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08.00.06 Ekonometrika va statistika
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08.00.08 Buxgalteriya hisobi, iqtisodiy tahlil va audit
08.00.09 Jahon iqtisodiyoti
08.00.10 Demografiya. Mehnat iqtisodiyoti
08.00.11 Marketing
08.00.12 Mintaqaviy iqtisodiyot
08.00.13 Menejment
08.00.14 Iqtisodiyotda axborot tizimlari va texnologiyalari
08.00.15 Tadbirkorlik va kichik biznes iqtisodiyoti
08.00.16 Raqamli iqtisodiyot va xalqaro raqamli integratsiya
08.00.17 Turizm va mehmonxona faoliyati

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MUNDARIJA

INNOVATSION SIYOSATNI AMALGA OSHIRISHNING USTUVOR YO'NALISHLARI – OLIY TA'LIM TRANSFORMATSIYASI, RAQAMLI MODERNIZATSIYA VA BARQAROR RIVOJLANISH OMILLARI.....	13
Sharipov Kongratbay Avezimbetovich	
O'ZBEKISTON YASHIL IQTISODIYOTGA O'TISHI: ZARURAT, MAQSADI VA AYRIM MUAMMOLARI, YECHIMLAR	16
Abduraxmanova Gulnora Kalandarovna	
FAN, TA'LIM VA ISHLAB CHIQARISHDAGI SO'NGGI TENDENSIYALAR VA INNOVATSIYALAR	25
To'ychiyev Olimjon Alijonovich	
QURILISH TASHKILOTLARIDA KREDITGA LAYOQATLILIKNI BAHOLASHNI RAQAMLASHTIRISH	30
Mavlanov Normo'min Normamatovich	
BUDJET TASHKILOTLARIDA DAVLAT XARIDLARINI SAMARALI TASHKIL ETISHDA ELEKTRON SAVDOLARNING AHAMIYATI.....	37
Turabov Sarvar Abdumalikovich	
O'ZBEKISTONNI MINTAQAVIY TA'LIM VA ILM-FAN HABIGA AYLANTIRISHNING ISTIQBOLLI YO'NALISHLARI	41
Mirzaliyev Sanjar Maxamatjon o'g'li	
HUDUDIY RIVOJLANISH STRATEGIYALARIGA INNOVATSION KOMPONENTLARNI INTEGRATSIYA QILISH USULLARI	46
Muminov Fazliddin Xusniddin o'g'li	
OROL DENGIZI MEROSI: EKOLOGIK FOJIANI BARQAROR EKOTURIZM IMKONIYATLARIGA AYLANTIRISH	52
Zufarova Nozima	
KORXONALARNING YASHIL MARKETING STRATEGIYASINI ISHLAB CHIQISH METODOLOGIYASINI TAKOMILLASHTIRISH.....	60
Ergashxodjayeva Shaxnoza Djasurovna	
O'ZBEKISTONDA ISHCHI KUCHI BOZORINING TAKRORIY AMAL QILISHINING NAZARIY JIHATLARI	66
Mamaraximov B.E.	
BANK-MOLIYA TIZIMIDA QIMMATLI QOG'OZLAR VA MOLIYAVIY INSTRUMENTLARDAN FOYDALANISH ORQALI GAROV DIVERSIFIKATSIYASINI TAKOMILLASHTIRISH YO'LLARI.....	70
Xolbozorov Husniddin Norbek o'g'li	
YASHIL IQTISODIYOT SHAROITIDA TO'QIMACHILIK SANOATIDA MARKETINGNING INNOVATSION KONSEPSIYALARI.....	76
Jumayev Olimjon Sadulloevich, Axmedova Shoxsanam Sindbod qizi	
SAVDO KORXONALARIDA EKOLOGIK MAHSULOTLARNI TARG'IB QILISH VA SOTISHNI RAG'BATLANTIRISH USULLARI	84
Jalalova Dildora Jamolovna	
DIRECTIONS OF FORMING AND PROVIDING A COMPETITIVE EXPORT-ORIENTED ECONOMY IN UZBEKISTAN	87
Asatullaev Khurshid Sunatullaevich, Nasirkhodjaeva Dilafruz Sabitkhanovna, Abdullayeva Madina Kamilovna	
FROM SCIENCE TO BUSINESS: HOW UNIVERSITIES STIMULATE INNOVATION	94
Prof. A. Bobozhonov, Prof. A.M. Shatre, Assoc. Prof. V. Kirilova Vladimirova, prof. R.Kh. Karlibaeva	
PROSPECTS FOR THE DEVELOPMENT OF GREEN TECHNOLOGIES IN UZBEKISTAN BASED ON ADVANCED INTERNATIONAL EXPERIENCE	100
Otamuratov Sarvar	
SPECIFIC FEATURES OF MIGRATION FROM UZBEKISTAN AND PROSPECTS FOR ORGANIZATIONAL IMPROVEMENT	105
Sabiroya Lola Shavkatovna, Shaislamova Nargiza Kabilovna	

KORXONA BARQAROR AXBOROT TIZIMINI YARATISH QIYINCHILIKLARI.....	112
Abidov Abdujabbar Abduxamidovich	
TIJORAT BANKLARI FAOLIYATIGA FOIZ RISKINING TA'SIRI VA ILMIY-NAZARIY ASOSLARI.....	119
Isakov.J.Ya	
CREATION OF A MECHANISM FOR THE DEVELOPMENT AND INTRODUCTION OF A MODEL OF COMPLETE TRANSITION TO THE NETZERO ENERGY SYSTEM IN UZBEKISTAN	127
Makhmudova Guljakhon N., Gulomova Nigora Farxadovna	
УСИЛЕНИЕ ВОЗДЕЙСТВИЯ ХОЗЯЙСТВЕННОГО МЕХАНИЗМА НА СТОИМОСТНУЮ ОЦЕНКУ ОСНОВНЫХ ФАКТОРОВ ПРОИЗВОДСТВА.....	133
Алишер Расулев, Сергей Воронин	
РОЛЬ ФИНАНСОВОЙ ГЛОБАЛИЗАЦИИ В РАЗВИТИИ МАЛОГО И СРЕДНЕГО ПРЕДПРИНИМАТЕЛЬСТВА: ПЕРСПЕКТИВА И ПРИКЛАДНЫЕ РЕШЕНИЯ ДЛЯ ИХ ПЕРЕХОДА К МСФО.....	143
Эргашева Шахло Тургуновна	
DEVELOPMENT PROSPECTS OF AGRICULTURAL ECONOMIC ACTIVITY UNDER DIGITAL TRANSFORMATION	151
Boburjon Vafoev	
ENERGETIKA TIZIMIDAGI KORXONALAR MOLIYAVIY HOLATINING TAHLILI.....	157
Matnazar Yusupovich Raximov	
АСПЕКТЫ УПРАВЛЕНИЯ РАЗВИТИЕМ ЭКОЛОГИЧЕСКОГО ТУРИЗМА В РЕСПУБЛИКЕ.....	162
Очилова Хилола Фармоновна	
TA'LIM XIZMATLARI BOZORINI TAKOMILLASHTIRISHNING O'ZIGA XOS XUSUSIYATLAR.....	167
Abdullayev Suyun Artikovich	
THE INTERCONNECTION BETWEEN DIGITAL LEARNING PLATFORMS AND THE DIGITAL ECONOMY.....	171
Kuchkarov Takhir Safarovich, Kholmonov Shodiyor Karshiboyevich	
BANK-MOLIYA TIZIMI VA XUSUSIY SEKTORNI RIVOJLANTIRISHDA YANGI TEXNOLOGIYALAR YORDAMIDA BANK FAOLIYATINI RAQAMLASHTIRISH IMKONIYATLARI	174
Norov Akmal Ruzimamatovich	
РАЗВИТИЕ БАНКОВСКО-ФИНАНСОВОЙ СИСТЕМЫ И ЧАСТНОГО СЕКТОРА В РАМКАХ ПЕРСПЕКТИВ ВСТУПЛЕНИЯ ВО ВСЕМИРНУЮ ТОРГОВУЮ ОРГАНИЗАЦИЮ	180
У.А.Юлдашева	
ЗЕЛЕННЫЕ ПОТРЕБИТЕЛИ - ПУТИ РАЗВИТИЯ ЗЕЛЕННОГО РОСТА В РАМКАХ УСТОЙЧИВОЙ ЭКОНОМИКИ	185
Дехканова Наргиза Шарифовна	
ЭКОЛОГИЧЕСКИЙ АУДИТ И ПЕРСПЕКТИВЫ РАЗВИТИЯ В УЗБЕКИСТАНЕ.....	192
Ходжаева М.Х.	
TADBIRKORLIKNI RIVOJLANTIRISHDA AHOLINING MOLIYAVIY SAVODXONLIGINI OSHIRISH YO'LLARI.....	199
Akbarova Barno Shuxratovna	
SUSTAINABLE ECONOMIC GROWTH THROUGH TOURISM UNDER THE GREEN ECONOMY FRAMEWORK	204
Jumayev Akbar Mahmudovich	
МАКРОИQTISODIY BARQARORLIKNI TA'MINLASHDA BANK TIZIMINI RIVOJLANTIRISH ISTIQBOLLARI.....	210
Erkinxojiyev Ismoiljon Ikromjon o'g'li	
YASHIL IQTISODIYOT SHAROITIDA MINTAQAVIY SANOAT KORXONALARIDA KORPORATIV MADANIYATNI RIVOJLANTIRISH VA BOSHQARUV SAMARADORLIGINI OPTIMALLASHTIRISH.....	216
Matrizayeva Dilaram Yusupbayevna	
UZBEKISTAN AT THE CROSSROADS OF HISTORY AND GREEN INNOVATION: FROM THE GREAT SILK ROAD TO A SUSTAINABLE FUTURE	220
Avalova Gulshod Murodullayevna	

ГЛАВНЫЕ ВЕКТОРЫ ГОСУДАРСТВЕННОЙ ПОЛИТИКИ ПО ОБЕСПЕЧЕНИЮ ЭКОНОМИЧЕСКОЙ БЕЗОПАСНОСТИ В УЗБЕКИСТАНЕ.....	226
Абдуллаева М.К.	
ENVIRONMENTAL MANAGEMENT IN THE INDUSTRIAL CLUSTERS SYSTEM IN UZBEKISTAN: MODERN TRENDS AND DEVELOPMENT PROSPECTS.....	233
Kholikova Rukhsora Sanjarovna	
HUDUDDAGI KICHIK BIZNESNING SAMARALI TARKIBIY TUZILMASINI SHAKLLANTIRISHDA MUTASSADI TASHKILOTLARNING O‘ZARO UYG‘UN HARAKATINI TASHKIL ETISH.....	239
Sharipov Kuvondik Baxtiyorovich	
BUSINESS ANALYTICS IN HISTORICAL PERSPECTIVE: LESSONS FROM THE INDUSTRIAL REVOLUTION TO THE DIGITAL AGE	246
Burxonova Sabo Tulanovna	
“COST ENGINEERING”NING NAZARIY ASOSLARI VA UNI IQTISODIY SAMARADORLIKNI OSHIRISHDAGI O‘RNI.....	252
Zaynitdinova Umida Djalalovna	
FEATURES AND WAYS OF FURTHER DEVELOPMENT OF THE DIGITAL ECONOMY.....	256
Kobilov Alisher, Majidova Irodahon	
ПИЩЕВАЯ ИНДУСТРИЯ УЗБЕКИСТАНА: АГРАРНЫЙ ИМПУЛЬС, ЭНЕРГЕТИЧЕСКОЕ ОБЕСПЕЧЕНИЕ И ЦЕНОВАЯ КОНЪЮНКТУРА.....	263
Юлдашев Голибжон Тургунович, Элдорбеков Гофурбек Искандарбек угли	
INCOME INEQUALITY AND MACROECONOMIC DETERMINANTS IN UZBEKISTAN: AN EMPIRICAL ANALYSIS	273
Muhammad Eid Balbaa, Marina Sagatovna Abdurashidova	
РЫНОК ТРУДА В УСЛОВИЯХ ФОРМИРОВАНИЯ ЗЕЛЕННОЙ ЭКОНОМИКИ УЗБЕКИСТАНА.....	276
Амирджанова Ситора Суннат кизи	
EKOLOGIK QO‘RIQXONALARDA MONITORING JARAYONLARINING IQTISODIY VA TASHKILIY ANAMIYATI.....	282
Homidov Hamdam Hasan o‘g‘li	
ГАРМОНИЗАЦИЯ НАЦИОНАЛЬНЫХ СТАНДАРТОВ БУХГАЛТЕРСКОГО УЧЕТА В РЕСПУБЛИКЕ УЗБЕКИСТАН В СООТВЕТСТВИИ С МСФО	288
Абдужалилова Дилноз Абдусаттаровна	
SUSTAINABLE TOURISM AND BIODIVERSITY PROTECTION: CASE OF UZBEKISTAN WITHIN THE UNESCO WORLD HERITAGE FRAMEWORK.....	294
Yuldasheva Dilnoza Ulugbekovna	
ПРАКТИЧЕСКОЕ ПРИМЕНЕНИЕ НЕЙРОМАРКЕТИНГА НА МАРКЕТПЛЕЙСАХ (WILDBERRIES, UZUM MARKET, ЯНДЕКС МАРКЕТ)	300
Юлдашев Жамшид Абрарович	
ЗЕЛЕНАЯ ЭКОНОМИКА КАК СТИМУЛ РАЗВИТИЯ РЫНКА ТРУДА УЗБЕКИСТАНА.....	309
Шаюсупова Наргиза Тургуновна	
GLOBALLASHUV SHAROITIDA YASHIL IQTISODIYOTNI RIVOJLANISHI O‘ZBEKISTONNING XALQARO SAVDOSIGA VA IQTISODIY XAVFSIZLIGIGA TAHDID SIFATIDA.....	315
Mamatov Mamajan Ahmadjonovich	
SUG‘URTA TASHKILOTLARI FAOLIYATI SAMARADORLIGINI OSHIRISH VA INNOVATSION SUG‘URTA MAHSULOTLARINI JORIY QILISH MASALALARI	321
Xalikulova Gulzada Tadjimuratovna	
O‘ZBEKISTON OZIQ-OVQAT BOZORIDA YASHIL MARKETING STRATEGIYALARIDAN FOYDALANISH ORQALI BARQAROR ISTE‘MOLNI RAG‘BATLANTIRISH	333
Eshmatov Sanjar Azimqulovich	
ИННОВАЦИОННЫЕ ЗЕЛЁНЫЕ ТЕХНОЛОГИИ В РАЗНЫХ ОТРАСЛЯХ ЭКОНОМИКИ: ГЛОБАЛЬНЫЙ ОПЫТ И НАЦИОНАЛЬНАЯ ПРАКТИКА	337
Назарова Ра‘но Рустамовна, Мусаева Гавхар Ахматжон кизи	
YASHIL IQTISODIYOTDA MEHNAT BOZORI: O‘ZBEKISTON TAJRIBASI VA ISTIQBOLLARI.....	343
Homidjonov Fozilxon Umarxon o‘g‘li, Haydarov Kamoliddin Baratovich	

GREEN INVESTMENT: PATHWAYS TOWARD A SUSTAINABLE FUTURE.....	348
Odilova Sitora Sayfitdin kizi	
YASHIL IQTISODIYOT SHAROITIDA O'ZBEKISTON SANOAT KORXONALARIDA MARKETING STRATEGIYALARINI TAKOMILLASHTIRISH.....	351
Kutbitdinova Mohigul Inoyatovna	
QURILISH MATERIALLARI SANOATIDA YASHIL TEXNOLOGIYALAR VA RAQAMLI TRANSFORMATSIYANING BARQAROR RIVOJLANISHGA TA'SIRI	356
Metyakubov Azamat Djumanazarovich	
ELEKTR SANOAT KORXONALARINING IQTISODIY XAVFSIZLIGINI TA'MINLASHDA MARKETING VOSITALARIDAN FOYDALANISH ISTIQBOLLARI.....	361
Tursunxo'jayev Sardor Jamoliddin o'g'li	
УЧЕТ ЗАТРАТ И МЕТОДЫ ОПРЕДЕЛЕНИЯ СЕБЕСТОИМОСТИ ПРОДУКЦИИ В НЕФТЕГАЗОВОЙ ОТРАСЛИ	368
Махкамова Саида Гайратовна	
MILLIY HISOBLAR TIZIMIDA INTELLEKTUAL MULK MAHSULOTLARINI MAKROIQTISODIY DARAJADA HISOBGA OLISHNING METODOLOGIK ASOSI.....	375
Sunnatov Muxtor Ne'matovich	
RENEWABLE ENERGY AND MACROECONOMIC STABILITY IN CENTRAL ASIA: PATHWAYS WITHIN THE GREEN ECONOMY	382
Khabibullo Abdullaev	
JAHON SUG'URTA AMALIYOTI ASOSIDA O'ZBEKISTON SUG'URTA BOZORIDA YANGI RIVOJLANISH YO'NALISHLARI.....	387
Abdimovminova Saodat Taxirjonovna	
INTEGRATING DATA SCIENCE INTO GREEN FINANCING AND ECO-INNOVATIONS: ACHIEVING THE GOALS OF UZBEKISTAN-2030	397
Norboev Odil Abraevich, Kungratov Ilmurod Kuzibay ugli	
O'ZBEKISTONDA SANOAT ISHLAB CHIQRISHINI DIVERSIFIKATSIYALASH AMALIYOTI VA ISTIQBOLLARI	404
Olimov Maqsudjon Komiljon o'g'li	
СОЗДАНИЕ ЗЕЛЕННОГО ЭНЕРГЕТИЧЕСКОГО КОРИДОРА В ЕВРОПУ: РЕГИОНАЛЬНЫЙ ПОТЕНЦИАЛ АЗЕРБАЙДЖАНА, КАЗАХСТАНА И УЗБЕКИСТАНА.....	411
Лала Гамидова Адиль, Арзуман Гусейнов Айдын	
MAHALLA TIZIMIDA AHOLINI OZIQ-OVQAT MAHSULOTLARIGA BO'LGAN ISTE'MOL TALABLARI MODEL.....	419
S. Qulmatova	
AHOLI ICHKI MIGRATSIYASINING MEHNAT BOZORIGA TA'SIRINI STATISTIK O'RGANISH	427
Mirolimov Mirislom Mirshokir o'g'li	
O'ZBEKISTONDA BANK TIZIMINI RAQAMLASHTIRISH TENDENSIYALARI VA MUAMMOLARI	434
Jumaniyozova Mukaddas Yuldashevna	
ЗЕЛЁНЫЕ ФИНАНСЫ: ГЛОБАЛЬНЫЕ ТРЕНДЫ И ПЕРСПЕКТИВЫ РАЗВИТИЯ В УЗБЕКИСТАНЕ	438
Фаттахова Муниса	
QISHLOQ XO'JALIGI SOHASI FAOLIYATINI DAVLAT TOMONIDAN MUVOFIQLASHTIRISH VA BOSHQARISH MEKANIZMLARINI TAKOMILLASHTIRISH	444
Tuxtamishev Shodimurod Qurbonboyevich	
MARKETING TADQIQOTLARI ASOSIDA MEVA-SABZAVOT MAHSULOTLARI EKSPORT SALONIYATINI OSHIRISH	452
Xojiyev Elshod Yoqub o'g'li	
СПОСОБЫ УПРАВЛЕНИЯ НАУЧНЫМИ УЧРЕЖДЕНИЯМИ В ЦЕЛЯХ ПЕРЕХОДА НА РАЗРАБОТКУ ЗЕЛЕННЫХ ИННОВАЦИЙ	459
Юдаков Александр Андреевич	
O'ZBEKISTONNI JAHON SAVDO TASHKILOTIGA A'ZO BO'LISHINING OZIQ-OVQAT XAVFSIZLIGINI TA'MINLASHGA TA'SIRI.....	466
Axmedova N.A.	

O'ZBEKISTON RESPUBLIKASIDA KLASTERLAR FAOLIYATINI TAKOMILLASHTIRISHNING IQTISODIY MEKANIZMI	471
<i>Sherkulov Shohruh Erkin o'g'li</i>	
DEVELOPMENT SCENARIOS OF UZBEKISTAN'S ACTIVE LABOR FORCE UNTIL 2030 AND THEIR ECONOMIC IMPLICATIONS.....	476
<i>Ganiev Bakhtiyor Zulfikor ugli, Rakhmonov Bekzod Sharibjon ugli</i>	
РАЗВИТИЕ ЗЕЛЁНОЙ ЭКОНОМИКИ КАК ФАКТОР СТИМУЛИРОВАНИЯ ЭКОНОМИЧЕСКОЙ АКТИВНОСТИ ЖЕНЩИН В УЗБЕКИСТАНЕ	481
<i>Дониерова Фотимабону Алишер кизи</i>	
YASHIL ENERGETIKA VA UNING IQTISODIY TARAQQIYOTDAGI O'RNI	488
<i>Babadjanova Malika Ruzimova</i>	
BENCHMARKING IN THE AUTOMOTIVE INDUSTRY: STRATEGIES FOR SUSTAINABLE COMPETITIVENESS	492
<i>Abdurashidova Nigora</i>	
УЗБЕКИСТАН СТРЕМИТСЯ К УСТОЙЧИВОМУ ЭКОНОМИЧЕСКОМУ РОСТУ, ВНЕДРЯЯ ПРИНЦИПЫ «ЗЕЛЁНОЙ» ЭКОНОМИКИ	498
<i>Сагдуллаева Гулнора Ботыровна</i>	
O'ZBEKISTONDA FAOLIYAT YURITAYOTGAN KOMPANIYALARNING GLOBAL MARKETING STRATEGIYALARIDAN FOYDALANISH YO'NALISHLARI.....	502
<i>Sharipov Ixtiyor Baxtiyorovich</i>	
ZAIF BANDLIKDAN UNUMLI BANDLIK SARI TRANSFORMATSIYA: O'ZINI O'ZI BAND QILISH	507
<i>Qurbonov Samandar Pulatovich</i>	
ВОЗОБНОВЛЯЕМАЯ ЭНЕРГИЯ В ГЛОБАЛЬНОЙ ЭКОНОМИКЕ: ТЕКУЩИЕ ТЕНДЕНЦИИ И БУДУЩЕЕ РАЗВИТИЕ.....	514
<i>Меҳрибан Самедова Тофик</i>	
RAQAMLI TEXNOLOGIYALARNING MEHNAT UNUMDORLIGINI OSHIRISHGA TA'SIRI	521
<i>Zafar Alisherovich Mamadiev, Nodira Isametdinovna Xasanxonova</i>	
SAVDO KORXONALARIDA BUXGALTERIYA HISOBINI XALQARO STANDARTLARGA INTEGRATSIYA QILISH MEKANIZMLARI.....	526
<i>Ablazov Lazizbek Abdiquosimovich</i>	
TIJORAT BANKLARINING TRANSFORMATSIYASI JARAYONINI TAKOMILLASHTIRISH.....	530
<i>Ziyadullaev Z.</i>	
TO'LOV TIZIMI KONSEPTUAL MODELINING SHAKLLANISH TAMOYILLARI	537
<i>Toshniyozov Sherali Kamoliddinovich</i>	
STAFF PERFORMANCE EVALUATION BASED ON KPI SYSTEM INDICATORS.....	546
<i>Rakhmatullaeva Shakhnoza Khamidovna, Sadriddinova Sevinchkhon</i>	
SUSTAINABLE DEVELOPMENT AND THE TRANSITION TO A GREEN ECONOMY IN THE CONTEXT OF GLOBAL ECONOMIC TRENDS	555
<i>Svetlana Yurievna Shatokhina</i>	
MILLIY TARBIYA OMILLARI VA MILLIY MADANIY YONDASHUV ASOSIDA TALABALARDA O'QUV TASHABBUSKORLIGINI RIVOJLANTIRISHNING NAZARIY-AMALIY ASOSLARI.....	560
<i>Azimova Nilufar Nuriddinovna</i>	
TIJORAT BANKLARI TOMONIDAN KICHIK BIZNES SUBYEKTLARINI TA'MINLASHDA BANK RESURSLARINING ROLI	567
<i>Xodjayeva Jeyrona Ravshonbek qizi</i>	
O'QUV DASTURINI INTEGRATSIYALASH VA YASHIL KO'NIKMALARNI RIVOJLANTIRISH: AKADEMIK VA SANOAT O'RTASIDAGI TAFOVUTNI YOPISH	572
<i>Qo'ziqulova Dilfuzaxon Maxammatisaqovna</i>	
DIGITAL TRANSFORMATION AND DIGITAL PLATFORMS AS A KEY FACTOR IN THE DEVELOPMENT OF SMALL BUSINESS ENTITIES	580
<i>Rizayeva Nilufar Oblakulovna</i>	

IQTISODIY OLIY TA'LIMDA STRATEGIK INNOVATSIYALAR: YASHIL KO'NIKMALARNI MILLIY VA GLOBAL BARQARORLIK MAQSADLARI BILAN MUVOFIQLASHTIRISH	585
<i>Xasanova Zarina Maxamadaliyeva</i>	
MARKAZIY OSIYODA YASHIL IQTISODIYOT: BARQAROR RIVOJLANISH YO'LIDAGI TO'SIQLAR VA ISTIQBOLLAR.....	594
<i>Aminov Shovkat O'ktam o'g'li</i>	
ПЕСПЕКТИВЫ РАЗВИТИЯ ЗЕЛЁНЫХ ОБЛИГАЦИЙ В УЗБЕКИСТАНЕ.....	598
<i>Саидахмедова Аида Мирзаевна</i>	
ПОВЫШЕНИЕ ЭКОНОМИЧЕСКОЙ ЭФФЕКТИВНОСТИ И СНИЖЕНИЕ РИСКОВ КОММЕРЧЕСКИХ БАНКОВ НА ОСНОВЕ ОБЕСПЕЧЕНИЯ БЕЗОПАСНОСТИ ТРАНЗАКЦИЙ В ФИНАНСОВЫХ ИНФОРМАЦИОННЫХ СИСТЕМАХ С ИСПОЛЬЗОВАНИЕМ СОВРЕМЕННЫХ СИММЕТРИЧНЫХ КРИПТОСИСТЕМ.....	605
<i>Раҳимбердиев Қ.Б.</i>	
ИНТЕГРАЦИЯ ФИНАНСОВЫХ И СТРАХОВЫХ ИНСТРУМЕНТОВ ДЛЯ СТИМУЛИРОВАНИЯ УСТОЙЧИВОГО ЭКОНОМИЧЕСКОГО РОСТА	612
<i>Ш.Ф.Кобилжонова</i>	
СОВЕРШЕНСТВОВАНИЕ КАПИТАЛА ХОЗЯЙСТВУЮЩИХ СУБЪЕКТОВ В КОНТЕКСТЕ РАЗВИТИЯ БАНКОВСКО-ФИНАНСОВОЙ СИСТЕМЫ И ЧАСТНОГО СЕКТОРА ЭКОНОМИКИ	618
<i>Д.А.Юлдашева</i>	
РОЛЬ БАНКОВСКО-ФИНАНСОВОЙ СИСТЕМЫ И СТРАХОВЫХ МЕХАНИЗМОВ В СТИМУЛИРОВАНИИ РАЗВИТИЯ ЧАСТНОГО СЕКТОРА	624
<i>Г.Т.Ахмедова</i>	
SUG'URTA BOZORI FAOLIYATINI RAQAMLI TEXNOLOGIYALAR ASOSIDA TRANSFORMATSIYALASH VA UNING RAQOBATBARDOSHLIGINI OSHIRISH MASALALARI.....	630
<i>Saidov Farrux Faxriddinovich</i>	
OPPORTUNITIES TO ENSURE SUSTAINABLE ECONOMIC GROWTH IN THE ENERGY SECTOR THROUGH THE TRANSITION TO A GREEN ECONOMY.....	635
<i>Ulashov Aliboy Rashid ugli, Istamova Nasiba Narzillo kizi</i>	
INKLYUZIV OLIY TA'LIMDA MUSTAQIL ISHLASH JARAYONINI TASHKILLASHTIRISH.....	641
<i>Akbarova Kamola Abdujabbor qizi</i>	
YOUTH-DRIVEN PATHWAYS TO GREEN EMPLOYMENT: A THEORETICAL EXAMINATION OF INCLUSIVE ECONOMIC STRATEGIES	646
<i>Suvpulatov Ozodjon Alijon ugli</i>	
KICHIK BIZNES INFRATUZILMASINI RIVOJLANTIRISHDA XORIJIY TAJRIBALAR VA UNING O'ZBEKISTON UCHUN AHAMIYATI	651
<i>Botirova Xulkar Olimjonovna</i>	
YASHIL IQTISODIYOT SHAROITIDA RAQAMLI TRANSFORMATSIYA VA BARQAROR RIVOJLANISH KLASTERLARI: NAZARIY ASOSLAR VA AMALIY YONDASHUVLAR.....	655
<i>Sherkulova Nodirabegim Baxordin qizi</i>	
BIOTECHNOLOGICAL SOLUTIONS IN URBAN PLANNING: OPPORTUNITIES AND LIMITATIONS OF "LIQUID TREES"	660
<i>Nosirkulov Asadjon Ahmadjon ugli</i>	
YASHIL IQTISODIYOTNI RIVOJLANTIRISHDA TIKLANADIGAN ENERGIYA MANBALARINING O'RNI.....	663
<i>Fayziyeva Dilso'z Bahodirovna</i>	
KREDIT PORTFELIDA MUAMMOLI KREDITLAR ULUSHINI KAMAYTIRISH YO'LLARI	668
<i>Salixova G.J</i>	
O'ZBEKISTONDA KANDOLAT MAHSULOTLARI BOZORINI RIVOJLANTIRISHDA YASHIL MARKETING STRATEGIYALARIDAN FOYDALANISH.....	672
<i>Boboyorova Maftuna Xaqqul qizi, Boboyorov Islombek Xaqqul o'g'li</i>	
OLIY TA'LIM TIZIMIDA RAQAMLI TEXNOLOGIYALARNI QO'LLASH METODLARINI TAKOMILLASHTIRISH.....	675
<i>Xusniddinov Yorqinjon Muhiddin o'g'li</i>	

MODA SANOATIDA CRM TIZIMLARINI ELEKTRON SAVDO PLATFORMALARI BILAN UYG'UNLASHTIRISHDAGI TO'SIQLAR	679
Xalilova Nafisa Komilovna	
ENHANCING FOREIGN ECONOMIC RELATIONS AS A DRIVING FACTOR IN THE DEVELOPMENT OF THE NATIONAL ECONOMY	683
Khaitova Feruza Bahrom kizi	
MARKAZIY OSIYO MAMLAKATLARIDA XORIJIY INVESTITSIYALARNING QAYTA TIKLANUVCHI ENERGIYA MANBALARIGA TA'SIRI	687
Akishova Shaxnoza Davlet qizi	
BUXORO VILOYATIDA HUNARMANDCHILIK FAOLIYATINING RIVOJLANISH TENDENSIYALARI: TAHLIL VA ISTIQBOLLAR.....	693
Ravshanova Gulchexra Ravshanovna	
SANOATNI RIVOJLANTIRISHNING MEKANIZMLARI TURLARI VA OLIMLARNING YONDASHUVLARI	698
Ne'matov Shoxruxbek Ma'murjon o'g'li	
O'ZBEKISTON BANK-MOLIYA TIZIMIDA KREDIT RISKLARINI BOSHQARISH AMALIYOTINI TAKOMILLASHTIRISH VA UNING XUSUSIY SEKTOR RIVOJLANISHIGA TA'SIRI.....	703
Norova Nozima Nabiyevna	
O'ZBEKISTON BANK-MOLIYA TIZIMIDA REAL SEKTORNI KREDITLASH MEKANIZMLARINI SAMARALI JORIY ETISH VA XUSUSIY SEKTOR RIVOJIGA TA'SIRI.....	709
Abduxomidov Ikromjon Maxamadin o'g'li	
MOLIYA TIZIMIDA BOJ-TARIF SIYOSATINI TAKOMILLASHTIRISH VA XUSUSIY SEKTOR RIVOJLANISHIGA TA'SIRI (OZIQ-OVQAT IMPORTI MISOLIDA).....	715
Rizaev Mirmahmud Xotamjanovich	
YASHIL MARKETING VA ESG INTEGRATSIYASI: STATISTIK TAHLIL VA BARQAROR RIVOJLANISH ISTIQBOLLARI	721
Charos G'ayratova	
ИННОВАЦИОННЫЕ НАПРАВЛЕНИЯ ИСПОЛЬЗОВАНИЯ ПРОМЫШЛЕННОГО КАПИТАЛА ДЛЯ ОБЕСПЕЧЕНИЯ УСТОЙЧИВОГО ЭКОНОМИЧЕСКОГО РОСТА В УСЛОВИЯХ ФОРМИРОВАНИЯ «ЗЕЛЁНОЙ» ЭКОНОМИКИ.....	727
Г.А.Хайитбаева	
YASHIL IQTISODIYOTGA O'TISH SHAROITIDA TIJORAT BANKLAR TOMONIDAN TADBIRKORLIK FAOLIYATINI KREDITLASH.....	734
Tajiddinov Jamshiddin Shamsutdinovich	
IQTISODIYOTNING TARKIBIY TRANSFORMATSIYASIGA XORIJIY INVESTITSIYALAR TA'SIRINI BAHOLASH MEKANIZMINI TAKOMILLASHTIRISH	738
Shodiboyeva Dilzoda Farhodjon qizi	
MOLIYA TIZIMI BARQARORLIGI VA BUDJET TUSHUMLARINI OSHIRISHDA TASHQI IQTISODIY FAOLIYATNING AHAMIYATI.....	743
Aktamov Akbarjon Aslan o'g'li	
ENSURING SUSTAINABLE ECONOMIC GROWTH IN THE TRANSITION TO A GREEN ECONOMY: AN ECONOMETRIC ANALYSIS OF THE RELATIONSHIP BETWEEN CARBON EMISSIONS AND ECONOMIC DEVELOPMENT.....	748
Shakhriddinova Sitara Tolibjon kizi	
YASHIL IQTISODIYOTGA O'TISH JARAYONIDA TIJORAT BANKLARIDA INVESTITSIYA LOYIHALARI SAMARADORLIGINI OSHIRISHDA ESG TAMOYILLARINING ROLI	760
Ostonaqulova Gulchehraxon Muhammadyoqub qizi	
YASHIL IQTISODIYOT TAMOYILLARI ASOSIDA SANOAT KORXONALARIDA YETKAZIB BERISH STRATEGIYALARINI ISHLAB CHIQISH	769
Yusupov Ulug'bek Mamayusupovich	
YASHIL IQTISODIYOT KONTEKSTIDA MAKROIQTISODIY BARQARORLIKNI MUSTAHKAMLASH: XALQARO TAJRIBA VA O'ZBEKISTON AMALIYOTI.....	776
Isroilov Islomiddin Kamoliddin o'g'li	

RAQAMLI TRANSFORMATSIYA SHAROITIDA SPORT TASHKILOTLARINING YANGI BIZNES MODELLARINI ISHLAB CHIQISH	782
G'ulomov Musirmon	
O'ZBEKISTONDA IQTISODIYOTGA XORIJIY INVESTISIYALARNI JALB ETISHNING USTUVOR YO'NALISHLARI VA ISTIQBOLLARI	786
Sharipova Shahnoza Baxtiyorovna	
O'ZBEKISTONDA INVESTISIYA MUHITIGA TA'SIR ETUVCHI OMILLAR VA INVESTISIYALARNING IQTISODIYOTGA JALB ETILISH HOLATI TAHLILI	795
Karimova Qunduz Atanazarovna	
O'ZBEKISTON TURISTIK XIZMATLAR BOZORIDA BANDLIK TRANSFORMATSIYASINI VA UNI TARTIBGA SOLISH HOLATINI TAHLIL QILISH	804
To'xtayeva Xurshida Farxodovna	
INVESTITSIYA LOYIHALARIGA TA'SIR QILUVCHI INVESTITSIYA RISKLARINI BAHOLASH.....	811
Zohidova Ruksora Komiljon qizi	
ТИПЫ НАЦИОНАЛЬНЫХ ФИНАНСОВЫХ РАЗВЕДОК: ОСНОВНЫЕ РАЗЛИЧИЯ, ФОРМЫ И МЕТОДЫ ОСУЩЕСТВЛЕНИЯ ДЕЯТЕЛЬНОСТИ.....	817
Эсанов Шохрух Отабекович	
FACE RECOGNITION PROGRAM IN PYTHON.....	823
Khurramova Maftunakhon Zhurabekovna, Khurramov Azizjon Bakhodir ugli	
FORMATION OF ACCOUNTING POLICY FOR INTANGIBLE ASSETS.....	827
Farxod T. Abdvaxidov, Ramazon A. Abdurakhmanov	
O'ZBEKISTON EKSPORT TARKIBINI YUQORI QO'SHIMCHA QIYMATLI MAHSULOTLARGA O'TKAZISH STRATEGIYASINI TAKOMILLASHTIRISH.....	834
Raximov Eshmurod Normuradovich	
EKSPORT FAOLIYATIDA ERKIN IQTISODIY ZONALARNING SAMARADORLIGINI OSHIRISH YO'LLARI.....	838
Berdivaliyeva Madina Komiljon qizi	
TURIZM KLASTERLARIDA TIBBIY XIZMATLAR INTEGRATSIYASI: XALQARO TAJRIBA VA O'ZBEKISTON AMALIYOTI	841
Yazdanova Shohista Tuyg'un qizi Farxodova Shohnoza Umidbek qizi	
O'ZBEKISTON HAVO TRANSPORTI TIZIMINING JAHON IQTISODIYOTIDAGI O'RNI VA RIVOJLANISH ISTIQBOLLARI.....	850
Azimova Moxinur Nozimovna	

BIOTECHNOLOGICAL SOLUTIONS IN URBAN PLANNING: OPPORTUNITIES AND LIMITATIONS OF “LIQUID TREES”

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Abstract: This article explores the innovative project “Liquid Trees” (Liquid 3), created by researchers at the University of Belgrade as a modern alternative to traditional urban greening. The system consists of bioreactors with microalgae (*Chlorella vulgaris*), which absorb carbon dioxide and generate oxygen much more efficiently than ordinary plants. A single unit can match the oxygen output of two mature trees or 200 m² of lawn, while also producing valuable biomass for agriculture, biofuel, and pharmaceuticals.

Key words: Liquid Trees, environmental issues, green economy, high technologies, urban life quality, soil enrichment, erosion, groundwater, appearance.

Annotatsiya: Maqolada Belgrad universiteti olimlari tomonidan ishlab chiqilgan “Suyuq daraxtlar” (Liquid 3) loyihasi — an’anaviy shahar ko’kalamzorlashtirishiga zamonaviy alternativ sifatida o’rganiladi. Ushbu tizim mikroalgalar (*Chlorella vulgaris*) joylashtirilgan bioreaktorlardan iborat bo’lib, ular karbonat angidridni yutadi va oddiy o’simliklarga nisbatan ancha samarali tarzda kislorod ishlab chiqaradi. Bir dona modul ikki tup katta daraxt yoki 200 m² maysazor kislorod ishlab chiqarish hajmiga teng keladi, shu bilan birga qishloq xo’jaligi, biotoplar va farmatsevtika uchun qimmatli biomassa ham yaratadi.

Kalit so’zlar: Suyuq daraxtlar, ekologik muammolar, yashil iqtisodiyot, yuqori texnologiyalar, shahar hayoti sifati, tuproqni boyitish, eroziya, yer osti suvlari, tashqi ko’rinish.

Аннотация: В статье рассматривается инновационный проект «Жидкие деревья» (Liquid 3), разработанный исследователями Белградского университета как современная альтернатива традиционному городскому озеленению. Система представляет собой биореакторы с микроводорослями (*Chlorella vulgaris*), которые поглощают углекислый газ и вырабатывают кислород значительно эффективнее обычных растений. Один модуль способен заменить кислородный эффект двух взрослых деревьев или 200 м² газона, одновременно производя ценную биомассу для сельского хозяйства, биотоплива и фармацевтики.

Ключевые слова: Жидкие деревья, экологические проблемы, зелёная экономика, высокие технологии, качество городской жизни, обогащение почвы, эрозия, подземные воды, внешний вид.

INTRODUCTION

“High-quality greening” is an integral component of urban improvement. Greening in cities serves a multitude of purposes simultaneously, with the most critical one being the improvement of the environmental situation. Plants produce oxygen essential for respiration, purify and ionize the air, and also increase its humidity levels. Plants are an indispensable element of cities.

Despite being necessary for maintaining a favorable environmental situation in the city, plants are often insufficient. The reason for this is simple—there is a lack of space for planting them. An unusual solution to this problem was found by scientists from the University of Belgrade in Serbia: they have developed an innovative project that could serve as an alternative to traditional greening in urban areas.

“Liquid Trees,” or Liquid 3, is the name given by the scientists to their innovative project. “Liquid Trees” are tanks filled with water and microalgae. The concept is that microalgae convert carbon dioxide into oxygen in the same way as conventional plants. Furthermore, they perform this task significantly more efficiently! According to data from a biotechnology company, the algae *Chlorella vulgaris* absorbs carbon dioxide 400 times faster than common plants.

Of course. Here is the English translation of the extended analysis and the potential impact on Uzbekistan's economy and environment.

LITERATURE REVIEW

The application of biotechnological solutions in urban planning has attracted increasing scholarly attention in recent decades, particularly with regard to photobioreactors and algae-based systems. Researchers emphasize that conventional urban greening—trees, lawns, and green roofs—plays a vital role in regulating air quality, humidity, and microclimate. However, in densely built environments, limited space for planting has driven interest in compact alternatives [1]. Microalgae, particularly *Chlorella vulgaris*, are widely studied for their high capacity to absorb carbon dioxide and generate oxygen. Experimental studies show that their CO₂ fixation rate is many times higher than that of terrestrial plants, making them attractive candidates for integration into the urban environment [2]. The “Liquid Trees” project in Belgrade is a notable example. It demonstrates how photobioreactors filled with microalgae can be placed in public spaces, delivering oxygen output comparable to two mature trees or 200 m² of lawn, while also producing biomass for agriculture, biofuel, and pharmaceuticals [3].

Earlier architectural experiments, such as the BIQ House in Hamburg with its algae façade system, showed that photobioreactors could serve multiple functions: energy generation, thermal regulation, and urban aesthetics [4]. Yet, scholars caution that such technologies have operational limitations, including the need for controlled lighting, nutrient supply, and regular maintenance [5]. Life-cycle analyses highlight that environmental benefits depend strongly on renewable energy input, water recirculation, and effective biomass utilization [6]. Critics also note that while “liquid trees” can complement greenery, they cannot fully substitute the broader ecological services of natural trees, such as habitat provision, evapotranspiration cooling, and stormwater management [7]. Overall, the literature positions microalgae photobioreactors as a valuable addition to sustainable urban infrastructure, particularly where soil-based greening is impractical, but stresses the importance of treating them as complementary rather than replacement technologies [8].

RESEARCH METHODOLOGY

The methodological approach of this study combines qualitative and analytical methods to examine the opportunities and limitations of “Liquid Trees” in urban planning. First, a review of scientific literature and international case studies was conducted to identify theoretical foundations and prior experiences with photobioreactors and algae-based greening systems. Second, comparative analysis was applied to evaluate the efficiency of microalgae (*Chlorella vulgaris*) relative to conventional urban vegetation in terms of carbon dioxide absorption and oxygen generation. Third, descriptive analysis was used to explore the potential socio-economic and environmental implications for urban infrastructure. Finally, synthesis of international best practices allowed the formulation of recommendations for adaptation in the context of Uzbekistan and other rapidly urbanizing regions.

ANALYSIS AND RESULTS

Operating Principle and Technological Advantages

The analysis of the “Liquid Trees” (Liquid 3) technology demonstrates that its central principle is based on photosynthesis in a closed bioreactor system. Microalgae, most commonly *Chlorella vulgaris* or *Scenedesmus*, consume carbon dioxide and nutrients in the presence of sunlight, thereby releasing oxygen into the surrounding environment. According to the developers, a single bioreactor can generate an oxygen output equivalent to two mature trees or approximately 200 square meters of lawn. The system is autonomous, as it is powered by solar panels that supply energy to water pumps, which ensure constant mixing of the algal suspension. This process significantly increases photosynthetic efficiency compared to terrestrial plants, which often face shading, poor soil conditions, and seasonal dormancy.

Another important feature is year-round activity. While deciduous trees cease photosynthetic activity in winter, microalgae remain effective provided that light and above-freezing temperatures are maintained. Additionally, the periodic harvesting of algal biomass creates secondary benefits: it may be used as high-quality biofertilizer, biofuel feedstock, or raw material in the pharmaceutical industry. These aspects enhance the circularity and economic potential of the technology.

Addressing Criticism and Limitations

It is essential to emphasize that “Liquid Trees” are not intended to substitute traditional parks, green zones, or soil-based greening. Their primary purpose is to mitigate air pollution in highly urbanized areas where physical space for planting trees is unavailable, such as intersections, plazas, or industrial zones. This

clarification addresses a common misconception among citizens. Nevertheless, limitations include the lack of ecosystem services such as shading, biodiversity support, and stormwater management, which natural trees provide. Moreover, regular technical maintenance—nutrient supplementation, cleaning, and temperature regulation—is required to ensure continuous functionality.

Implications for Uzbekistan's Environment

The potential introduction of "Liquid Trees" in Uzbekistan's cities (Tashkent, Samarkand, Nukus) could yield several ecological benefits. First, it may help combat air pollution and dust, especially during summer dust storms, by reducing concentrations of particulate matter (PM_{2.5}, PM₁₀) and capturing localized CO₂ emissions from traffic and industry. Second, bioreactors could contribute to mitigating the "urban heat island" effect by cooling surrounding air through water evaporation. Third, the innovative visual design of these installations could play an educational role, raising ecological awareness among the population, particularly the youth. One important consideration, however, is water availability. Although the system functions as a closed loop with minimal evaporation losses, strategies such as rainwater harvesting or the use of treated wastewater would further increase sustainability.

Economic and Social Outcomes

The economic analysis suggests several positive outcomes. Firstly, local production and maintenance of such bioreactors could stimulate the development of small and medium-sized enterprises in biotechnology and "green" technologies. Secondly, domestic cultivation of microalgae strains would reduce dependency on imports and, in the long term, Uzbekistan—with its abundance of sunny days—could emerge as a regional hub for biomass production for food, cosmetics, and pharmaceutical industries. Thirdly, the modern and environmentally friendly appearance of cities adopting this technology would enhance their attractiveness to tourists, skilled professionals, and foreign investors. Finally, job creation would be stimulated in fields such as installation, maintenance, environmental monitoring, and applied microbiological research.

Implementation Pathway

For practical adaptation, a phased approach is recommended. A pilot project involving 10–15 bioreactors should be deployed in high-pollution zones of Tashkent, such as Chorsu Square and major traffic intersections. Scientific monitoring, conducted in collaboration with leading national universities, must accompany implementation to provide reliable data on effectiveness. Financing could be secured through public-private partnerships, combining local government co-financing, international green funds, and private investment. Furthermore, public education campaigns and adaptation of local microalgae strains resistant to Uzbekistan's climate would maximize both technological efficiency and social acceptance.

CONCLUSION

For Uzbekistan, "liquid trees" are not a panacea but a promising additional tool in the fight against the environmental problems of urbanized areas. It could stimulate the development of a green economy, create new high-tech industries, and improve the quality of life in cities.

However, residents of the cities where "Liquid Trees" have been installed have expressed their dissatisfaction. They argue that the microalgae tanks do not enrich the soil, reduce erosion, or contribute to the improvement of groundwater quality. Additionally, city dwellers complain about the unconventional appearance of the tanks.

Nevertheless, the "Liquid Trees" project represents an interesting and promising idea that could help improve the environmental conditions in major cities.

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