorithm which mimics the flock of birds that has got various applications in solving optimisation problems with non-linear objective functions. In the current research, extensive work has been done to solve the binary and mixed integer linear programming problems using PSO with the novel technique of residual distribution to incorporate the constraints into the problem and other techniques to fix the decision variables as specified in SARAÇ, T., & ÖZSOYDAN, F. (2011) and Taşgetiren, M. F., & Liang, Y. C. (2003). Deduced the best combination of parameters of PSO i.e., c1, c2, w& particle size to get the best optimal solution in minimum iterations possible by working on sphere function. Practical applications of operations such as lot-sizing and fixed charge problems have been solved using the Discrete PSO on MATLAB R2018B and results have been validated with the traditional optimisation techniques. The future work is in the direction of solving a Capacitated Facility warehouse location optimisation problem in reference to the work done in Gao, C., Song, Y., Shen, J., & Li, Y. (2018) using hybrid PSO i.e., with the inclusion of selection of particles and mutation as similar to genetic algorithm, which is mentioned in Angeline, P. J. (1998, May).

8. Green and Sustainable Public Procurement

Authors: Dr. Bhakti Parashar and Dr. Amrita Chaurasia

Abstract

Green Public Procurement (GPP) is now being utilised to influence the market towards providing the public sector with goods and services that have a minimal environmental effect. It is a globally recognised environmental policy tool, although the scale varies from country to country. Meanwhile, states looking to buy items, services, and works at random, as well as their application, are the result of changes in environmental legislation. The Green Public Procurement (GPP) has proven to be an effective tool for achieving the environmental policy objectives set by the European Commission on its Communications. At the same time, government should consider it a complex process in which all goods and services must be seamlessly integrated into a complex system of laws, structure, innovation, health care, nutrition, and education. The purchase of green public property has the potential to serve as a model and guide for individual consumers, as they are given the task of transforming the green into a common community. In this context the paper seeks to determine the sustainability and usefulness of green public purchases.

9. Role of Industry 4.0 in Improving Resilience of Project Driven Supply Chain

Authors: Santhosh Kannan D, Vijaya Dixit and Priyanka Verma

Abstract

Project-driven supply chain (PDSC) comprises coordination between off-site supply chain activities and onsite project activities (Shishodia, Verma, & Jain, 2020). Each activity of the PDSC includes all supply chain functions, including order management, procurement, material management, manufacturing, sales, and service. These activities are dependent on a variety of suppliers and contractors. For risk mitigation in PDSC, selecting these suppliers and contractors creates a trade-off between cost and resilience. In PDSC, the demand for materials is driven by project activities that are fulfilled by the supply chain.

The three key pillars that underpin the Project-Driven Supply Chain (PDSC) are activity, suppliers, and contractors. The resilience capability associated with these three pillars determines the performance of the overall PDSC. In this paper, it is explored that by introducing technologies considered under Industry 4.0, the resilience behaviour of the three pillars of PDSC will get affected.

Multiple criteria affecting the resilience performance of project activities, suppliers, and contractors are gleaned from various sources, including peer-reviewed journals, textbooks, and public projects. Later, we used the TOPSIS method to determine the resilience score of each industry 4.0 metric across the three pillars of a project-driven supply chain (PDSC). (Biswas, Pramanik, & Giri, 2016) TOPSIS is an MCDM tool that is used to solve problems with a limited number of options for selection and evaluation. In TOPSIS, the shortest distance to an ideal solution is frequently utilised to find ideal positive and negative solutions.

This research links PDSC's resilience and (Akdil, Ustundag, & Cevikcan, 2018) Industry 4.0 metrics using a neutrosophic linguistic set. The neutrosophic set has the power to bring forth the degree of indeterminacy and falsehood and the degree of truth membership. It also supports making real-time decisions. A single-valued neutrosophic set-based weighted average operator is used that aggregates all the individual decision makers' perspectives into a single view for rating the importance of criteria and alternatives. The resilience score for all activities, suppliers, and contractors is identified with the help of neutrosophic TOPSIS.

Later, the resulting resilience score is employed as a parameter in the proposed optimisation model. This research aims to classify PDSC players (contractors, suppliers, and activity) based on their resilience performance and later allocate players with the highest resilience scores to project activities. The data from the resilience score is fed into the suggested extended model. The proposed optimisation model is a mixed-integer linear programming problem that optimises the entire resilience score of a project-driven supply that has been under study. The cost and resilience scores are the two primary trade-offs for this model. As a result of this research, managers can use the resilience metric to look for proactive decisions before starting a project and improve the system's adaptability by utilising Industry 4.0 technology. The resulting

weighted scores also assist field practitioners (such as contractors, suppliers, and project managers) in making better industry 4.0 investment decisions for constructing a resilient system.

10. Developing Forecasting Models for Natural Gas Pricing

Authors: Avinash Chandra Singh, Snehal Singh, and Dr. Asad H. Sahir

Abstract

Natural gas is an important fuel which is gaining popularity as a result of its environmental safety and purity. Furthermore, less potentially hazardous by-products are emitted into the environment using this fuel. Forecasting data for usage and pricing of natural gas is of value to energy economists, economic and procurement planners and finance professionals.

Forecasting is the science of making predictions about unknown future occurrences and is only required when there is a degree of uncertainty. Predictions are also unneeded when events are within one's control. The recent geopolitical developments and economic climate encourage the development of excellent forecasting procedures which may assist reducing and analysing uncertainty, allowing them to make better decisions.

The terms forecasting and programming are not interchangeable. Forecasting is preoccupied with forecasting what will occur in the future, whereas planning is concerned with the planner's vision for the future.

In this presentation, the presenters will showcase their work in forecasting natural gas price through the use of three software – MATLAB, Tableau and EXCEL. For MATLAB, financial forecasting of data is done in three parts.

1. Access: The first step was to gain access to the data, which can be in the form of an excel sheet, a database, or data feeds.

2. Research: Once the data is obtained, it must be visualised, analysed and financial models need to be developed and calibrated

3. Share: The next step is to export the files in various formats. PDFs,.dll, C/C++, and JAVA.net are all examples of extension files.

The objective of the presentation is to showcase the development of MATLAB, EXCEL and TABLEAU and its application to natural gas prices using historical data, and showcase its applicability for future economic analyses.

11. Supplier Risk Intelligence Model – Application of advanced analytics to improve resiliency

Authors: Murugan Pugalenthi and Pankaj Chopra

Extended Abstract

Background – Supply Chain disruption causes extensive damage to the profitability and the long-term sustainability of a firm

- Supply disruptions are inherent in any supply chain and maybe hard to predict. Some recent examples are the unforeseen disruptions due to COVID-19, The Texas Freeze, Panama Canal Blockage and more recently the Russia-Ukraine situation. Most of these disruptions on one hand are hard to predict and on the other hand they are capable of sudden and extensive damage to the supply chain of an organisation, the output of an industry and eventually the GDP of respective countries and that of the world. This situation is further intensified by the interconnectivity of supply chain across companies, industries, and countries.
- The ability of a firm / industry / country to sense these potential disruptions in their early stages and their ability to respond to these disruptions is a source of competitive advantage and can enable the firm to gain share in the market, be a source of revenue and profit driver, help recruit new customers and further strengthen their relationship with their existing customers.
- The numbers are mind-boggling. Over 94% of companies have experience a negative impact on revenue due to supply chain disruption. McKinsey calculates that within 10 years, supply chain disruptions tally to close to half (45%) of a year's worth of profits for companies. One long-term disruption to production could cost companies 30-50% of a year's EBIDTA. Due to supply shortages, the price of commodities rose 19% between May 2020 and May 2021. (Source: White House). (83%) reported reputational damage due to supply chain disruptions (Source: Interos).

The spectrum of risk goes beyond the traditional Geo-political and Financial Risk

Historically we have witnessed companies struggling to sense and respond to traditional risks like Geo- political, Financial and Operational. However, going forward several other types of risks have come up and they have the potential to cause even greater disruption. These are risks like Cyber, Social, Regulatory, Governance, Diversity, Sustainability etc. which may need a totally different approach to sense and respond. The landscape becomes even more complex when we include Tier-2 and Tier-3 suppliers as firms generally don't have a direct line of sight to these suppliers and many of these suppliers comprise smaller organisations who are not set up to manage such risks.

Given the interconnected nature of modern supply chains, understanding suppliers' health around Financial, Operational, Diversity, Geo-political, Environmental, Social, Governance, Regulatory compliance, Cyber Security, and Reputation in the marketplace, has become increasingly critical for procurement teams to gain insights into suppliers and to proactively identify and manage unknown hidden supply risks for critical raw materials at a Tier 2 or 3 level, thereby increasing

business and operational resilience. It is also very essential to improve the organisational ability to understand the severity of the risk, size of the impact and alternate options quickly to respond to the risk.

Internal and External data, advanced Data Engineering, a comprehensive set of Data Management tools and a sophisticated suite of Data Science Capabilities are needed to build this competitive advantage

Due to this increasingly complex landscape in of our VUCA (volatility, uncertainty, complexity and ambiguity) world and the potential far-reaching impact of supply disruptions, it is rather hard to sense and respond to these risks using traditional tools and manual processes. Hence there is a need for organisations to pivot and develop capabilities that enable us to assess, analyse and leverage data from multiple sources, build what-if scenarios and the impact of disruption on revenue and profit in real time, and develop a 'sense and respond' platform that is data driven, analytics enabled and leverages Machine Learning to enable quick problem resolution. This will enable organisations to quickly mitigate supply disruptions versus spending considerable time in problem identification, data availability, data engineering and scenario planning.

Vision on the risk management, Data availability (internal/ external), Technology infrastructure, analytics & data science capabilities, Process integration & Governance are critical success factors to build supplier risk intelligence model which would help the organisation in elevating the risk management capabilities.

Building the supplier risk intelligence model and scaling up

In supply chain procurement, following capabilities are crucial to build the risk intelligence model:

a) Ability to create commodities, components to Finished Goods to the multi-tier suppliers in the internal data sources with supplier networks data (external data sources)
b) Visibility into multi-tier suppliers actual manufacturing locations, parent organisations, and other attributes
c) External data which covers the risk events and triggers - on the third-party data sources and publicly available unstructured near real-time data feeds (i.e., financial reports, press releases, social media, etc.)
d) Data engineering and modelling ability to build scalable solution by blending various type of data
e) Application of machine learning (ML), artificial intelligence (AI) technologies and statistical modeling
f) Consumption layer with right user interfaces which are personalised for every personas.

Out-of-the-box solution that can provide multiple-tier supplier visibility are currently not available and building a robust solution would require significant effort with a balanced and enterprise approach to data and technology that will enable end-user focused operating model,

define roles, responsibilities, and decision rights. To that end, the first step is to build a dynamic, easy to use, data driven supplier risk intelligence solution for a forward-looking use case to get incremental visibility of multiple tiers of supplier network for a set of commodities across categories.

- Identify manageable set of direct commodities across categories by considering spend data, number of supplier and criticality. Map each commodity in scope accurately to its finished goods/product/brand, to their sales and profits, to Tier 1 suppliers using existing internal data sources.
- Partner with third party external data vendors such as D&B, RavenPack, Resilinc for gathering supplier networks data and publicly available data from a variety of sources to curate the risk feeds/ triggers.
- Deploy machine learning (ML), artificial intelligence (AI) technologies to map Tier 1 supplier manufacturing locations, and dropping below Tier 1 to Tier 2, Tier 3 through to the nth tier suppliers and their manufacturing locations for end-to-end traceability across all levels for critical components.
- Apply data science tools and advanced analytics to analyse data points around manufacturing location, related risk feeds, business continuity plans, risk mitigation strategies, time to recover during disruptions, etc. This will help in painting a picture about the risks with respect to the supplier manufacturing location, level of impact and mitigation recommendations.
- Build interactive visualisation tools for actionable insights into supply chain risks and send proactive alert notifications for respective procurement team's response using workflow solution based on the data science models.

Testing the supplier risk intelligence solution with the targeted users to prove the concept is vital to capture the learning and understanding the key success factors for the full-scale implementation. The same framework can be scaled up to indirect procurement and services procurement as well with few modifications. This approach results in improved response time for any risks which a supplier base would encounter and elevate the risk management capabilities ensuring the growth of the organisation by serving the customers effectively.

Changing Organisation Culture

Considering the breadth and impact of these risks and their ability to severely disrupt the revenue and profit of companies, managing risk should be front and center in an organisation and deeply embedded in the Supply Chain and Procurement function. Risk and managing risk should not only come up during a global supply chain disruption but should be day to day priority. Managers and leaders should be trained to 'sense' risk and regularly engage with the 'risk management platform' as one of their top priorities. Every senior leadership review should have a standing topic on 'risk management' and the readiness of every team member in sensing and responding to risk should be a part of their Goals and Objectives.

Role of Governments

Respective governments can play a crucial and decisive role in this area by addressing the most severe types of risks that can impact a significant part of their national industry. E.g. IT industry in India, Automotive components industry in China, Automotive Industry in Germany, Minerals and Metals mining in Africa etc. The governments can help by i) Providing Risk Management Expertise to small and medium sized companies, ii) Provide financial risk insurance and iii) Prepare policy responses to large scale risks. As per OECD, policy makers should also undertake to review systemic issues that private risk management strategies are not in a position to deal with. Determining the role of governments in ensuring well- functioning international supply chains is a challenging task, particularly as these supply chains involve cascading tiers of suppliers in many countries.

Some policy actions that governments should consider are:

- Assess the role of government for different types of risks (e.g. specific supply chain risks in the provision of essential goods and services).
- Risk prevention through efficient regulations, international cooperation, and regular reviews of risks and vulnerabilities.
- Mechanisms to detect and anticipate crises (e.g. monitoring the vulnerabilities in supply chains, international exchange of information, early warning indicators).
- Risk management strategies and guidelines.

12. Implementing Industry 4.0 Technologies in a Project Driven Supply Chain

Authors: Harshal Chauhan, Vijaya Dixit and Priyanka Verma

Abstract

A project is a dense network of activities dependent on each other and involves delivering an end product. To complete a project, multiple stakeholders must work together, ensuring that all the materials, items, and information are delivered on time. At this stage, Supply Chain becomes an essential part of Project Management. The amalgamation of the Supply Chain activities with project operations is considered as Project Driven Supply Chain (PDSC) (Xu & Zhao, 2009). Project management coupled with supply chain activities is the need of today's high-demand industry. Coupling of supply chain activities (logistics, warehousing, and inventory) with project activities (scheduling, sequencing, etc.) has a major role in Project Driven Supply Chain (PDSC). PDSCs are unique as each project will have its distinctive requirements, which leads to issues with coordination between project activities and the supply chain leading to delays in the project and, thus, longer lead time (Mello et al., 2016).

The leading cause of these issues has been the lack of proper information flow between the stakeholders in the PDSC. To tackle this problem, the application of Industry 4.0 is proposed in this work for managing PDSC efficiently. Industry 4.0 involves the introduction of automation in industries and the integration of newer production technologies in manufacturing. It aims to improve working conditions and increase production quality by including various emerging digital technologies and automation to bridge the digital and physical world (Nardo et al., 2020). These technologies are starting to be implemented in the manufacturing and construction industry. Still, no such study is present for PDSC. Through this work, we aim to understand how Industry 4.0 technologies can affect a PDSC. Based on a proper literature survey, the core concept of Industry 4.0 is captured, followed by the different technologies that come under it. Ten technologies like blockchain, the Internet of Things, Cloud, Augmented reality, virtual reality, data analytics, simulation, robotics, machine learning, and cyber security are selected based on the literature, which is believed to positively affect a project-driven supply chain. A real-life project is selected where different activities in that project are evaluated. Later best 3 Industry 4.0 technologies are suggested that can improve activity performance. It later explores how Industry experts interpret Industry 4.0 and its concepts in their projects. Their opinion is taken regarding different project activities, the cost associated, and what they view as the vital Industry 4.0 technology for the respective activity. The collected data is then entered into our framework, where we will be using the four objectives of a project, namely scope, quality, schedule, and cost, to measure the project's success. The framework consists of a linear programming model where our objective is to maximise the previously mentioned objectives of the project. As a result of the proposed model, managers can understand how certain technologies affect specific project activities. The results of the proposed model can help in planning the spend of budget for the installation of these technologies across different activities of the project. This way, instead of spending all the budget initially on installing these technologies, project stakeholders can spend partially on technologies required at the initial phase and then plan for the remaining spending accordingly.

13. Natural Language Processing: An Application case study of Inventory Standardisation in Indian Railways

Authors: Dr. Rajnish Kumar and Ayush Sharma

Abstract

Various zones, workshops, and establishments, in short units, of Indian Railways have been using store items maintained in inventory for smooth functioning of day-to-day operations. These items, numbering nearly 3,50,000 at present, have been, in most cases, allotted different and non-uniform identification codes, referred to as Price List (PL) No, and descriptions across different units of IR. The non-uniform identification codes and the non-standardised descriptions for store items lead to issues in stock transfer between different units of IR hampers central procurement, mitigates the potential for purchase price reduction from vendors and creates bottlenecks in accounting and monitoring of stocks among other disadvantages.

Despite several years of efforts, only a minute percentage of total stores items in the Indian Railway have been unified to date. In view of the aforesaid issues in managing store items on the Indian Railway, it is proposed to use Artificial Intelligence (AI) and Machine Learning (ML) based algorithms to aid and speed up the process of PL Unification across IR. Here we propose to hasten this process by use of the best suited AI/ML string matching algorithms(cite) to match the description/drawing number/specification number for each item under a nominated unifying railway with a similar item in other units of IR.

During the study, we explored various string matching algorithms which are broadly classified on the basis of the method used by them to match two strings these are lexical similarity (Valentin & Maarten, 2005), semantic similarity (Courtney D & Rada, 2005), and knowledge-based similarity (Wael H & Aly A, 2013). Here we tried the different algorithms from each class such as Jaro, LCS, BERT, etc.

Bidirectional encoder representations from Transformers (BERT) (Fei et al., 2019), BERT makes use of Transformer, an attention mechanism that learns contextual relations between words (or sub-words) in a text. The transformer includes two separate mechanisms — an encoder that reads the text input and a decoder that produces a prediction for the task. Here we have used only the encoder mechanism as the goal of the study is to generate the language model.

Matches shown by the BERT algorithm with score one were the complete match, for scores above 0.85 have also shown matches that were almost similar and the matches below 0.5 were almost dissimilar. Thus we can say that BERT proved a better algorithm than other matching algorithms for our study.

The goal of the study was not just to get accurate results but also to give the results back to the user in an optimised or quick manner. Since the search space contained around 3.5 million descriptions to which the input description needed to be matched there was a need for efficient processing. This problem was addressed by storing the embedding for each description in search space and indexing them using annoy indexing algorithm. In this way, we were able to provide an accurate and optimised solution for the unification of PL Nos in the Indian Railway.

14. Implementation of Optimisation Model to replace existing Bus Setup with E-Bus & propose Procurement Strategy

Authors: Ankush Pawar and Sushmita A. Narayana

Abstract

Over the past decade, India's cities have been witnessing an increasing trend in motorisation with deteriorating air quality, and there have been calls to promote public transport as a way out of this gridlock. According to E-Vahan Portal, the total No. of Registered Vehicles has drastically increased from 55 million in 2001 to 142 million in 2011 among which 83% are 2-Wheeler & 4-Wheeler Vehicles. The major reasons for this steep rise are Lack of Proper Public Transport, direct-to-direct connectivity & increasing per capita income of people leading to high level of air pollution. This has created need to develop models for public transport for switching to Electric Buses from conventional Bus Setup. The aim of the Research is to propose & implement an optimisation model to replace the existing conventional bus setup with E-Bus & look for possible solution for procurement models of E-Buses. As an implementation, the model was applied at 4 routes of DTC (Delhi Transportation Corporation).

15. Causal ML framework for Commodity Price Prediction using Time Series Based Stochastic Model for Dynamic Contract Design

Author: Rishabh Tripathi

Abstract

In the world of Infrastructure development projects, the commodities most useful during construction stage which include wire rods, steel rebar and HRC sheets, cement, coarse sand and aggregates and mineral fuels (Coal, Petroleum & Natural gas) as utilities form a substantial proportion (55% - 60%) of construction cost. These are either procured from bulk manufacturers / Vendors / Suppliers directly (on spot prices) or after inviting quotation's bids for material procurement and subsequently entering into a contractual agreement at pre-determined price levels on a future date while accounting for revision in quantities based on changing scope and scheduling plans and inflationary revisions in commodity prices in short and long term due to ever changing global political and economic events.

Even if the terms of procurement contract are meticulously defined to account for any globally catastrophic / Force Majeure events (ex. War, Pandemic) leading to supply disruptions and uncontrolled fluctuations in prices, when actual purchase of such commodities as raw materials take place at pre-determined contractually agreed prices at pre-defined points / periods in time, it may lead to losses on the part of either developer (as primary consumer) or supplier due to differences in actual (spot) and predicted (future) price levels.

As this is not a single time purchase decision and transcends over several time-periods whether in short term (< = 12 months) or long term (> 12 months), such losses will gradually accumulate to turn into a substantial proportion of input cost exceeding that of developer's procurement budget for planned material expenses and thus imposes an additional burden on developer for contingency expenses and to redesign more flexible contracts with provisions for incorporating such accidental or unplanned material procurement expenses in future.

The purpose of this research is accurate representation of future market price of commodities which are typically used as construction materials using Machine Learning (ML) models based prediction, so as they may closely depict spot prices on the realised date of actual purchase.

16. Green and Sustainable Procurement in Economy - The Linkage between Sustainable Growth and Green Procurement – An Indian Perspective

Authors: R. Ravichandran, Dr. Reshma Sultana Ph, Dr. Shruti Mishra, Brindha L and Anwesha Chattopadhyay

Abstract

The growth of industry and economy – in current times have been aided mostly by high amount of procurement of materials and goods, and to a great extends been responsible for sustainability or otherwise of our operations in the context of our circular economy. It is in this context that the concept of Green and sustainable procurement takes a central role. With the Government ramping up spends on Infrastructure, this becomes further crucial to ensure that the spends are more in linkage to sustainable development and it is here the concept of green procurement comes to play a major role. If sufficiently good efforts are taken, it is quite possible to increase the Green content in procurement, which might as well lead it to more sustainable options. The Natural of circular economy again makes it imperative for us to focus more on green procurement aspects. It is observed that the countries in the EU are more poised to use green procurement models, and business process, as compare to Asia and Americas, thus providing a big fillip to continuing the sustainable environment and growth paradigm. AI also here helps us to tackle the challenges we face on the way, in the cause of balanced, sustainable, circular 3 economy. The current pandemic induced behaviour has further accentuated the need for moving the value chain of products and services into the DT (digital technologies) and again it is AI which is expected to play a key role in the process. The authors have reviewed the existing body of literature in this regard and shares their perspectives on what could possibly be the way Green and sustainable procurement in circular economy would take in our journey to make the long run economic development more sustainable and beneficial to various sectors of industry and also for maintaining sustainable living possible. Developments in Green procurement business models are likely to give way to integration of AI, and DT technologies, disruptive innovations are more likely to be arising in our Indian economy, and possibly accelerate the adoption of Green and sustainable procurement by initiatives from the Government and the private sector The author also takes a look at the sectors where it is likely that products and services are going for adopting more into Green and Sustainable procurement. In a circular economy, and with public procurement likely to go up, its implications for going green for the consumers and society are of quite a high order.

17. Is Telemedicine worth the Effort? A study on the impact of cost of effort on a healthcare platform with heterogeneous preferences

Authors: Jagan Jacob and Fang Wan

Abstract

In the healthcare system, an important component of enhancing the patient experience is to provide more flexibility to patients regarding how, when, and where to receive treatment (Feldman et al., 2016). In pursuit of this objective, telemedicine and virtual care have quickly become important tools to deliver patient care and expand access to medical resources. Particularly, elderly people can greatly benefit from this new type of service because telemedicine is able to help them with a variety of challenges in healthcare. Older people usually suffer from long-time illnesses rather than being intermittently sick. A study by the National Council on Aging in 2018 shows that 92% of older patients have at least one chronic disease, and 77% suffer from at least two. The objective of geriatric medicine is to slow the progression and reduce morbidity. Thus, the successful geriatric practice requires longitudinal management of progressive disease and anticipation of complications (Merrell, 2015). Unfortunately, as patients become frailer and older, they are less able to come on their own to intermittent care visits. Access to specialist care is further confounded by transportation for the older patients who live in rural areas (Scott et al., 2018). Telemedicine is designed to solve the problem and make healthcare more accessible for elderly people. It involves remote health-related services such as monitoring, advice, and education between doctors and patients online over a secure connection. Through telemedicine, geriatric physicians and patients are able to efficiently monitor disease progress, diagnose problems such as cancer early, look for early signs of deterioration, and support healthy lifestyles.

However, the reality is that only a limited number of geriatric care adopted the concept of telemedicine. In fact, a study by the National Council on Aging (2018) showed that in the U.S. alone, 82% of consumers do not use such services. The hesitance to utilise telemedicine stems from a variety of reasons. This sad reality can be first attributed to a lack of awareness and knowledge. Front-edged technology is usually considered “age-unfriendly”. A good portion of elderly patients has limited computer and technology skills. They are not comfortable with utilising modern technology for receiving a medical diagnosis in time. Some survey also shows elderly consumers need insurance education on reimbursement issues to ease their way to this new type of service. Additionally, some senior patients take doctor's visits as a part of their social life. They do not trust the efficiency of virtual communication. Therefore, patients have different preferences in terms of service types in geriatric care. The senior healthcare platform is faced with heterogeneous demands.

To bridge the gap between patients, physicians, and health systems, healthcare providers have to justify the cost-effectiveness of implementing front-edged technology, especially in geriatric care. Telemedicine reduces unnecessary non-urgent ER visits and eliminates transportation expenses for regular checkups, while lack of training and inadequate payment pose barriers to the use of telemedicine. Particularly, the ongoing global crisis of the COVID-19 pandemic brings this question to the major attention of the decision-makers more than ever. It has forced

healthcare institutions and regulatory bodies to turn to alternative ways of providing healthcare while limiting exposure to the virus. Telemedicine is presenting itself as the ideal solution to these woes by limiting patient displacement to hospitals, and allocating hospital capacity to important cases, all while curbing the disease's spread. However, the investment of launching upfront telehealth technology and staff training can take a large portion of the healthcare institutions' budget, especially under the current economic crash. A remote and more accessible health service also requires a higher level of diagnostic skills and additional on-call physician time (Acharya and Rai, 2016). Therefore, telemedicine may not be optimal for all healthcare institutions considering the cost burden on the health providers' end.

In this paper, we are going to address the cost-effectiveness issue of implementing a telemedicine program in hospitals and study the impact of health providers' effort cost to use the new technology. When should hospitals stay with the traditional in-person service, or convert their service to allow virtual visits? Previous studies mainly focused on the patients' point of view and how they made choices based on their utility and travel cost. We want to look from the physicians' and the hospital manager's perspectives, and study how they would make optimal strategies of their medical resources for the incoming stream of patients.

We consider the healthcare institution as a service platform with health providers as the agents offering their service in-person or remotely through the telemedicine system. Patients have the option to receive their treatment by physical or virtual visits to the hospital. Although virtual visits save travel hassle from the patients' side, virtual visits ask for a higher level of attention, knowledge, and additional on-call time of the health providers. We consider those extra requirements as the effort cost of the doctor. In other words, doctors have their own preferences regarding treating remotely (telemedicine) or in-person (at the hospital, face-to-face). We normalise the effort cost from the existing in-person visit as zero. We begin by assuming that the hospital pays the doctor the same amount per unit time regardless of the type of service. The patients demand health services randomly over time according to known stochastic processes. The aim is to maximise the total expected utilisation of the medical resources as well as the revenue over the time horizon.

Using a stylized model, we find that if the doctor decides to accept either type of patient (those who seek treatment via telemedicine or an in-person visit to the hospital), his or her revenue may increase or decrease with an increase in the arrival rate of the patients choosing the less preferred option. Offering only the service option with the higher average revenue is preferred if the hospital has full control over which service type is accepted. That is, if the hospital can compel the doctor to accept either service regardless of the doctor's preference, the hospital finds it more profitable to offer only the service type which generates higher revenue per unit time, and reject the other type requests. More importantly, the doctor and the hospital may not choose the same optimal strategies for some values of effort costs. We show that this incentive misalignment issue can be solved by offering extra compensation for the less preferred service type of the agent, which in turn affects the doctor's strategy as well as the hospital's rewards. In other words, providing extra compensation for accepting the less preferred service option can resolve the misaligned incentives between the doctor and hospital. We also find that when it comes to

social welfare, depending on how much weight the hospital puts on its own revenue and service level (fraction of patients treated), offering either service option (or both) can be optimal.

18. SNA application in Blockchain Technology Adoption: A gap analysis using TAM and Degree Centrality

Authors: Neeraj Kumar Sahani, Vijaya Dixit and Priyanka Verma

Abstract

Blockchain Technology has now become an emerging technology across the globe due to its multiple features like cyber-attack proof, transparency across the blocks, traceability, and many more. Research is going on for its adoption across industries, still there are many challenges like lack of awareness about blockchain technology, government regulations, initial investments, etc., that restricts organisation from where to start in the supply chain network. This research paper focuses on evaluating the maturity score using TAM (Technology Acceptance Model) with the help of sample questionnaires of each entity in the supply chain network and the corresponding degree of centrality. This paper deals with analysing the gap between the powerful node in the network and its maturity score to interpret the dominance level of the node and its adoption rate of blockchain technology for sustainable acceptance of the model across the organisation.

19. Analysis of Critical Success Factors for Implementing Blockchain Technology in a Project-Driven Supply Chain by the Neutrosophic-AHP

Authors: Richa Singh, Priyanka Verma, and Vijaya Dixit

Abstract

A project-driven supply chain differs from the other supply chains as different projects come with varying resource requirements and demand a high degree of customisation from a technical and production point of view. There are significant flaws in the project-driven supply chain due to the involvement of multiple stakeholders. Industry 4.0 can change how PDSC deals with all the challenges present in the current value chain.

One popularly discussed and center of attraction for different researchers is Blockchain Technology. The use of blockchain increases visibility in the supply chain and helps in data aggregation and validating the information. It provides a way for multiple stakeholders to automate the contracts. But as it works with the concept of decentralisation, it increases the privacy risk. Thus, blockchain technology gives a different perspective to the existing project-driven supply chain and requires more research. This study is focused on identifying the critical success factors for the integration of blockchain with a project-driven supply chain. For the successful completion of the study, the framework used involves three stages. In the first stage, a thorough literature review has been done to identify the initial list of Critical success factors. In the second stage, expert opinions have been taken to finalise critical success factors for the adoption of blockchain; in the last stage, N- AHP is used to finalise critical success factors.

On the basis of reviewed literature and expert opinion, six factors and sixteen sub factors has been identified. Three different cases related to different project; water treatment plant, aerospace defense, Shree ram mandir construction, has been taken to analyse the critical success factor for the implementation of blockchain technology. Survey has been conducted and on the basis of project requirement, expert has given their opinion. After collecting responses, we have applied N-AHP to calculate weight of each factor and ranking has been done. We have observed that for different project, ranking of critical success factor is different. Project requirements plays very important role in the adoption of blockchain technology i.e., in defense projects data security has more importance than other construction projects. “Transparency”, “provenance tracking” and “fraud detection” always remains in the top five critical success factors in these projects, other factors change their ranking based on the project challenges and how blockchain technology can mitigate those challenges. The analysis shows what could be the critical success factors from the managerial and technical point of view for adopting blockchain technology in the project-driven supply chain, which combines two disciplines to increase transparency and trust in operations. The study will contribute to practice and academic literature by highlighting the factors that should be considered to adopt blockchain successfully.

20. Efficient Risk Mitigation strategies in Public Infrastructure Service contracts using Monte Carlo Simulation and DEA

Authors: Samir K Srivastava and Dhanshyam Mahavadi

Extended Abstract

Public infrastructure service projects are characterised by long-term resource commitment and risks (Besley & Ghatak, 2001; Chiara et al., 2007). Empirical evidence suggests that revenue risk is the most critical risk in typical Build-Operate-Transfer (BOT) type transportation infrastructure contracts (Bain, 2009), and results in severe cashflow crises, service disruptions, frequent negotiations, and project failure (Irwin, 2007; Power et al., 2016; Quimbayo et al., 2019). In order to mitigate such risks and ensure service continuity, governments often incorporate multiple performance guarantees in the procurement contracts. The uncertain nature of these guarantees creates contingent liabilities, which, if inadequately designed, result in acute fiscal burden to governments (Power et al., 2016). Diligent design of efficient risk mitigation strategies is imperative to ascertain value-for-money (VfM) in public infrastructure service projects (Irwin, 2007).

This paper aims to provide a decision framework for the design of an efficient mix of strategies for risk mitigation in BOT road infrastructure contracts. We identify multiple guarantees and financial support mechanisms through an extensive review of the relevant extant literature, as well as various project documents, contracts and model concession agreements of Indian BOT road projects. We model the most common and relevant risk mitigation strategies – minimum traffic guarantee (MTG) (Brandao & Saraiva, 2008), minimum revenue guarantee (MRG) (Power et al., 2016; Quimbayo et al., 2019), excess revenue share (ERS) (Zhang et al., 2021), revenue shortfall loan (RSL) (Vassallo & Solino, 2006), tax holidays (TH) and lumpsum capital grants (CG) – with traffic demand as the most critical stochastic parameter, along with the probabilistic initial traffic, O&M cost inflation, and the toll prices. We evaluate these individual support mechanisms and various combination strategies on different performance metrics – the probability of having negative cashflows (a measure of risk mitigation), the social welfare (a measure of VfM) and the expected cost of strategies (the measure of the fiscal burden) – using Monte Carlo simulation analysis (Cheah & Liu, 2006). We estimate the technical efficiency and cost efficiency measures of each strategy using Data Envelopment Analysis (DEA) (Charnes et al., 1978; Ishizaka & Nemery, 2013), and rank each of them based on their efficiency scores. The objective is to mitigate the risk to the maximum possible extent and maximise social welfare at a minimum cost. We demonstrate the entire decision framework using a real case project in India.

We find that, in general, combination strategies are more efficient than individual guarantees. Having no risk mitigation strategy is not a valid option; the choice of appropriate combinations mitigates risk efficiently. Revenue shortfall loan is the most efficient mechanism but has a low risk-reduction capability. A staged combination of MRG and ERS is the second most efficient strategy, followed by the combination of MRG, ERS and RSL. Tax holidays and the combinations involving TH are the most inefficient strategies. Guarantees on traffic are more efficient than guarantees on revenues. Lump sum capital grants are a highly inefficient strategy

individually, but when combined with MRG, ERS and RSL, low capital grants provide efficient risk mitigation without loss of much social welfare.

The contributions of this paper are holistic. First, we suggest a detailed simulation framework for the evaluation of various guarantees. Second, we present multiple combination strategies and analyse their interactions to identify fiscally efficient strategy mixes. Finally, we provide a detailed methodology to estimate the efficiency of strategies and choose the most efficient strategy mix. Our findings and the solution methodology enable policymakers and practitioners to negotiate and design effective public infrastructure service contracts. The paper extends the literature on contingent government supports and sets new directions for researchers, academicians and policy advisers.

21. Data Analytics for Procurement

Author: Sushant Kumar Panda

Extended Abstract

Why Data Analytics

In normal situation mostly the decisions are taken by business leaders using their judgement, intuition and the past experience. While this decision-making process has its importance, now-a-days the explosion of data from various different sources provides an opportunity to explore these data sets using Exploratory Data Analytics (EDA) techniques and advanced analytics techniques. The outcome of this analytics can lead to fact-based decision-making process. The prudent decision- making process definitely is to blend both fact-based and judgement-based processes.

Data Analytics is done to solve specific business problems. Once the business problem is identified we need to set an objective for the analysis project and list all insights which we need to make better decisions. The next step is to scrutinise the data sets available and pick up relevant data sets required for your analytics project.

Types of Data Analytics

There are four types of data analytics – Descriptive, Diagnostic, Predictive and Prescriptive in the order of difficulty and complexity. So, it is advisable to begin your analytics journey with Descriptive and Diagnostic analytics using world leading BI tools like Tableau or Power BI. Once the business users see the benefits of analytics you can plan to do Predictive and Prescriptive Analytics also.

Descriptive and Diagnostics analytics are best done using BI tool as mentioned above and visual analytics & Exploratory Data Analytics techniques. EDA uses basic statistics to get insights from raw data. In our case we plan to start with these two types of analytics using Tableau. Hence, we will building various dashboards and use drill down, slice dice features for better insights from the data sets. We will be using Python or R as when and if required.

Steps in Data Analytics

As mentioned above we need to fist define the business problem, which we are trying to solve and the necessary insights required from the existing data. The next step is to scrutinise and understand the relevant data for its sources, structure, cleanliness, granularity, agility, etc.

Having understood the list of insights required and the relevant data, the next step is to architect the data model, clean & integrate the data and make a data mart which will be the data source for BI tool. This step requires data management skills which may need ETL tools.

The next step is to analyse and visualise the analytics outcomes in terms interactive visual dashboards and perform quality test and UAT.

What Analytics in Procurement

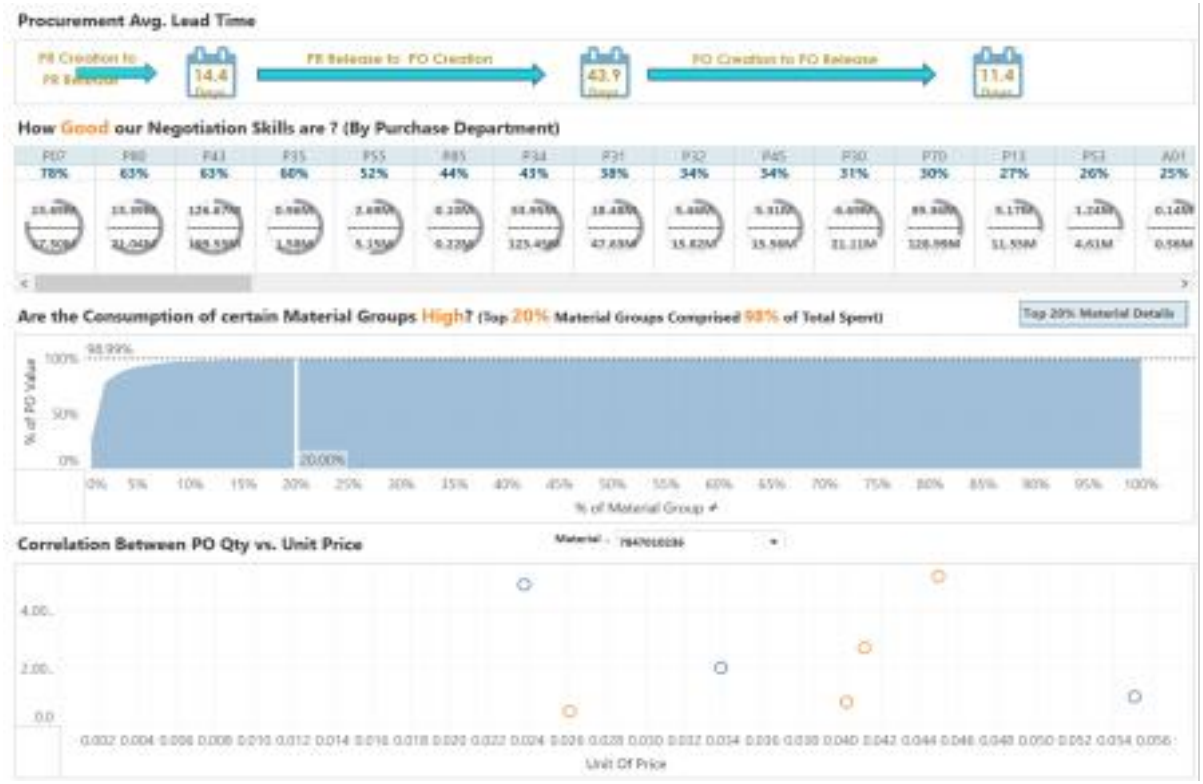
For procurement departments, information is power. Insights gleaned from historical data on product pricing and vendors can strengthen the buyer's negotiating position and drive better pricing. Few procurement functions are currently making the best use of the huge amounts of data they generate.

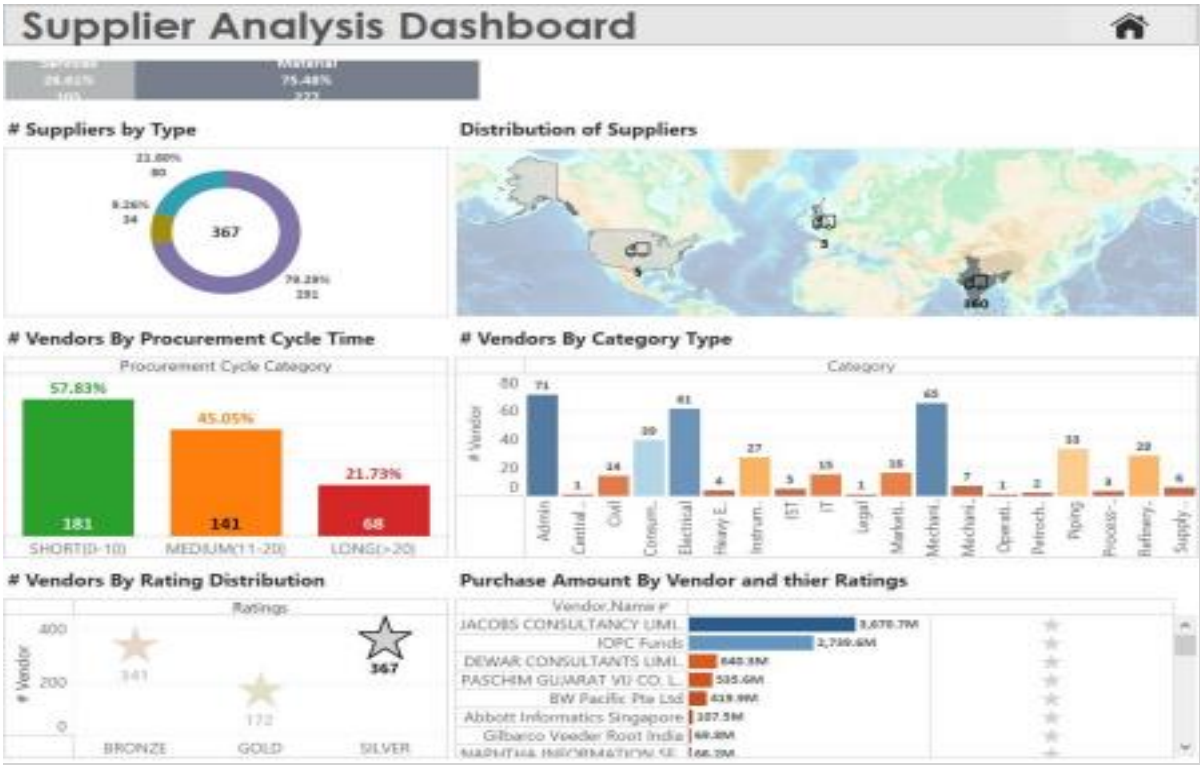
In case of procurement, we can initiate data analytics to get insights for following areas to begin with.

- Procurement Trend for various departments. Any seasonality in procurement?
- Price trend for commonly purchased item/good/services?
- Are we procuring the same item/service at different price from different vendors? If so, the list of vendors and their service levels.
- Is the reverse auction process working effectively to bring down the average price? In which department it is working effectively?
- Is reverse auction process effective after 2-3 rounds of reverse auction for procurement of the same items?
- Who are the top 20 or 30 suppliers to GoI? Are there any common owners for these companies?
- Many more business questions

Few sample interactive dashboards in Procurement

Procurement Efficiency Dashboard





The above few dashboards are just example of what quick insights you can get from procurement data. There are many more analysis can be done depending on the business insights one wants to get.

Advanced analytics in Procurement

Besides the descriptive analytics as shown above you can plan advanced analytics as mentioned below.

As per McKinsey statistical models and advanced analytics can help procurement departments achieve cost savings of 3 to 8 percent, compared to traditional pricing models. By employing robust data analytics, procurement managers can uncover new insights from data to use in negotiations, vendor segmentation and performance management, and annual purchasing strategy.

Procurement functions generate more data than any one employee can track and manage. At one midsize manufacturing company with approximately $2 billion in annual revenue, for example, procurement had data on more than 20,000 transactions for a single category, each with four to five statistically significant drivers of price.

But the models used by most procurement functions dramatically simplify the available data to make it easier for purchasers to handle. A lot of potentially valuable insights get lost along the way. Take the cost curve. This widely used modeling approach provides an overview of the average price paid to range of vendors over a year. The model is appealingly simple, but averaging prices can obscure the most critical aspects of vendor performance. For, say, an agricultural product with significant seasonal price variation, the highest-price vendor may be the only one that can supply the product only during the high-cost season, giving it no incentive to match others' prices.

The advantages of advanced analytics

Advanced-analytics techniques use algorithms to recognise patterns in complex data sets, allowing procurement analysts to query all their data, determine the statistically significant drivers of price, and cluster the data according to those drivers. The resulting clusters represent a set of purchases without significant differences in cost drivers and thus reveal the real differences in vendor performance.

A crucial advantage is that unlike people, advanced-analytics systems don't bias their decisions based on gut feeling, or place undue weight on outliers in the data. The systems also enable the testing of thousands of permutations very quickly to determine which statistical clusters fit the data best. In the agriculture example, the algorithm would not need to be told that seasonality is a driving force. It will make this determination from the data. If logistics costs also have a big impact, the algorithm will reveal the distance brackets that make a statistically significant difference.

But advanced-analytics systems can do more than quantify the cost drivers that procurement teams already know about: they can uncover entirely new insights. A recent analysis of vendors

revealed one among 400 that was clearly acting as a broker and applying a markup to every sale. With so many transactions, each with four to five significant drivers of price, these subtle trends are nearly impossible to isolate and act on without advanced analytics.

Three use cases for advanced analytics

Three areas—negotiation, vendor segmentation, and yearly planning—reinforce the value that a statistical approach powered by advanced analytics can deliver.

Negotiation

The first step in successful negotiations is to prepare a fact base with information on previous purchases. One manufacturer illustrates the complexity of this task. It spends hundreds of millions of dollars on raw materials through tens of thousands of transactions with hundreds of vendors. Pricing is affected by multiple factors and fluctuates throughout the year, so the manufacturer uses an advanced-analytics algorithm to group historical purchases into statistically significant clusters. This information can then easily be displayed in any format already familiar to the user—typically a spreadsheet.

Advanced analytics enables the manufacturer to quickly identify a cluster of vendors by entering a description of the upcoming purchase (for example, a specific material that is available within 50 miles of the plant). A summary of cluster data highlights the average price of similar purchases, as well as a list of available vendors and the prices they offer. Equipped with a robust, quantitative fact base, the manufacturer can come to the negotiating table with pricing based on historical data and information on vendors that operate in this space. In the first month of using the improved fact- based negotiation approach, the manufacturer's procurement function was able to achieve an 8 percent reduction in its cluster prices just by driving the highest purchase prices down toward the average.

Vendor management

Vendor segmentation and management is a relationship-oriented endeavor. As such, it is particularly vulnerable to the many biases that affect human interaction. While the personal nature of the relationship remains important, conclusions about vendor performance should be based on data, rather than feelings. Since advanced analytics is especially useful in isolating vendor performance within a cluster, it can help eliminate biases from the evaluation.

Consider a steel manufacturer that buys scrap steel as a major material input for its new steel. The manufacturer has 50 vendors that are spread among 100 statistically significant clusters, and each vendor appears in multiple clusters. Advanced analytics can deliver a snapshot of each vendor's aggregate performance.

To determine which vendors are the best performers by pricing, the steelmaker can create a scoring system that awards or deducts points for each transaction. For example, Vendor 1 sells a particular grade of automotive scrap, sourced locally for $100 a ton (landed cost). The cluster average for this scrap is $120 a ton. Since Vendor 1 sold the steelmaker scrap at a price lower than the cluster average, it receives one point for the transaction. After totaling the vendor scores

across all transactions, the manufacturer can plot each vendor on a relative point scale. A high score on this scale indicates a vendor that consistently outperforms the cluster average price and would be a top choice.

Yearly planning

Advanced analytics can be particularly helpful in analysing purchasing data to support a comprehensive sourcing strategy. Let's say that a chemicals manufacturer identifies 50 clusters for a single raw-material input. It has a good idea on pricing within each cluster, as well as the vendors that routinely offer the best deal. The next step is to decide how to shift volume among the clusters to minimise cost. From a strategic-planning standpoint, a procurement organisation might seek to eliminate clusters 45 to 50 and replace with volume from clusters 1 to 10. Purchasing managers might also explore adding new clusters from previously untapped sources. Cluster data will make it clear which clusters offer the best value to help guide the strategy, and vendor performance data will help identify which vendors are the top candidates for increased volume.

Modeling can also inform inventory-carrying decisions. For instance, the chemical manufacturer's data could show that it pays a 10 percent premium on spot purchases when its safety stocks are depleted. The procurement team can then make a data-driven decision about whether to pay the carrying cost for additional inventory, or pay a premium price for spot purchases.