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(7.12.1938–17.06.2021)**

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## Special issue in memory of Dr. Jean-Marie Proth (7.12.1938 – 17.06.2021)

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**Abstract:** Issues 1 and 2 of 2024 are composed of papers selected for the special section in memory of Dr Jean-Marie Proth. Some papers are extended versions of articles presented at the 10th IFAC MIM 2022 conference ([hub.imt-atlantique.fr/mim2022/](http://hub.imt-atlantique.fr/mim2022/)) in the invited sessions in memory of Dr. Proth.

**Keywords:** Production planning and control; scheduling; assembly line balancing, bin-packing, discrete event systems; facility layout.

### Introduction

Issues 1 and 2 of 2024 are composed of papers selected for the special issue in memory of Dr Jean-Marie Proth. Some papers were initially presented in the special sessions dedicated to the work of Jean-Marie Proth organized at the 10<sup>th</sup> IFAC MIM conference in Nantes, in June 2022, and then the authors were invited to submit extended versions to IJPR: <https://hub.imt-atlantique.fr/mim2022/>. Additional papers were submitted in response to the special issue call. The editors of this special issue are former PhD students and colleagues of Jean-Marie.

Dr. Jean-Marie Proth passed away on June 17, 2021. Jean-Marie was a member of the Editorial Board of the International Journal of Production Research and published a large number of articles in our journal and in other leading journals. Jean-Marie Proth has authored or coauthored 15 books (textbooks and monographs). He was invited 55 times as a keynote speaker or invited professor throughout the world.

He was a co-editor of the Journal Applied Stochastic Models and Data Analysis, and served as an Associate Editor of the IEEE Transactions on Robotics and Automation and IEEE Transactions on Industrial Informatics. Dr. Proth was the Chairman of the Program Committee of many international conferences and the Vice-President of Flexible Automation International Society for Productivity Enhancement (ISPE).

He was a pioneer and leading scholar in many directions of industrial engineering and operations research, made meaningful contributions to the production planning and control domain, e.g.: flow control, scheduling, planning, and hierarchical production management. Dr. Jean-Marie Proth's research has impacted numerous professors and scientists who are now leaders in these areas.

Jean-Marie focused on solving systems of partial differential equations, especially for the design of buffer stocks, the development of specific algorithms for some scheduling problems in real time, supply chains engineering, assembly line balancing, and bin-packing problems. His results in the modeling, analysis, and evaluation of discrete event systems, especially Petri Nets for modeling and analyzing the behavior of discrete event systems, data analysis for design of production systems, innovative tool to perform cross-classification for group technology (called GPM, Garcia-Proth Method). The algorithm GPM was used not only in the group technology and layout design, but also to decompose linear systems of very large size in order to approximate the solution. Many other research problems were solved by Jean-Marie Proth, e.g., in city logistics applications, an algorithm was proposed which proceeds by division of the territory and can guide a vehicle in a city, taking into account fluctuations in traffic, etc.

Dr. Jean-Marie Proth was the head of the well-known SAGEP (simulation, analysis and management of production systems) team of INRIA (National Research Institute in Automation and Computer Science) for many years, the team focused on the preliminary design and the management of manufacturing systems. The main research directions are the following ones:

- Modelling and evaluation of discrete event systems. Most of the research done in this area is based on Petri nets;
- Management of manufacturing systems. This area includes, but is not limited to scheduling and hierarchical management of production, as well as predictive maintenance;
- Supply chain engineering and management under uncertainty;
- Design/management of self-serviced urban electric vehicles.

An important effort has been made to develop and implement bin-packing software tools for sub-contractors of steel companies. This industrial activity provided the opportunity to introduce a new approach for large-size multicriteria bin-packing problems.

Professor Proth was also an Associate Member of the Institute for Systems Research and Mechanical Engineering, University of Maryland, and a Professor at the European Institute for Advanced Studies in Management (Brussels).

Selected books by Dr. Jean-Marie Proth:

- "Mathematical technics in production planning", by A. BENSOUSSAN, M. CROUHY and J.M. PROTH, North Holland Publishing, 1983.
- "Mathematical Tools in Production Management", by J.M. PROTH and H. HILLION, Plenum, 1990.
- "L'ordonnancement et ses applications", by C. CHU and J-M. PROTH, Masson, 1996.
- "Petri Nets: A Tool for Design and Management of Manufacturing Systems", by J-M. PROTH and X. XIE, Wiley and Sons, 1996.
- "Supply Chain Engineering. Useful Methods and Techniques", by A. DOLGUI, J.-M. PROTH, Springer, 2010

The special issue papers included in the two-part issue, have been reviewed following the standards of IJPR and accepted after several revisions. Short introductions of selected papers are presented next.

### **Part 1 (Vol. 62, Issue 1, 2024):**

The paper (Date and Nagi, 2024a) considers a hybrid location theoretic and facility layout perspective for a new problem of optimal placement of multiple rectangular facilities in presence of existing rectangular facilities, where all facilities could be interacting (exchanging flow) through boundary input/output points and the distances are rectilinear and "barrier free". The novel contribution of this paper is the rigorous development of optimality results for simultaneous placement of multiple facilities and exact algorithms to this open problem.

The companion paper (Date and Nagi, 2024b) study problems of realistic dimensions for placing multiple new rectangular facilities in an existing layout with pre-existing rectangular facilities. The paper develops explicit and implicit enumeration schemes based on state-space search and a flow decomposition lower-bound. A large class of construction and heuristic methods are proposed to effectively solve industrial-sized problems.

Yin et al. (2024) addresses the improvement of humanitarian relief networks with uncertain demands and evacuation rates of injured people. An integrated facility location, supply inventory and distribution, and evacuation planning problem is formulated, a distributionally robust model is proposed and an enhanced Branch-and-Benders-cut algorithm is developed to help decision maker achieve the best balancing of considered metrics.

Battaïa, Dolgui and Guschinsky (2024) study the machining lines composed of multi-positional machines with rotary tables and vertical and horizontal modules of machining equipment. Both equipment selection and line balancing decisions are considered at the preliminary design of a line in order to minimize its total cost. A mixed-integer linear program and a heuristic algorithm are developed. Extensive numerical tests are carried out and analysed with a view of solving efficiently large-scale industrial cases.

The article by Huang et al. (2024) studies delayed reconfigurable manufacturing systems and respond to the requirement to improve their convertibility. Part family formation and configuration design are simultaneously considered. A multi-objective joint optimization technique based on NSGA-III is developed taking into account investment and reconfiguration costs as well as similarity coefficient and delayed reconfiguration.

In (Sawik, 2024) an efficient mixed integer programming formulation for balancing and scheduling of mixed-model assembly lines with alternative disjunctive precedence constraints among assembly tasks is proposed. The new model introduces a new disjunctive precedence selection and task assignment variable and new constraints to optimally choose one relation for each subset of alternative precedence relations.

The paper (Alfaro-Pozo and Bautista-Valhondo, 2024) deals with assembly line balancing with space limitations and ergonomic considerations. Ergonomic risks of tasks are taken into account. Two linearized models and corresponding solution approaches are proposed and compared. The numerical study demonstrates some loss in the efficiency of the line when the decision maker searches for ergonomic improvements for workstations. The proposed approach helps balancing ergonomics and productivity.

The article (May, Nestroy, Overbeck et al. 2024) presents techniques for automated simulation model generation for production systems. The approach is based on event-based data. Methods from process mining and machine learning are applied. Colored Petri Nets serve as conceptual and operational description of simulated systems.

The article (Elyasi, Altan, Ekici et al. 2024) studies the production planning problem of Vestel Electronics company with uncertain demand and both dedicated and flexible/hybrid manufacturing systems. The authors suggest measures and models for production planning to mitigate the variation of demand and to make adaptive decisions taking advantage of the cost-effectiveness of dedicated and the responsiveness of flexible manufacturing systems. A scenario-based model is proposed and a column generation-based heuristic is developed for realistically sized real-world instances.

The paper (Kusiak 2024) on data science and artificial intelligence in digital manufacturing, introduces new concepts of explainable artificial intelligence based on XRule algorithms. The decision-trees implemented in the XRule approach incorporate preferences of decision makers. The concept of federated explainable artificial intelligence is proposed to develop algorithms and methodologies supporting solutions that meet the needs of a large number of users. Examples of industrial applications are reported.

Singh and Sarin (2024) develop a new production control methodology to solve a Stochastic-Demand Assembly Job Shop Scheduling Problem for mass customization. The objectives are to keep the production costs low, minimize the loss due to excess inventory, reduce the time of delivery of products to the customers. An algorithm is developed and tested, the results are compared with those obtained with the commercial solver CPLEX®, the proposed algorithm obtains solutions with lower costs and smaller optimality gaps.

The article (Antons and Arlinghaus 2024) aims at understanding the role of manufacturing network architecture in scheduling. It develops multi-agent based discrete-event simulation models for centralized and decentralized control of

manufacturing systems. The centralized approach uses mixed integer programs to search for optimal decisions. Three manufacturing network topologies are considered. The simulations provide insights on the complexity of scheduling problems for both centralized and decentralized approaches.

The paper (Castellano, Gallo, and Glock 2024) develops analytical expressions of the cost function for a single-vendor, multiple-buyer coordinated supply chain with unequal-sized batch shipments and cycle-dependent safety stocks and suggests an optimisation algorithm. Numerical experiments are reported to compare the results of the proposed algorithm to those of a benchmark algorithm based on a commercial solver, and to demonstrate advantages of the proposed model.

In the article (Sethi and Chutani 2024), the authors define a forecast horizon beyond which the demand and price forecast do not affect the optimal decision during some initial periods defined to be a decision horizon. The case of a wheat trading firm that is attempting to determine an optimal buying and selling policy is considered. Using a control theoretic framework, the paper shows that the decision and forecast horizons arise from lower and upper bounds imposed on the commodity on-hand inventory. The mathematics are elegant and deeply related to earlier research of Jean-Marie Proth.

The paper (Karagiannis, Minis, Arampantzi et al. 2024) develops a mixed-integer programming model to minimize the warehousing and distribution costs for forward and reverse product flows. This comprehensive model selects warehouse(s), determines inventory levels, product unit loads to be transported, and truck routing for forward and reverse flows. For the industrial case of a Greek 3PL company, the authors demonstrate an impressive cost reduction of about 10.8% for forward flows. They also provide insights of additional savings of warehouse capacities through sensitivity analyses.

The article (Aldrighetti, Calzavara, Martignago et al. 2024) develops a three-step methodological framework to design resilient supply networks. The first step is to input the current state of the supply network, define vulnerabilities, and identify KPIs to monitor. The second step is modeling and exploration of alternatives with explicit consideration of robustness, recovery, and flexibility. The third stage is evaluation and validation of the alternatives in a decision-support style. The authors demonstrate this framework on an industrial case study and show how to achieve 100% service rate for the anticipated disruptions.

## **Part 2 (Vol. 62, Issue 2, 2024):**

The review paper (Khakifirooz, Fathi, Dolgui et al. 2024) considers new trends in scheduling applications and theory and analyze how the domain changed while considering J.M. Proth's predictions and advice in his publications. A specific attention is reserved to dynamic scheduling, real-time assignment, and cyclic scheduling in production systems, taking into account Industry 4.0 technologies and resilience issues for the supply networks.

The article (Xue, Li, Wang et al. 2024) addresses the joint optimization of job-to-server assignment and job-sequencing for randomly released jobs to be served by a set of distributed servers with random service times, travel time and travel cost. The problem is formulated as a two-stage stochastic programming with assignment decision in stage 1 and job-sequencing in stage 2 when random release times and service times are revealed. A stochastic-logic Benders decomposition approach is proposed to solve the sample average approximation of the problem.

In the paper (Thenarasu, Rameshkumar, Di Mascolo et al. 2024), the authors study a Partial Flexible Job Shop Scheduling problem that has substantial real-life applications. For making quick decisions in real-time, a novel method of integrating multi-criteria decision-making algorithms and the discrete event simulation model is proposed to define job priorities in large-scale problems involving multiple.

Avgerinos, Mourtos, Vatikiotis et al. (2024) consider a problem from a textile manufacturer. The problem is formulated as a scheduling problem on unrelated machines with sequence-dependent and machine-dependent setup times, and a constraint on the number of simultaneous setups. A mixed integer program and a lower bound are suggested. New extensions of known metaheuristics coupled with constraint programming algorithms are proposed. Extensive experiments are performed to study the complementarity of methods in different instances.

The article (Feng and Peng 2024) investigates a robust identical parallel machine scheduling problem with a two-stage time-of-use tariff and not-all-machine option, in which only interval bounds on job processing times are known. The problem is formulated into a min-max regret model to maximise the robustness and is solved by an iterative relaxation-based exact algorithm and a memetic differential evolution-based heuristic.

In the article (Pan, Wang, Cao, et al. 2024), the authors study specific scheduling problems for steelmaking-casting. They propose scheduling approaches which use the deep reinforcement learning techniques, Markov decision process, heuristic rules, a backward strategy and a branching dueling double deep Qnetwork to design an algorithm minimising the total production time and electricity cost by avoiding peak of electricity consumption.

In (Wang, Ren, Bai, et al. 2024), the authors consider cloud computing scheduling problem with packets (tasks) from different customers (agents) competing for the common cloud resource. The related problem can be considered as a new multi-agent flow-shop scheduling problem to minimise the total completion time of agents. For this NP-hard problem, a branch and bound algorithm with pruning rules and lower bounds is designed and a bi-population cooperative co-evolutionary algorithm is proposed to address the generalised bi-scenario version.

The paper (Haned, Kerdali and Boudhar 2024) reports a new analysis of complexity for the problem of scheduling on identical machines with preemption and setup times for different properties of setup times. Lower and upper bounds are proposed. For the special case with two machines, a dynamic program and an FPTAS are suggested. Heuristics and a genetic algorithm are developed for more general cases. Interesting insights from numerical tests show that the best heuristics are those

based on the largest setup time and the largest sum of the processing and setup time rules.

In (Kucukkoc, Keskin, Karaoglan et al. 2024), the authors consider a real-life parallel batch scheduling problem for frozen products in a food processing company. It is reduced to the parallel p-batch scheduling problem with batch delivery, content-dependent loading/unloading times and energy-aware objective function. A mixed integer linear programming model is designed, numerical tests are given. For large scale instances, a metaheuristic algorithm is also developed.

The paper (Teran-Viadero, Alonso-Ayuso and Martín-Campo 2024) suggests new models for a real-life problem in cardboard industry which is a specific 2-dimensional guillotine cutting stock problem. Mathematical models are proposed and tested using real life data from the company. The tests demonstrate the effectiveness of the models which reduce the produced material and leftovers, diminishing operation times and production costs.

The study by Zhang, Chu, Che, et al. (2024) is related to the sustainable perishable food supply chains. It focuses on exploring the closed-loop inventory-routing problem with returnable transport items selection for perishable food. To address the problem, an integer linear program is constructed and an efficient tailored kernel search matheuristic is designed to maximise the total profit of the holistic supply chain.

The article (Bensoussan and El Ouardighi 2024) proposes inventory and production control models to study the performances of  $(s, S)$  inventory policy under voluntary environmental efforts. Using the quasi-variational inequalities approach, the authors analyze the properties of a cost-benefit tradeoff by taking into account the environmental efforts of a producer faced with market demand dependent on these environmental efforts. Insights are given for this new perspective of inventory control problem.

In the article (Wang and Chen 2024) the authors consider a multi-item distribution system with multiple regional distribution centers supplying from a central distribution center which again supplies from outside. Both the central distribution center and regional distribution centers use continuous-review  $(Q, S)$  policy for joint replenishment of all items. Analytical models are proposed for policy evaluation and a decomposition and coordination approach is proposed for policy optimization. Numerical experiments are performed for sensitivity analysis and managerial insights.

The paper (Facchini, Mossa, Sassanelli et al. 2024) leverages upcoming Internet of Things technology to optimize material handling within a manufacturing plant. A milk-run system with dynamic routing for tugger trains delivering materials in a production system is developed. For a case study from an automotive company, the authors show that the delivery strategy was effective in maintaining the requisite inventory stock at the stations, it improved thutilisation of tugger trains, and reduced the daily path for the tuggers.



The paper (Kritikos and Ioannou 2024) studies a new capacitated minimum spanning tree problem, where time windows are associated with the arcs of the graph, and a unit flow cost is associated with each arc, while a non-negative integer demand is associated with the terminal node. A MIP model is proposed, and valid inequalities are proved to improve the model. Extensive numerical tests are reported. The model can be used in distribution network design, military logistics and humanitarian relief operations.

Finally, the article (Wang, Tang and Zhang 2024) considers an inventory stacking decision problem. It consists in assigning positions to items which are stacked vertically. Such type of problem appears, for example, in container terminals or when steel plates are stacked in steel plants. The influence of information available on arrival and departure of items is examined. Models are proposed incorporating different availabilities of information.

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