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Computational Science and Its Applications – ICCSA 2024 Workshops

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Preface

These 11 volumes (LNCS volumes 14815–14825) consist of the peer-reviewed papers from the 55 Workshops of the 2024 International Conference on Computational Science and Its Applications (ICCSA 2024) which took place during July 1–4, 2024 in Hanoi (Vietnam). The peer-reviewed papers of the main conference tracks are published in a separate set consisting of two volumes (LNCS 14813–14814).

The conference was held in a hybrid form, with some participants present in person, hosted in Hanoi, Vietnam, by the Thuy Loi University. We enabled virtual participation for those who were unable to attend the event, due to logistical, political and economic problems, by adopting a technological infrastructure based on open source software (jitsi + riot), and a commercial Cloud infrastructure.

ICCSA 2024 was another successful event in the International Conference on Computational Science and Its Applications (ICCSA) conference series, previously held in Athens, Greece (2023), Malaga, Spain (2022), Cagliari, Italy (hybrid with few participants in presence in 2021 and completely online in 2020), whilst earlier editions took place in Saint Petersburg, Russia (2019), Melbourne, Australia (2018), Trieste, Italy (2017), Beijing. China (2016), Banff, Canada (2015), Guimaraes, Portugal (2014), Ho Chi Minh City, Vietnam (2013), Salvador, Brazil (2012), Santander, Spain (2011), Fukuoka, Japan (2010), Suwon, South Korea (2009), Perugia, Italy (2008), Kuala Lumpur, Malaysia (2007), Glasgow, UK (2006), Singapore (2005), Assisi, Italy (2004), Montreal, Canada (2003), and (as ICCS) Amsterdam, The Netherlands (2002) and San Francisco, USA (2001).

Computational Science is the main pillar of most of the present research, industrial and commercial applications, and plays a unique role in exploiting ICT innovative technologies, and the ICCSA conference series have been providing a venue to researchers and industry practitioners to discuss new ideas, to share complex problems and their solutions, and to shape new trends in Computational Science. As the conference mirrors society from a scientific point of view, this year's undoubtedly dominant theme was the machine learning and artificial intelligence and their applications in the most diverse economic and industrial fields.

The ICCSA 2024 conference is structured in 6 general tracks covering the fields of computational science and its applications: Computational Methods, Algorithms and Scientific Applications – High Performance Computing and Networks – Geometric Modeling, Graphics and Visualization – Advanced and Emerging Applications – Information Systems and Technologies – Urban and Regional Planning. In addition, the conference consisted of 55 workshops, focusing on very topical issues of importance to science, technology and society: from new mathematical approaches for solving complex computational systems, to information and knowledge in the Internet of Things, new statistical and optimization methods, several Artificial Intelligence approaches, sustainability issues, smart cities and related technologies.

In the Workshops proceedings we accepted 281 full papers, 17 short papers and 2 PhD Showcase papers. In the Main Conference Proceedings we accepted 53 full papers, 6 short papers and 3 PhD Showcase papers from 207 submissions to the General Tracks of the conference (acceptance rate 30%). We would like to express our appreciation to the workshops chairs and co-chairs for their hard work and dedication.

The success of the ICCSA conference series in general, and of ICCSA 2024 in particular, vitally depends on the support of many people: authors, presenters, participants, keynote speakers, workshop chairs, session chairs, organizing committee members, student volunteers, Program Committee members, Advisory Committee members, International Liaison chairs, reviewers and others in various roles. We take this opportunity to wholehartedly thank them all.

We also wish to thank our publisher, Springer, for their acceptance to publish the proceedings, for sponsoring part of the best papers awards and for their kind assistance and cooperation during the editing process.

We cordially invite you to visit the ICCSA website https://iccsa.org where you can find all the relevant information about this interesting and exciting event.

July 2024

Osvaldo Gervasi
Beniamino Murgante
Chiara Garau

Welcome Message from Organizers

After the very hard times of COVID, ICCSA continues its successful scientific endeavors in 2024, hosted in Hanoi, Vietnam. This time, ICCSA moved from the Mediterranean Region to Southeast Asia and was held in the metropolitan city of Hanoi, the capital of Vietnam. Hanoi is a vibrant urban environment known for the hospitality of its citizens, its rich history, vibrant culture, and dynamic urban life. Located in the northern part of the country, Hanoi is a bustling metropolis that combines the old with the new, offering a unique blend of ancient traditions and modern development.

ICCSA 2024 took place in a secure environment, allowing for safe and vibrant in-person participation. Combined with the active engagement of the ICCSA 2024 scientific community, this set the stage for highly motivating discussions and interactions regarding the latest developments in computer science and its applications in the real world for improving communities' quality of life.

Thuyloi University, also known as the Water Resources University, is a prominent institution in Hanoi, Vietnam, with a strong reputation in engineering and technical education, particularly in water resources and environmental engineering. In recent years, the University has expanded its academic offerings to include computer science, reflecting the growing importance of technology and digital skills in all sectors. This year, Thuyloi University had the honor of hosting ICCSA 2024. The Local Organizing Committee felt the burden and responsibility of such a demanding task and put all necessary energy into meeting participants' expectations and establishing a friendly, creative, and inspiring scientific and social/cultural environment that allowed for new ideas and perspectives to flourish.

Since all ICCSA participants, whether informatics-oriented or application-driven, realize the tremendous advancements in computer science over the last few decades and the huge potential these advancements offer in coping with the enormous challenges of humanity in a globalized, 'wired,' and highly competitive world, the expectations for ICCSA 2024 were high. The goal was to successfully match computer science progress with communities' aspirations, achieving progress that serves real, place- and people-based needs and paves the way towards a visionary, smart, sustainable, resilient, and inclusive future for both current and future generations.

On behalf of the Local Organizing Committee, I would like to sincerely thank all of you who contributed to ICCSA 2024.

Nguyen Canh Thai

Organization

ICCSA 2024 was organized by Thuyloi University (Vietnam), the University of Perugia (Italy), the University of Basilicata (Italy), Monash University (Australia), Kyushu Sangyo University (Japan), the University of Minho (Portugal), and the University of Cagliari (Italy).

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Econometrics and Multidimensional Evaluation of Urban Environment (EMEUE 2024)

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Environmental, Social, Governance of Energy Planning (ESGEP 2024)

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Ecosystem Services in Spatial Planning for Resilient Urban and Rural Areas (ESSP 2024)

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Ethical AI Applications for a Human-Centered Cyber Society (EthicAI 2024)

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14th International Workshop on Future Computing System Technologies and Applications (FiSTA 2024)

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Geographical Analysis, Urban Modeling, Spatial Statistics (Geog-An-Mod 2024)

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Geomatics for Resource Monitoring and Management (GRMM 2024)

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International Workshop on Information and Knowledge in the Internet of Things (IKIT 2024)

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Regenerating Brownfields Enhancing Urban Resilience Appeal (INFERENCE 2024)

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International Workshop on Territorial Planning to Integrate Risk and Urban Ontologies (IWPRO 2024)

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MaaS Solutions for Airports, Cities and Regional Connectivity (MaaS 2024)

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Development of Urban Mobility Management and Risk Assessment (MAINTAIN 2024)

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Multidimensional Evolutionary Evaluations for Transformative Approaches (MEETA 2024)

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Building Multi-dimensional Models for Assessing Complex Environmental Systems (MES 2024)

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Models and Indicators for Assessing and Measuring the Urban Settlement Development in the View of Zero Net Land Take by 2050 (MOVEto0 2024)

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Carmen Guida	University of Naples Federico II, Italy
Chiara Di Dato	University of L'Aquila, Italy

4th Workshop on Privacy in the Cloud/Edge/IoT World (PCEIoT 2024)

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Scientific Computing Infrastructure (SCI 2024)

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Alexander Bogdanov	St. Petersburg State University, Russia
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Downscale Agenda 2030 (SDGscale 2024)

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Socio-Economic and Environmental Models for Land Use Management (SEMLUM 2024)

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Paola Amoruso	LUM, Italy

Ports of the Future - Smartness and Sustainability (SmartPorts 2024)

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Marco Petrelli	Roma Tre University, Italy

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Massimiliano Bencardino	University of Salerno, Italy

Smart Transport and Logistics - Smart Supply Chains (SmarTransLog 2024)

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Smart Tourism (SmartTourism 2024)

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Sustainable Evolution of Long-Distance Freight Passenger Transport (SOLIDEST 2024)

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Sustainability Performance Assessment: Models, Approaches, and Applications Toward Interdisciplinary and Integrated Solutions (SPA 2024)

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Francesca Perrone	Sapienza University of Rome, Italy
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Specifics of Smart Cities Development in Europe (SPEED 2024)

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Venue

ICCSA 2024 took place on the main campus of Thuyloi University in Hanoi, Vietnam.

Plenary Lectures

Harnessing Artificial Intelligence for Enhanced Spatial Analysis of Natural Hazard Assessments

Prof. Dr. Biswajeet Pradhan

Director - Centre for Advanced Modelling and Geospatial Information Systems (CAMGIS), School of Civil and Environmental Engineering, Faculty of Engineering and IT, University of Technology Sydney, Australia

Abstract. In the realm of natural hazard assessments within spatial domains, the advent of Artificial Intelligence (AI) represents a paradigm shift, revolutionizing the way we conceptualize, model, and interpret environmental risks. This keynote address illuminates the profound impact of AI technologies, particularly machine learning algorithms and data-driven approaches, in reshaping our understanding and prediction capabilities concerning natural disasters.

By assimilating and scrutinizing vast spatial datasets, AI-driven models offer unparalleled accuracy and efficiency, facilitating timely and precise hazard assessments. Real-time processing of geospatial information not only enables rapid predictions but also forms the cornerstone of proactive disaster management strategies. Furthermore, AI's capacity lies in its adeptness at deciphering intricate spatial patterns inherent to natural hazards, unraveling subtle cues and previously unnoticed correlations within the data fabric.

This keynote delves into how AI's nuanced interpretation, coupled with advanced algorithms, elevates hazard modeling, providing deeper insights into the spatial dynamics of environmental risks. By augmenting traditional methodologies and revealing hidden patterns, AI fosters comprehensive risk assessments, fostering informed decision-making processes. The fusion of AI and natural hazard assessments in spatial domains heralds a more resilient approach to disaster preparedness and response.

Join us in embracing this transformative era, where AI's sophisticated modeling techniques and precise spatial interpretations converge, heralding proactive and effective mitigation strategies amidst the ever-evolving landscape of environmental challenges.

Short Bio. Distinguished Professor Dr. Biswajeet Pradhan is an internationally established scientist in the field of Geospatial Information Systems (GIS), remote sensing and image processing, complex modelling/geo-computing, machine learning and soft-computing applications, natural hazards and environmental modelling. He is the Director of the Centre for Advanced Modelling and Geospatial Information Systems (CAMGIS) at the Faculty of Engineering and IT at the University of Technology, Sydney (Australia). He was listed as the World's Most Highly Cited Researcher by the Clarivate Analytics Report for five consecutive years, 2016–2020, as one of the world's most influential minds.

He ranked number one (1) in the field of "Geological & Geomatics Engineering" during the calendar year 2021–2023, according to the list published by Stanford University Researchers, USA. This list ranks the world's top 2% most highly cited researchers based on Scopus data. In 2018–2020, he was awarded as World Class Professor by the Ministry of Research, Technology and Higher Education, Indonesia. He is a recipient of the Alexander von Humboldt Research Fellowship from Germany. Between 2015–2021, he served as "Ambassador Scientist" for the Alexander Humboldt Foundation, Germany.

Professor Pradhan has received 58 awards since 2006 in recognition of his excellence in teaching, service and research. Out of his more than 850 articles (Google Scholar citation: 70,000, H-index: 129), more than 750 have been published in science citation index (SCI/SCIE) technical journals. He has authored/co-authored ten books and thirteen book chapters.

Software Engineering Research in a New Situation

Prof. Carl K. Chang

Professor Emeritus, Iowa State University, USA

Abstract. With the rise of Generative Artificial Intelligence (GAI), epitomized by Large Language Models (LLMs), a profound shift has unfolded in software engineering research. In this presentation, I will traverse my four-decade journey in software engineering research, focusing on situational awareness in the era of the Internet of Things (IoT). I have witnessed the turbulence brought forth by the AI community that demands changes in our approaches. Meanwhile, owing to the pervasiveness of services computing, services became the first-class citizen in modern-day software engineering methodologies.

I argue that situational awareness must permeate the entire lifecycle to consistently deliver software services that align with the dynamic needs of users and the ever-evolving environments. I will elucidate this argument by reviewing the Situ framework, offering a comprehensive illustration of my perspective. Furthermore, I will outline my vision regarding the formidable research challenges considering the rapidly shifting landscape dominated by an irresistible and profoundly disruptive generative AI tsunami.

Short Bio. Carl K. Chang is a former department chair and Professor Emeritus of Computer Science at Iowa State University. His research interests include requirements engineering, net-centric computing, situational software engineering and digital health. Chang was the 2004 President of the IEEE Computer Society. Previously he served as the Editor-in-Chief for IEEE Software (1991–1994), and as the Editor-in-Chief of IEEE Computer (2007–2010). He was the 2012 recipient of the Richard E. Merwin Medal from the IEEE Computer Society. Chang is a Life Fellow of IEEE, a Fellow of AAAS, and a Life Member of the European Academy of Sciences (EurASc).

Interpretability and Privacy Preservation in Large Language Models (LLMs)

Prof. My Thai

University of Florida (UF) Research Foundation Professor
Associate Director of UF Nelms Institute for the Connected World

Abstract. Large Language Models (LLMs) have transformed the AI landscape, captivating researchers and practitioners with their remarkable ability to generate human-like text and perform complex tasks. However, this transformative power comes with a set of critical challenges, particularly in the realms of interpretability and privacy preservation. In this keynote, we embark on an exploration of these pressing issues, shedding light on how LLMs operate, their limitations, and the strategies we can employ to mitigate risks. We begin by examining the interpretability in LLMs, which often function as enigmatic "black boxes." Their complex neural architectures make it challenging to understand how they arrive at specific outputs. This lack of transparency raises questions of trust and accountability. When deploying LLMs in real-world applications—whether for chatbots, content generation, or decision-making—it becomes crucial to demystify their decision paths.

We will use explainable AI (XAI) to offer faithful explanations, from the black-box to white-box models, and from feature-based [1, 2] to neuron circuits-based [3, 4] explanations. By visualizing attention mechanisms, feature importance, and saliency maps, we empower users to comprehend LLM predictions. XAI not only fosters trust but also encourages responsible utilization of LLMs.

We next turn our attention to one of the utmost concerns and challenges: data privacy. LLMs process vast amounts of data, raising risks of data leakage, model inversion, the right to be forgotten, and inadvertent exposure of sensitive information. Furthermore, the integration of LLMs into diverse applications also significantly brings these challenges to the next level [5]. This talk explores strategies to protect privacy, including differential privacy, federated learning, and data encryption.

Short Bio. My T. Thai is a University of Florida (UF) Research Foundation Professor, Associate Director of UF Nelms Institute for the Connected World, and a Fellow of IEEE and AAIA. Dr. Thai is a leading authority who has done transformative research in Trustworthy AI and Optimization, especially for complex systems with applications to healthcare, social media, critical networking infrastructure, and cybersecurity. The results of her work have led to 7 books and 350+ publications in highly ranked international journals and conferences, including several best paper awards from the IEEE, ACM, and AAAI.

In responding to a world-wide call for responsible and safe AI, Dr. Thai is a pioneer in designing deep explanations for black-box ML models, while defending against explanation-guided attacks, evident by her Distinguished Papers Award at the Association for the Advancement of Artificial Intelligence (AAAI) conference in 2023. At the same year, she was also awarded an ACM Web Science Trust Test-of-Time award, for her landmark work on combating misinformation in social media. In 2022, she received an IEEE Big Data Security Women of Achievement Award. In 2009, she was awarded the Young Investigator (YIP) from the Defense Threat Reduction Agency (DTRA), and in 2010 she won the NSF CAREER Award. She is presently the Editor-in-Chief of the Springer Journal of Combinatorial Optimization and the IET Blockchain Journal, and editor of the Springer book series Optimization and Its Applications.

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The Optimal Functional Mixture for Student Housing Initiatives: An Italian Case Study

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Abstract. Student housing is one of the main alternative asset classes within the real estate sector. In Italy, this sector is experiencing rapid growth and presents an excellent opportunity for attractive returns. However, the gap between the demand and supply of student accommodations remains substantial, therefore, the spread of student housing initiatives is supported by National Recovery and Resilience Plan dispositions that foster its application. The aim of the work is to define a goal-programming based model able to maximize the profit of the private subject involved into the initiatives that concern the enhancement of student housing accommodations. It concerns the definition of a management model that provides for the possibility of allocating part of the rooms to tourist hospitality. Starting from these considerations, in this paper an operations research problem whose objective is to identify the optimal mix of functions that allows the maximization of the profit of the structure manager is proposed. The obtained results show interesting margin of profit in the case for which the integration with the National Recovery and Resilience Plan are considered.

Keywords: student housing · operative research · scenario analysis · profit maximization

1 Introduction

Independently living university students traditionally choose between two types of accommodation: on-campus dormitories and private housing (rooms) near campus. Since the mid-1990s, purpose-built student accommodation (PBSA) has emerged as an alternative to traditional types of private housing and has become an increasingly important source of housing for students. PBSA share some features with dormitories: they are designed for student needs and the rooms are generally shared, but unlike dormitories, it is a service provided by market operators and it is based on the rent of bed. The level of quality varies, but it often includes higher quality services than those provided by dorms.

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Among the several drivers of the PBSA spread, the number of international students seeking education abroad is relevant. It has been on rise, especially in countries like the United States, the United Kingdom, Australia, and Canada. This trend has led to an increasing demand for student housing, particularly in major university cities. Students are ever more concerned about environmental issues, and developers are responding to this demand by providing sustainability features such as energy-efficient appliances, eco-friendly building materials, and waste-recycling systems. The technological enhancement for students living experiences has led to include online rental payments, mobile apps for communication and maintenance requests, and high-speed internet access. The COVID-19 has significantly affected the dynamics of the market giving the possibility to offer more flexible leasing options, such as shorter lease terms and ability to cancel or modify leases with minimal penalties. This flexibility has become crucial for students who may need to adjust their living arrangements due to changing circumstances.

Many students and investors consider PBSA market as a safer and more convenient option compared to traditional rental housing. However, student housing has become less affordable since 2013, leading to widespread public concern. The determinants of PBS housing affordability, which is a large component of college costs, are key policy interest. From 2013–2020, the effective rent per bed increased by about 25% higher for purpose-built student housing and 30% for student-competitive housing (defined as conventional apartments within three miles of a campus). A natural explanation for the rise in housing costs is represented by the growing demand from university students. This contingence would seem to fit in with the fact that student housing became less accessible just as university enrolments increased. When universities increase their enrollment, more student housing units are built. However, if there are changes in the traditional housing rental market, specially built student housing rents increase more than proportionally. It is sometimes the case that tax relief or regional subsidies lead to higher rents for student housing.

As total student numbers increase, notably international students who often maintain higher budgets and are less familiar with local housing, it is expected to see a rise in demand for PBS housing. The OECD predicts that the number of globally mobile students will increase to around 8 million by 2025, compared to 5 million in 2019. The growing middle class is driving demand for goods and services across various sectors, including higher education. Current annual average occupancy rates are high across Europe, ranging from 95% to 98%.

1.1 Italian Student Housing Market

Italy has a significant student population, with over 2 million students enrolled in higher education institutions across the country. This includes both domestic and international students pursuing undergraduate and postgraduate degrees. Major cities in Italy with renowned universities attract many students. These cities include Milan, Rome, Florence, Bologna, Padua, Turin, and Pisa, among others. The demand varies depending on factors such as the reputation of the university, the availability of programs, and the city's attractiveness for students.

After several years, the completion of the first modern assets is possible to observe, some of which are already operational. The *Aparto Giovenale* in Milan was sold by

Hines to an Italian pension fund for over € 100 M, completing in the first quadrimester of 2023. The project repositioned an obsolete property through complete refurbishment and is in an established residential area nearby Bocconi University, providing a new international campus with 600+ high quality beds, completed in 2022. To these three other properties of international target are added, for a total of 2,000 beds in 2022 in the city of Milan. Moreover, in 2022 *Patrizia AG* invested 70 million of euro in the forward purchase of a new-build PBSA in Turin, strategically located in Via Frejus to the west of the city center, which is within 1 km of Polytechnic of Turin, household to 33,000 students and 3.5km from the University of Turin. The transaction closed as envisioned in 2022 and the asset was inaugurated in September 2023 without the sale conditions changing. Rome, on the other hand, remains an exception, being the European city with the lowest coverage and a very low number of projects due to various reasons, mainly related to the difficulty of realize new buildings and converting existing ones.

The supply of student accommodation in Italy falls significantly short in meeting the escalating demand from both international and national students. Italy and Portugal, in comparison to Denmark and the UK, show the most inadequate provision rates with 1/10 of the latter's availability. In order to bring the offer of student housing to the standards of the best European peers (coverage rate of at least 20% of off-site students), it is necessary to increase the current allocation of about 100,000 beds. The future student housing supply in the main Italian cities will see over 23,600 beds to be completed by 2027. The current bed supply in Italy is almost 65,500 units: most of them (61%) are regional facilities under the Right to University Education, whilst 20% are managed by private operators, 12% are directly managed by universities, and the remaining 7% are legally recognized private and public student housings.

This suggests promising prospects for investment growth potential in Italy, to fulfil the rising demand from students pursuing tertiary education outside their home cities and from abroad. Milan (12,400 beds) and Turin (3,300 beds) record the highest bed completion rate by 2027, followed by Rome (2,300 beds), Florence (around 2,300 beds) and Pavia (507 beds). Of these additional 23,600 beds by 2027, 32% of them are already under construction, and more than half are concentrated in Milan. The total student housing availability by 2027, across the main cities, will total nearly 61,000 beds assuming the planned ones complete as anticipated and construction commences without delay across the pipeline.

Several large PBSA transactions has taken place and investment volumes remain high in the sector. The total investment volume reached €11.7 billion in the first three quarters of 2022, a 130% increase on the same period in 2021 and a record high. Forecasts of investment volumes up to 2024, which will gradually increase with the addition of new assets, will record between 800 million and 1 billion euros invested between Milan, Bologna and Florence.

The types of student accommodation in Italy vary, including dormitories, PBSA, shared apartments, and private rental properties. While some students prefer the convenience of dormitories or PBSA, others opt for shared apartments for reasons of affordability, independence, and cultural immersion.

The student housing sector in Italy presents investment opportunities for developers, investors, and real estate companies. There is potential for the development of new

student accommodation properties or the renovation of existing buildings to cater to the needs of students. Investors, especially institutional and international ones in the Italian market, are increasingly requiring ESG (Environmental Social and Governance) compliant assets: if LEED or BREEAM certifications criteria are not satisfied, the assets are generally less liquid. Appetite for low-cost rental accommodation is growing because of its social impact and because of virtually guaranteed occupancy. Currently, it represents a 30% share of the pipeline market. Single rooms have been always the most popular accommodation type, and this is even more true after COVID-19: this type is the first to be "sold out" during allocations, followed by double rooms. Those students who live in a double room during their first academic year, usually upgrade to a single room, the next year. High quality amenities in student housing and in campuses, create a premium on rental levels. The units are highly sought after by students, creating over-demand for prime assets and full occupancy. Incorporating high quality amenities into an asset generally has an overall minimal impact on refurbishment and running costs and can be absorbed relatively fast through cashflows.

The higher priced rooms are significantly more than the city average which breaks back to about 850 €/bed/month for Milan and Florence, 700 €/bed/month for Rome, followed by Turin and Bologna that are slightly lower. The average prices comprise both free-market rent and low-cost rental accommodation. On the private free-market rent, high quality amenities and connectivity to the local University, are currently driving demand leading to strong levels of rental growth.

2 Aim

The work is part of the outlined framework. The aim of the present research is to define a goal-programming based model able to maximize the profit of the private subject involved into the initiatives that concern the enhancement of student housing accommodations. It concerns the definition of a management model that provides for the possibility of allocating part of the rooms to tourist hospitality, especially for those structures that are situated in a location with a good tourist vocation, which takes the form of hybrid structures for mixed use "studentate-hotel". Starting from these considerations, in this paper an operations research problem whose objective is to identify the optimal mix of functions that allows the maximization of the profit (U) of the structure manager is proposed. Moreover, on the basis of the existing national incentives in the field of student housing, two scenarios are hypothesized in the present work: the first, called "Business As Usual (BAU)" provides for the resolution of the operational research problem previously introduced by establishing a sustainable rent equal to 25% of the total revenues associated with management; the second scenario, called "project scenario", provides for the identification of the functional mix capable of maximizing the operator's profit while keeping the rent defined in the BAU scenario unchanged, providing for a loan equal to 75% of the rent and adding the constraint previously described to ensure the prevalence of the student residence function over the tourist-accommodation function.

The reminder of the paper is as follows: in Sect. 3 a literature review is presented concerning the applications of optimization models to profit maximization and to the issue of student housing; In Sect. 4 the proposed model is described; In Sect. 5 the

application of the model to the case study is described and in Sect. 6 the conclusions of the work are drawn.

3 Background

Several Authors have studied the student housing market in the reference literature. For example, Ong, Petrova and Spieler (2013) [1] study the determinants of students' housing demand. Levy and Tucker (2006) [2] assess the business cycle vulnerability of student housing. Newell and Marzuki (2018) [3] study the characteristics of student housing from a portfolio perspective.

In the field of the student housing issues, among the several employed techniques, the goal programming-based ones are developed in order to achieve specific objectives related to several issues, such as (i) the housing units allocation by considering factors as room assignments, roommate compatibility and preferences (Rashidi, 2020; Hassan, 2016; Min, 1988) [4–6]; (ii) the assignment of housing units through the balance between maximizing student satisfaction, minimizing costs and ensuring equitable distribution of resources (Deliktas and Ustun, 2017) [7]; iii) the identification of a balance between affordable housing options and high-quality living standards (Li et al., 2023) [8]. Other studies are focused on the improvement of campus facilities and the prioritization of the related interventions according to several constraints, such as student needs, available budget and sustainability goals (Xu, 2022; Legorburu and Smith, 2020) [9, 10]. Within this application field, goal programming techniques have been applied to optimize how institutions can assign faculty members to classes, set objectives related to service quality, accessibility, and effectiveness in order to better meet the several needs of their student population are other relevant application fields of optimization models (Ding et al., 2019; Ascione et al., 2017; Al-Yakoob and Sherali, 2006) [11–13]. Promoting diversity and inclusion is another topic addressed through the development of goal programming models for increasing representation of underrepresented groups, fostering a welcoming campus environment, and implementing inclusive housing policies. The management of the optimal enrollment strategies has been studied by Aulck et al., 2020 [14] in order to set objectives related to student diversity, academic achievement, graduation rates, and alumni success, by guiding decision-making in enrollment-related activities.

Overall, the literature on the application of goal programming to the student housing market demonstrates its potential to address complex decision-making problems and optimize outcomes in various areas.

The development of profit maximization models based on goal programming techniques can be identified in several applications fields. For example, Mohajan and Mohajan (2022) [15] discuss profit maximization policies for the sustainable production by using four variable inputs, such as capital, labor, principal raw materials and other industry-related data where mathematical economic models are applied by considering budget constraint. Maximizing profits in a highly competitive cloud market is a huge challenge for cloud providers. Ganushchak-Efimenko et al., (2020) [16] develop an algorithm for making the optimal decision on the feasibility of implementing a particular innovation project. Liu (2006) [17] employs geometric programming technique to derive the objective value for the long-run profit maximization. Baki and Cheng (2021)

[18] aim for profit maximization of a small-medium enterprise company in Malaysia by using linear programming model. Tyapkina et al. (2017) [19] provide for an optimization model a model for profit maximization of production and products selling procedures. Nordin et al. (2021) [20] maximize the total return of the total amount invested with a different percentage of annual return by proposing a linear programming model. Oikonomou et al. (2018) [21] investigate the impact of the choice of optimization technique when constructing Socially Responsible Investment (SRI) portfolios and compare their performance along the dimensions of risk, risk-return trade-off, diversification and stability.

4 Methodology

In recent years, the students have seen an evolution of their management model, including the possibility of allocating part of the rooms to tourist hospitality, especially for those structures that are located in locations with a good tourist vocation. This business model, which is embodied in hybrid structures for mixed use student-hotel, allows at the same time to increase revenues and contain the rates for room rental to students. This approach is particularly performant where the maximum demand for rooms with accommodation function occurs in the periods of the academic year in which there are no lessons, and therefore students are more likely to vacate the room against a reduction in the annual rent. On the other hand, this model complicates the management of the structure making it necessary to pay attention to varied users with different needs and standards. Obviously the costs and services offered to tourists are different from those of students, and often the management model is further complicated by the possibility of obtaining public funding for operators who reserve a portion of their rooms at a reduced fee for deserving students and deprived of financial means to access free rental market.

In the structures for student-hotel use there are different types of rooms (single, double, mini-accommodation, etc.) which can carry out various alternative functions, that is *(i)* throughout the year for student use at an ad hoc fee or *(ii)* at a market fee, or *(iii)* for part of the year for student use and for receptive use, or *(iv)* exclusively for receptive use.

Starting from these considerations in the present research a problem of operative research is structured whose aim consists in the identification of the mix of optimal functions that allows the maximization of the profit (U) of the private manager of the structure. The profit of the involved private subject is determined as the difference between the revenues (revenues from the rooms, rent of the conference room, catering, bar, canteen, etc.) and all related costs (cleaning, utilities, purchases of food & beverage, staff, rent, ordinary maintenance, etc.) estimated using the same approach as the Uniform System of Accounts for the Lodging Industries [22].

Defined the aim of the problem of operative research, the variables are represented by the number of rooms ($N_{i,j}$) relative to the i-th type afferent to the j-th function. The only constraints consist in the imposition that $N_{i,j}$ belongs to the set of natural numbers and that the sum of the number of rooms for each type is less than the number of rooms belonging to that type present in the structure.

Hence, $N_{i,j}$ is the number of rooms of the property, where i = single, double, mini-accommodation, etc. represents the room type, and j = 1,2,3,4 indicates one of the alternative functions described above, for each type (T_i) we have:

$$N_{i,j} \in \mathbb{N} \cap \sum_{i,j} N_{i,j} \leq T_{i,MAX}$$

where $T_{i,MAX}$ represents the maximum number of rooms associated with the i-th type.

In some cases, better described below, there is a system of incentives where priority is given to the student function, especially if the fee is subsidized; in this case the predominance of the student function over the tourist function-requires compliance with the following inequality:

$$\forall i : N_{i,1} \geq N_{i,2} \geq N_{i,3} \geq N_{i,4}$$

The described problem of operative research summarized in Table 1, is solved through the implementation of the simplex algorithm [23], particularly suitable for solving linear programming problems.

Table 1. Goal, variables and constraints of the algorithm

Category	Formula	Meaning
Goal	$U := MAX$	Maximization of the profit
Variables	$N_{i,j}$	Number of rooms relative to the i-th type afferent to the j-th function
Constraint	$N_{i,j} \in \mathbb{N}$	$N_{i,j}$ belongs to the set of natural numbers
Constraint	$\sum_{i,j} N_{i,j} \leq T_{i,MAX}$	Sum of the number of rooms for each type lower than the number of rooms belonging to that type present in the structure
Constraint	$\forall i : N_{i,1} \geq N_{i,2} \geq N_{i,3} \geq N_{i,4}$	Predominance of the student function over the tourist one

5 Case Study

The operational research problem described above is implemented in a case study on the development of a building located in the center of a medium-sized city in southern Italy to be used as a hybrid student residence, identifying the optimal functional mix that can maximize the profit of the store. The project involves the renovation of an existing property with the creation of a structure that can accommodate a maximum of 72 users divided into 40 rooms (8 single, 28 double and 4 mini-apartments). Inside the property it is also planned to build a bar a restaurant/canteen and a conference room.

5.1 Analysis of the Market Demand

To characterise the demand for beds, a comparative analysis is carried out of the number of students enrolled, registered students and foreign students enrolled by A.A. 2010/2011 at A.A. 2022/2023 with reference to the university located in the city where the intervention is located (henceforth briefly "the university"), the region and Italy. In order to make the data relating to the three geographical scales easily comparable, the diagrams have been constructed on a 100 basis (registered, enrolled and foreigners A.A.2010/2011 = 100).

The analysis of the trend associated with the trend of enrollment for A.A. shows in the last A.A. a growth in the student population attending the university, growth in line with national data and more pronounced than regional data. Despite this, the analysis of the number of students on a 100 basis shows that the university's student population has fallen more sharply than at national level, in line with the average regional trend. The enrolment trend shows, starting from A.A. 2019–2020, a marked growth of new students in the university, reflecting national data and exceeding regional ones. Finally, if we focus exclusively on the number of enrolled foreigners, there is a constant increase in enrollment both in the university and at regional and national levels, with higher in the university than regional and national (Figs. 1, 2 and 3).

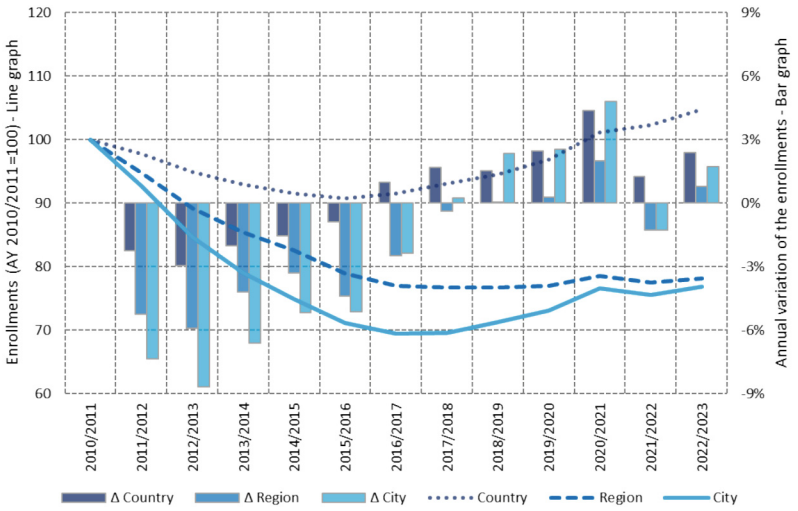

Fig. 1. Enrollments trend and annual variation of the enrollments in Italian universities

The increase in beds that would materialize downstream of the transaction would bring the ratio of beds and students enrolled from 0.9% to 1.1%, well below the Italian and regional average. This observation allows to assume a vacancy almost nothing of the rooms intended to accommodate the function student residence [24]. The hypothetical occupancy of the rooms used for tourist-receptive function has a strongly seasonal trend, as found by the monthly ratio between the attendance and the number of beds in hotel establishments built from ISTAT data for the city of analysis; starting from this

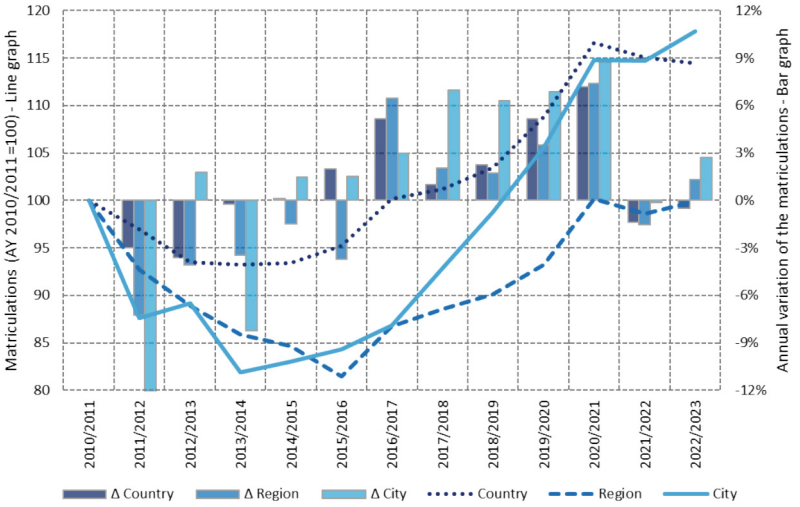

Fig. 2. Matriculations trend and annual variation of the matriculations in Italian universities

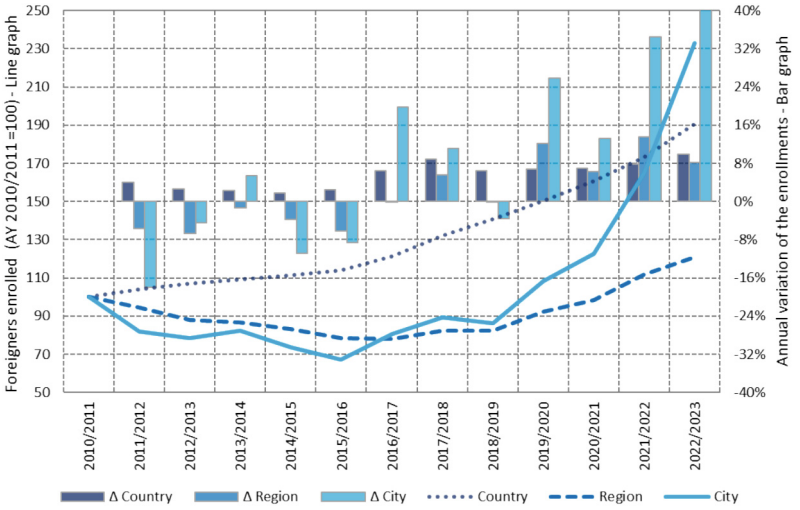

Fig. 3. Enrollments trend of foreigners and annual variation of the foreigner's enrollments in Italian universities

consideration in the hypothesis of mixed management of the rooms (function j = 3 - part of the year for student use and part for accommodation) it is assumed that in the high season (15 June–15 September), coinciding with the interruption of classes, the rooms are used with tourist-receptive function (Fig. 4).

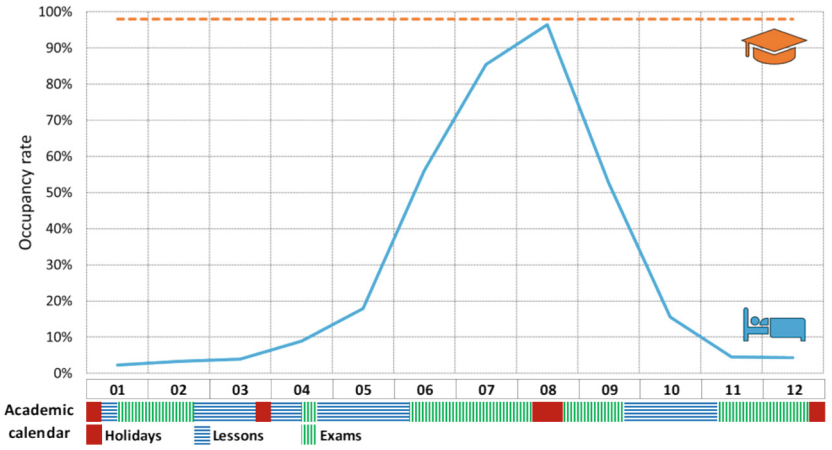

Fig. 4. Student and hotel occupancy rates and organization of academic activities

5.2 Proposed Management Model

For the determination of the profit of the manager it was necessary to reconstruct all the revenues and costs associated with this type of structure. The main form of revenue is linked to the rooms so, downstream of a market analysis, it was planned, for each type of room, the monthly rate assuming that the function is student (differentiated in case of standard and preferential rate) and the daily rate in the hotel hypothesis, variable depending on the seasonality (Table 2).

Table 2. PBSA and hotel rates

Room	PBSA rates (€/month)			Hotel rates (€/day) for season		
	Standard	% discounted	Reduced	Average	Low	High
Single	480	15%	408	70	54	86
Double	600	15%	510	100	77	123
Apartment	750	15%	638	140	108	172

It is assumed that the preferential rate will be less than 15% compared to the standard rate, as provided for by [25].

The turnover related to the canteen, restaurant and bar business has been estimated assuming an average daily consumption and an average amount per meal, both variable by type of consumption and user. The turnover deriving from the conference activity is determined assuming the number of annual events and a revenue associated with the event rental, in line with the reference market.

Through the analysis of the reference literature [26] and of the evaluation best practices [27, 28], the costs associated with the management of beds are estimated both in the

case of the student and in the case of tourist accommodation. To determine the costs associated with conferences, the cost of cleaning per event and the costs of food & beverage related to welcome coffee, coffee break, light lunch and aperitif are identified. Finally, the costs associated with canteen and catering activities are determined as a percentage of the respective revenues. The sustainable rent is determined as a percentage of the total turnover of the structure. The analysis of the profit of the operator, the percentage of the costs on revenues and the percentage of the profit on turnover allows to evaluate the performance of the project and the feasibility of the intervention from the point of view of the manager.

5.3 Model Application

The analysis of the endowment of facilities dedicated to student hospitality shows a gap between the quantity and quality of accommodation on average in Europe and those in Italy, especially in the cities of the center-south. This not only penalizes students, but it also makes our universities less attractive to foreign students, creating the ideal conditions for the proliferation of a huge "grey" market of houses rented exclusively to students, strongly changing the rental market without offering an adequate level of services to students. For these reasons through the National recovery and resilience plan (PNRR) [29] the total available resources are equal to 1,198,000,000.00 euros in order to finance at least 60,000 additional beds by 30 June 2026. The PNRR contribution granted by the Ministry of Universities and Research to the managing entity, as a result of the implementation and availability of each bed in the framework of the selected and financed interventions, is determined in a fixed amount of 19,966.66, and is related to the coverage of part of the rental income for the first three years of management of the facilities. The measures financed under this decree must provide for deadlines compatible, at the latest, with the provision of beds for the assignment by the deadline of 30 June 2026.

In order to accelerate this process, the PNRR foresees an active role for private investors through the co-financing of actions to acquire the availability of beds for university students, by obtaining the right of ownership or establishing a long-term lease or other form of use of the buildings or parts thereof. Expenditure eligible for part-financing shall relate to the purchase of buildings or parts thereof or to rent or other use, under contracts of more than nine years' duration. The buildings must be suitable for the function of university residence and managed directly by the proposers, or, after agreement with the proposers, by both public and private entities. In the case of purchase, the costs incurred for the execution of the works after the purchase are eligible for co-financing, but no redevelopment is allowed.

In coherence with the incentive mechanism activated by the PNRR, two scenarios are hypothesized in the present work: the first, called "Business As Usual" (BAU) provides for the resolution of the previous problem of operational research; the second scenario, called "Project", provides for the identification of the functional mix capable of maximizing the operator's profit while maintaining unchanged the fee defined in the BAU scenario, providing for a financing of 75% of the rent and adding the previously described constraint to ensure the predominance of the student function over the tourist-receptive one.

The application of the algorithm to maximize the profit of the manager highlights - in the case of the BAU scenario - the achievement of the maximum profit in the event that all the rooms are used as a mixed function, i.e. hotel use from 15 June to 15 September and use of student accommodation in the remaining period of the year (Eq. 1):

$$MAX\,(U_{BAU}) \Rightarrow \begin{cases} T_{1,3} = 8 \\ T_{2,3} = 28 \\ T_{3,3} = 4 \end{cases} \tag{1}$$

The application in the case of the project scenario leads to the achievement of the maximum profit in the case of a fair distribution of rooms compared to the 4 functions provided. This means that 25% of the rooms (2 single, 7 double and 1 mini-room) are used for student accommodation at market rate, another 25% for student accommodation at discounted rate, 25% exclusively for tourist accommodation and the last 25% for mixed use, that is in the period of high season for hotel use and the rest of the year for student use (Eq. 2):

$$MAX\left(U_{project}\right) \Rightarrow j = 1,2,3,4 \begin{cases} T_{1,j} = 2 \\ T_{2,j} = 7 \\ T_{3,j} = 1 \end{cases} \tag{2}$$

Analyzing the performances associated to the two different scenarios we can observe that (Table 3): *(i)* the profit of the manager in the two cases is comparable; *(ii)* in the scenario of "Project" there is an increase of the ratio profit/ revenues and *(iii)* there are interesting performance for the ratio revenues/ costs regarding the scenario BAU.

This result not only guarantees in the Project scenario a greater promotion of hospitality for deserving students and deprived of other means but allows a minimization of the risk associated with management guaranteed by the presence of a high differentiation of functions throughout the year. On the other hand, in the Project scenario there is an increase in complexity in the management of the structure and this strongly constrains the performance associated with the management model to the financing guaranteed by the PNRR (equal to 75% of the management fee).

Table 3. Comparison between the main performance indicators

Performance indicator	BAU scenario	Project scenario	Comment
Profit	202,000 €	215,000 €	+6.4%
Profit / Revenues	31%	46%	+48.4%
Revenues / Costs	2.3	2.8	+22.0%

6 Conclusions

In recent years there has been an increase in the attention of investors in the student housing sector thanks to the low risk of investing in this asset class, guaranteed by low arrears and high occupancy, and the presence of incentives allocated through the PNRR.

However, the growth of the costs associated with the management of these facilities and the impossibility of reversing these increases on users, given the need to contain room rates, especially in less attractive cities, has seen the compression of the operator's profit. This has triggered the birth of new business models aimed at maximizing the profits of the manager by opening these facilities to users other than students, both enhancing the spaces such as conference rooms, and promoting a mixed management student-hotel.

Based on these considerations, a management model of these structures, of the student-hotel type, has been proposed in the present paper, in order to determine the maximum profit of the manager to vary the alternative functions. In this way, by applying the principles of operational research, it was possible to compare the results derived from two scenarios, respectively "Business as Usual" and "Project". The comparison and the analysis of the obtained results allowed to show that in both the scenarios the profit of the manager is similar, while the ratio between profit and revenues and revenues and costs is better in the Project scenario. This means that not only in the Project scenario a greater promotion of hospitality for deserving students is guaranteed, but this allowed a minimization of the associated risk with a high differentiation of intended functions.

The future development of the present work consists in the application of a sensitivity analysis [30–33] in order to determine the evolution of the operator's profit as functions change and the application to different case studies. Furthermore, the integration of risk considerations related to the two scenarios and the proposed model could be useful for further research.

Note.
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