TABLE OF CONTENTS

INTRODUCTION

Typically, school is defined as a place for educating kids. However, a school is not only an institution for providing education; it serves as an environment that plays a significant role in shaping a child's character. Apart from the traditional perception of classrooms and textbooks, schools act as dynamic spaces where various dimensions of a child's personality are developed.

Most Russian students dedicate a significant part of their daytime at school. Therefore, it is important for school to serve not only as an educational environment but also a location to develop of their personalities.

Modern cities are focusing more on creating child-friendly environments that support children development. This idea is central to the concept of child-friendly cities. Many studies highlight the importance of spaces that meet the needs of children and help them grow. These spaces should provide children a supportive environment for learning, communication, and physical activity. Also they should help children build confidence, feel safe, and be respected.

The infrastructure of modern Russian schools maintains a continuity with the Soviet-era school system, prioritizing academic achievement over the holistic development and upbringing of students. This emphasis is reflected in the architecture of school buildings and educational spaces that have yet to undergo renovation.

The goal of the research is to develop the approach and recommendations for the implementation of Child Friendly City Principles in internal and external school environments.

The tasks of the research are:

− Review theoretical and practical approaches to studying educational infrastructure and its surroundings in the context of Child Friendly City principles.

− Analyze existing methods for assessing internal and external school environments, identifying the needs of schoolchildren.

− Develop a methodological framework for evaluating school environments based on ChildFriendly City principles, specifying key parameters and assessment criteria.

− Apply the developed approach to schools in the Leningrad region, conducting design workshops with schoolchildren, empirical assessments of the environment, and GIS-based spatial analysis.

− Analyze the results of the case study to identify spatial, environmental, and social factors that influence the quality of school environments.

− Develop recommendations for internal and external school environment design, integrating Child Friendly principles.

The object of the study is the internal and external environments of schools.

The subject of the study is the evaluated performance of school environments, based on child-friendly city principles.

The theoretical framework of this research is based on the methodological principles outlined in UNICEF's Child-Friendly Schools (Handbook and the Child Friendly Cities Initiative Handbook. These manuals provide guidance on creating inclusive, safe, and engaging environments for children in schools and urban areas. The study also uses the principles from M. Dudek's "Schools and Kindergartens: A Design Manual" (2015), which focuses on the spatial design of child-centered learning spaces. Additionally, the research is informed by Russian academic work, particularly the publication "Assessment of Educational Environments: Theory and Practice" (2023) by Ivanova E.V., Vinogradova I.A., Le-van T., Filatova B., and Yakshina A., which provides both theoretical and practical approaches for evaluating the quality and comfort of school environments in Russia.

The academic novelty lies in the development of a new approach to the evaluation of the quality of internal and external school environments. This includes participatory events to create criteria, evaluate them, and formulate recommendations. The study applies this approach to schools in the Leningrad region to develop innovative insights to the field of school environment assessment and improvement.

The research consists of an introduction, 4 chapters, a conclusion, and a reference list.

The first chapter, "Theoretical Concepts of School Environments" is dedicated to the analysis of approaches to define the school environment, uncovers the concept, and analyzes the metrics of the "Child Friendly City" concept.

The second chapter, "Research Methodology" examines existing methods for the assessment of school spaces within the context of the principles of the "Child Friendly City." Based on the reviewed works, a method for evaluating school environments is proposed.

The third chapter, "Study of School Spaces in the Leningrad Region" demonstrates the application of the method to the selected schools in the Leningrad region.

The fourth chapter, "Recommendations for Designing School Spaces" presents urban planning recommendations based on the data analysis.

The topic of the thesis corresponds to the field of the study program 07.04.04 "Urban Planning."

1 Theoretical Concepts of School Environments

1.1 Conceptualization of the Main Categories in the Study

1.1.1 School Environment

The term school environment usually includes three connected aspects: the physical, academic, and social settings that all influence a child's development during their time at school [27].

In terms of the physical environment, schools are made up of various spaces designed for different functions. Classrooms are the main places for learning and student-teacher interaction. Flexible furniture arrangements in these rooms can affect how students feel about their learning, their attitude, and how they rate the quality of their classes. Libraries provide a quiet place for reading and studying, while also encouraging group work and offering access to a wide range of books and resources. Gyms are important places for physical education and development through classes and extracurricular activities. Other indoor areas like wardrobes, hallways, and school canteens help meet students' daily needs and give them space to relax during breaks.

Well-designed physical spaces play an important role in improving learning and overall well-being.

School yards function as adaptable spaces accommodating various activities, including educational, social, and recreational pursuits.

In the academic environment, the relationship between teachers and students plays an important role in learning. Good communication helps to create a positive classroom environment. Problems with classroom management and teaching methods can affect student performance. Studies show that teaching social and emotional skills early in life helps to improve student behavior. Good ways of evaluating students help them learn and guide teachers in their work. Teachers in primary schools use different methods to help students learn through experience, stay active in class, and solve problems.

The social environment at school is very important for how students grow and develop. One of the concepts is justice, which means respecting everybody's' rights.

Justice is based on on ethics, rational thinking, natural law, equality, and sometimes religious values.

Another important aspect is natural environment. While many studies highlight the need for environmentally friendly behavior, they often focus only on environmental issues and do not consider the benefits that students can gain from adopting sustainable habits, such as responsibility, cooperation, and a sense of purpose.

Social coexistence refers to how students interact with each other, which has a strong impact on their personal growth. The way students feel about their school, and whether the school respects and accepts individual differences, affects how students relate to one another. Finally, the level of social support students feel at school is closely linked to their overall well-being and emotional health.

1.1.1.1 Child Friendly City Concept

The Child Friendly Cities (CFC) initiative is a joint effort between local governments, agencies, youth groups, and community members. They work together to protect and promote children's rights, based on the UN Convention on the Rights of the Child. The main goal is to make cities better places for children and young people. This means giving them a voice in decisions and involving them in family and community life [5].

The initiative also works to make sure all children have access to important services like healthcare, education, housing, clean water, and toilets. It protects children from violence and abuse and encourages the creation of parks and green spaces. Children should have safe places to walk, play, meet friends, and take part in cultural and social events.

Equality is a key part of the CFC approach. Every child—no matter their background, religion, income, gender, or ability—should be treated fairly and have access to the same services. The goal is to build inclusive cities that support the rights and well-being of every child.

The CFC initiative follows important rules for good city management:

– Fairness and inclusion – helping children who face the biggest challenges and making sure they are not left out.

– Accountability and transparency – being clear about who is responsible for each task and making sure progress is measured.

– Public participation – providing children the opportunity to make decisions about the surrounding environment.

This initiative is aimed to encourage cities adjust legislation, set up systems, and take actions that support children's rights. They also need to stay flexible and be ready to adjust plans as children's needs change.

The CFC initiative is adopted in more than 40 countries around the world. These are primarily European countries, as well as the United States, Canada, Brazil, Japan, South Korea, and others.

The concept proves its effectiveness. For instance, in South Korea the local committee reports children in the cities that adopted these principles to be 2.7 times more likely to feel respected compared to peers elsewhere. Participation experiences enhanced confidence, respect for others, and social interactions, empowering children with opportunities to contribute to their communities, become a part of local planning process, and better understand their surroundings through direct involvement [1].

The introduction of the concept in Rishon LeZion, Israel, incorporated child participatory approaches into urban planning. Discussions involving over 250 children, young people, and representatives from various local government departments, contributed to action plans for city government to implement over a two-year period. Children actively participated in the renovation and development of schoolyards and public green areas [14].

A systematic literature review of the research on CFC from Scopus showed a total of 89 articles on the topic from 2001 to 2020 with 33 documents created in the last 3 years. It highlights the growing attention to the topic. However, the study indicates that governance aspect of the concept knowledge should be enhanced for providing a greater effect on transition to child friendly urban environments [31].

Since December 2012, the implementation of the UNICEF project has been discontinued in Russia. However, the absence of this project does not diminish the attention it receives from Russian scientists. Based on their research, a higher assessment of the urban environment for children has been identified in Russian cities with a population exceeding 500,000, especially in terms of educational accessibility. At the same time, in smaller cities, there is a greater satisfaction noted with green areas and play spaces for children [33].

The interview with leading Russian design studios demonstrates that architects create new spaces according to the CFC principles. Architects engage children in the creation of spaces and consider the latest research findings in pedagogy, sociology, and psychology, considering the unique dynamics of the interaction between a child and the urban environment. The main principles they proclaim are safety and autonomy of the spaces, environmental sustainability, diversity, identity, inclusivity, involving children in the design process, and creating an environment that invites both children and adults to play [35].

In summary, through these guiding principles, governance in a Child Friendly City aims to create an inclusive, accountable, and responsive environment that prioritizes the well-being and rights of every child.

1.1.1.2 Child Friendly School Concept

The Child Friendly School (CFS) model is connected to the Child Friendly Cities concept and specifies on progressively elevating schools and education systems to high-quality standards. It focuses on all aspects influencing the well-being and rights of the child as a learner. The objective is not only to enhance teaching but also to improve overall school functions. Quality standards, according to CFS, should ensure universal access, smooth academic progression, and timely completion of the educational cycle. Additionally, these standards seek to provide an enriched educational experience for students to thrive, develop, and achieve their full potential [32].

CFS models emphasize the active involvement and support of all stakeholders, termed 'duty bearers,' including parents, communities, teachers, school

heads, education planners, civil society groups, and local/national governments. Their engagement is crucial for creating conditions and allocating resources necessary to achieve envisioned quality standards.

The scope of CFS models goes beyond traditional educational excellence, focusing on the holistic needs of the child. It encompasses health, safety, security, nutrition, and psychological well-being. CFS models are intersectoral and address child participation, creation of spaces for expression, and respect for rules and regulations.

Quality in CFS models is evaluated on multiple dimensions, including the preparedness of boys and girls to start and continue school, how well schools receive and uphold the rights of students, the health and well-being of students, safety and gender-sensitive environments, adherence to child-centered teaching methods, encouragement of child participation, investment in stimulating classrooms, availability of environmentally sustainable facilities, and the use of pedagogy that combats discrimination based on gender, ethnicity, or social background. Proponents argue that the dynamic interplay of these factors constitutes a 'packaged solution' for a confidently described 'child-friendly school.'

1.1.2 Problem Statement

The infrastructure of modern Russian schools maintains continuity with the Soviet-era school system. Primarily focused on academic achievement, it subsequently addresses the development and upbringing of students. This is evident in the architecture of school buildings and educational spaces that have not yet undergone renovation. Additionally, continuity with the Soviet school system is reflected in the curricula and extracurricular plans, including subjects and courses, as well as the corresponding focus of the supplementary education system.

The structure and design of school facilities inherited from the Soviet era hinder the organization of the educational process based on modern methodologies, which emphasize the active involvement of students. Traditional subject classrooms with rows of desks still dominate schools, impeding the creation of spaces for

collaborative work, individual workstations outside classrooms, and lecture halls for continuous lectures.

Modern school buildings are not designed to support collaboration. They often lack flexible spaces for group work and do not have quiet areas outside classrooms and lecture halls for communication and interaction between children and school staff.

The development of school spaces involves different stakeholders. The Ministry of Education sets learning standards and guides policies for improving school environments. School administrators are responsible for applying these policies, managing resources, and maintaining safety. Teachers and school staff help manage the educational process. Architects and construction companies design and build schools, in correspondence with current educational needs and regulatory requirement. Students and parents bring important views and feedback. The wider community and NGOs promote public opinion and suggest ways to make school spaces better.

Although there has been progress, some problems still exist in improving school spaces. Many school buildings are old and do not meet modern teaching needs or safety rules. Schools often do not have enough money to make important changes or try new ideas.

Space is not always used well. For example, many classrooms are still set up in traditional ways, which can make it harder to use modern, active teaching methods. Also, when the community is not involved, it can slow down improvements. Solving these problems will require teamwork from everyone to create safe, modern, and effective learning spaces.

Current researches on school environments often miss how physical spaces and learning processes work together. Most studies focus on whether school buildings follow health and safety rules, with a strong focus on infrastructure. While these checks are important, they often do not look at how the design of school spaces affects students' learning and overall experience.

Traditionally, schools have been evaluated mainly by looking at academics, such as teaching methods, lesson plans, and test scores. However, it is important to take a wider view that also looks at how the physical environment affects learning and student well-being.

Also, studies by local authorities often look at students' personal qualities and values. This information is helpful, but it usually does not show how school spaces affect these qualities. By linking student development with the school environment, researchers can better understand how learning and physical spaces work together. This can lead to better education policies and teaching methods.

1.1.3 Current Legislative Framework

Schools follow several rules and regulations. Sanitary rules (SanPiN) set standards for things like temperature and lighting inside school buildings. Construction norms (SNiP) cover building materials and systems like electricity and plumbing. Fire safety rules say which materials can be used and how furniture should be placed. All these rules influence how schools are built and how they look and function, both inside and outside.

Federal state educational standards for the school curriculum do not include specific requirements for the physical environment.

The primary document governing the design of spaces in educational institutions is the set of rules 251.1325800.2016 "Educational institution buildings. Design rules." [23] These regulations focus on where schools can be built, evaluating the site's features and whether it's suitable for construction. They emphasize the need for enough space for both the school building and surrounding grounds. The rules also require checking that the site meets all necessary standards, such as proper fencing according to sanitary guidelines and adequate lighting.

The organization of the educational institution's territory is also regulated, presenting a system of open spaces divided by activity types and age groups. It emphasizes the alignment of sports equipment and small architectural forms with age groups to prevent injuries. Compliance with sanitary requirements and standards, including the approval of sanitary rules, is asserted, along with regulations

for the safety of equipment for children's playgrounds according to the Technical Regulation of the Eurasian Economic Union "On the Safety of Equipment for Children's Playgrounds" (TR EAEU 042/2017) [8].

The regulation covers the organization of zones for the rest and play of students, considering various age groups. The necessity to provide conditions for the unhindered movement of people with limited mobility on the site is also noted. Volumetric-planning and structural solutions for buildings are discussed considering urban planning and climatic conditions of the construction area, emphasizing the importance of compliance with interior finishing requirements according to established standards.

There are specific requirements for school placement, and the features of the site are thoroughly examined to assess the possibility of constructing a school in the given location. Adequate space must be allocated for both the building itself and the school grounds. The territory of the educational institution is seen as a system of open spaces divided by activity types and age groups, accommodating equipment, structures, small architectural forms, and greenery. Sports equipment and small architectural forms must correspond to age groups to prevent student injuries, considering the Technical Regulation of the Eurasian Economic Union "On the Safety of the Equipment for Children's Playgrounds" (TR EAEU 042/2017) [8]. Room equipment and interior finishing are regulated by sanitary requirements.

At the regional level, the minimum allowable capacity for newly constructed schools is 525 students [40]. The minimum allowable land size depends on the capacity of the facility:

– Up to 400 students: 55 sq. m per student;
– Over 400 to 500 students: 65 sq. m per student;
– Over 500 to 600 students: 55 sq. m per student;
– Over 600 to 800 students: 45 sq. m per student;
– Over 800 to 1100 students: 36 sq. m per student;
– Over 1100 to 1500 students: 23 sq. m per student;
– Over 1500 to 2000 students: 18 sq. m per student;

– Over 2000 students: 16 sq. m per student.

Also, the government provides requirements for school accessibility that are described in Table 1.

Table 1 – Regional requirements for school accessibility [40]

Area Type	Schools	
	Minimum Acceptable Accessibility Level	Maximum Allowable Level of Territorial Accessibility
Urban Areas	91 students per 1000 people of the permanent population	500 meters
Rural Areas	61 students per 1000 people of the permanent population	Institutions of the 1st stage of education - not more than 2 km walking distance and not more than 15 minutes of transportation accessibility. Institutions of the 2nd and 3rd stage of education - not more than 4 km walking distance and not more than 30 minutes of transportation accessibility.

The review of the rule set requirements demonstrates that the main requirements for the physical environment of educational spaces focus on safety and sanitation norms, with limited consideration for the psychological and social aspects of children's development.

1.2 International Approaches to School Design

1.2.1 Sustainable Development Goal 4

At the world level, requirements for the the quality education are set be Sustainable development goals. These are a set of 17 global goals established by the United Nations in 2015 as part of the 2030 Agenda for Sustainable Development. These goals are designed to address various global challenges and promote a more sustainable and equitable world. Each goal is accompanied by specific targets, and they collectively aim to tackle issues related to poverty, inequality, environmental sustainability, peace, and justice.

Sustainable Development Goal 4 is focused on ensuring inclusive and equitable quality education and promoting lifelong learning opportunities for all. This goal recognizes the transformative role of education in coping the cycle of poverty, fostering individual development, and contributing to overall societal progress [10].

Though main targets refer to quality and equitable access to education for children, target 4.a *Build And Upgrade Inclusive And Safe Schools* covers the issues of school environment. This target proclaims creating and enhancing education facilities that meet child, disability and gender sensitive needs and provide safe, non-violent, inclusive and effective learning environments for all.

As the progress of educational systems in diverse countries is at different levels, the target indicators evaluate children's access to essential amenities crucial for quality education. These indicators encompass access to electricity, computers, and the Internet for educational purposes, as well as infrastructure and materials tailored for students with disabilities. Furthermore, the evaluation considers fundamental elements such as access to drinking water and facilities for sanitation and handwashing. The goal emphasizes that early childhood development, care, and education are multidimensional, encompassing various facets of a child's well-being, including physical, social, emotional, and mental aspects.

1.2.2 Child Friendly Schools Manual

The manual, crafted by UNICEF specialists drawing from the experiences of 155 countries, aims to establish universal guidelines for delivering quality education to all children. It comprehensively addresses academic, physical, and social dimensions of school environments, with a substantial focus on the child's developmental perspective, both externally and internally [32].

Recognizing the variations in educational environments due to local climate, human capacity, resources, and priorities, the manual compiles exemplary practices in diverse aspects of school design. It underscores the significance of tailoring design and infrastructure to accommodate the unique needs of children at different stages

of development, encompassing variances in knowledge, skills, and the capacity to grasp various concepts.

The manual highlights basic principles of child-friendly school design that should be applied when planning a facility. They are presented in the Table 2.

Table 2 – Recommendations for creating child-friendly schools [32]

1. Structure	The buildings should be well integrated with the environmental and cultural context.
2. Administrative offices	Administrative staff should be located separately but provided transparency in monitoring school activities.
3. Safe water	Fresh drinking water should be provided.
4. Hygiene	A separate space should be provided with water and soap or other cleaning agent for children to wash their hands.
5. Toilets	Separate toilets or latrines should be available for girls and boys. Privacy, cleanliness and safety are major considerations when planning location and design of facilities.
6. Environmental conditions	Classroom areas should be equipped with windows and provided with light. Schools should be protected from noise, excessive pollution, and odours. When this is not possible, design measures should be used to minimize the impact of these problems.
7. Colour	Choose materials and finishes in their natural, light colors, complemented by warm natural tones as accents, influenced by local cultural preferences.
8. Power	Ensuring the school is equipped with a power source to support lighting, connectivity for communication equipment, and other appliances. Considering integrating alternative energy sources such as solar, wind, and biogas into the school's design where suitable.

Table 2 (continued)

9. Safety	School designs must include fire safety plans, use child-safe and fire-resistant materials, keep the site clean, and be located away from hazardous areas.
10. Health	Schools should have a basic first-aid kit or medicine cabinet for emergencies. Being near a clinic allows regular health visits and ensures prompt treatment for children.
11. Library	A quiet space like a library should be in provided school for learning. It should be easy to access and kept free from noise to help students focus.
12. Landscaping	School grounds are an important part of the learning environment but are often neglected. Trees help block sun, dust, and noise, and make the area look nicer. Planting local plants and edible crops teaches kids about growing food. Trees also make the space feel calm. Letting children help plan the landscaping makes the school more child-friendly.
13. Bathrooms	Separate facilities for male and female teachers are needed. For students, practical and safe arrangements include designated bathrooms for boys and girls within or near classrooms, potentially shared among clusters to protect younger children.
14. Relaxation rooms	Child-friendly schools for nursery and lower-elementary levels should have relaxing spaces with homelike elements, creating a friendly atmosphere.

Table 2 (continued)

15. Individual spaces	Including flexible spaces for group and individual learning, accommodating various learning styles and providing opportunities for both collaborative and independent study.
16. Open spaces	Accessible open spaces, like play yards, gardens, and decks, facilitate physical activities and outdoor learning for children. These spaces can also serve the community for town meetings and local gatherings after school hours in child-friendly schools.
17. Kitchen	Design meal preparation spaces with equipment to maintain food freshness and prevent poisoning.
18. Protection	Child-friendly school design aims to prevent bullying and abuse through non-violent discipline strategies and visible activities. The enclosure and boundaries, like fences, serve to protect children from external elements, define boundaries, and create space for gardening.

The manual emphasizes on understanding and respecting the cultural and environmental backgrounds of children. This approach helps shape design principles that children can relate to, strengthening their sense of identity and belonging to their community and surroundings. When schools are designed with children at the center—supported by families and the wider community—they become more than just buildings. They turn into vibrant spaces that encourage active learning and teaching. In these environments, teachers guide and support the learning process, while students take an active role in exploring and developing their unique skills and potential.

1.2.3 Social Aspects of School Design

The forefront of physical school environment practices extends beyond catering basic needs, as demonstrated by UK researchers. Their studies affirm that factors such as a connection to nature (through natural light, air, and views),

individualization (in terms of a sense of ownership, connectivity, and flexibility), and visual stimulation (involving complexity and color) have a significantly positive impact on students' academic performance [3].

A contemporary concept gaining traction is the creation of deskless spaces. Research conducted in Finland provides evidence of its positive effects on both students and teachers. Children reported an increased sense of communication and the ability to form close friendships with classmates. Teachers, in turn, highlighted the enhancement of their pedagogical experience. This innovative approach not only transforms the physical layout of classrooms but also fosters a conducive environment for social interaction and improved educational experiences for both students and educators [20].

Studies demonstrate the beneficial influence of greenery in the external environments of schools on children's emotional well-being, while concurrently revealing detrimental effects associated with the presence of artificial surfaces in close proximity to school premises or residential areas. These findings underscore the significance of considering natural elements in the design of school surroundings to promote positive psychological outcomes for children [18].

The study exploring how school playgrounds can support the psychological needs of tweens identified factors influencing autonomy, competence, and relatedness. Autonomy was supported by diverse play activities and proximity to classrooms, while competence thrived with challenging and various play scenarios. Relatedness was fostered through social interaction spaces. Positive social play experiences transferred to positive emotions in the classroom. The study suggests that designing school playgrounds with children's perspectives in mind can boost their autonomous motivation, promoting physical and social activity and addressing sedentary behaviors [30].

The study by Cody B. Hodson [12] investigates the relationship between green environments within school attendance areas and academic performance. School attendance areas are spatial partitions of school districts, representing the neighborhoods where students reside and attend school. The research higlights how

access to nature within school attendance areas impacts both individual students and overall school performance. It also considers the impact of neighbourhood, such as reduced commute lengths and increased opportunities for physical activity.

The link between behavior and a school's broader physical environment, extending up to 10 minutes away, was researched in the United Kingdom. The the government-backed report on school discipline acknowledged the significant impact of surroundings on behavior in the learning and working environment. The study investigates strong connections between the deterioration of a neighborhood's physical condition and various educational factors, including pupil behavior, truancy rates, teacher morale, and a school's ability to achieve satisfactory exam results [24].

Enrico Giori's research project, "We Want a School!", explores the outcomes of integrating fifth-grade students into the school design process. In contrast to initial skepticism, the students exhibited creative thinking, proposing substantive ideas for a school that addresses societal issues, promotes inclusivity, and transcends conventional boundaries [15].

The project resulted in an illustrated children's book that serves as a model for involving kids in designing spaces. It includes a manifesto written by the students, with rhyming lines based on their own words, and illustrations by Giori [9].

Giori's method focuses on giving children a meaningful role in the design process. During the project, students learned how to share ideas, give feedback, and turn their thoughts into real results. They also explored storytelling, different ways of learning (like diffused learning), and how education can happen outside the classroom. One activity, where they listed places with educational value beyond school, helped them better understand how design works in everyday life.

The students' creative ideas—like having lessons at night—are shown in the book, highlighting how imagination and practical thinking can come together in the design process. The illustrations also show scenes from different points of view, giving a completer and more inclusive picture of the students' ideas. These reflect

21

their desire for flexible spaces, areas that can be easily changed, and learning both indoors and outdoors.

The project shows how important it is to make the field of design more accessible to young children. It proves that when kids are given a voice, their ideas can positively shape communities. Giori believes the key innovation in this project was truly listening to everyone involved and showing that good design can come from working together and including all voices.

1.2.4 Contemporary School Best Practices

1.2.4.1 Suji Dream School

Suji Dream School in South Korea is a strong example of how natural landscapes can be smoothly integrated into the school environment (Figure 1) [26]. The school's design encourages easy connections between different areas, creating a calm and supportive space for learning and development.

Inside the school, natural materials are used in the design to strengthen the idea of being close to nature. This not only improves how the school looks but also helps create an eco-friendly and welcoming atmosphere. These materials help students and teachers feel more connected to the natural world, supporting their well-being and positive mindset.

Figure 1 — Suji Dream School Exteriors [26]

1.2.4.2 Ban de Vagney School

The Ban de Vagney School, a creation of Tectoniques Architects + SQUAD, epitomizes an approach rooted in the aspiration to establish a fluid and cohesive

ecosystem that intricately considers scales ranging from urban dynamics to classroom settings [25]. The architects aim was to shape Vagney into a highly functional educational tool that seamlessly adjusts to and complements its surroundings.

The building strategically aligns with the road, adhering to urban principles, and strategically harnesses favorable solar orientation. Extensive open spaces (Figure 2), flooded with natural light, provide inviting areas thoughtfully furnished for both private activities and collaborative engagement, elevating the overall educational environment.

Figure 2 — Ban de Vagney School Open Space [25]

1.2.4.3 Huizhen High School

Huizhen High School (Figure 3) was awarded the World Building of the Year at the 2023 World Architecture Festival. Designed by Hangzhou-based Approach Design Studio in collaboration with the Zhejiang University of Technology Engineering Design Group, the school presents a bold shift from the typical efficiency-focused model of Chinese education. The studio's director highlights the importance of creating "blank spaces" within the school—areas where students can relax, reflect, and enjoy the surroundings, offering mental breaks from academic pressure [11].

The school's unique architecture stands out with 30 classrooms and suspended learning areas nestled among trees and plants. Zigzagging walkways guide students through lush greenery, ensuring constant contact with nature as they move through the campus.

Unlike traditional layouts, the classrooms are scattered throughout the forested campus, turning them into immersive, interactive learning spaces that offer a fresh approach to education.

Figure 3 — Huizhen High School Interiors [11]

1.2.5 Summary

Global education programs mostly aim to give all children equal access to good school buildings, as these play an important role in a country's progress. A big part of today's education is making sure schools have comfortable spaces that help children grow academically, physically, socially, and emotionally.

Studies show that both the inside and outside of school buildings affect how well students do and how they feel. Inside, good classroom design, comfortable furniture, and nice surroundings help students focus, take part, and learn better. Outside, green spaces, playgrounds, and safe paths support children's health and development in other ways.

By understanding how school environments affect learning, we can build spaces that support both education and well-being and prepare children for a healthy and successful future.

1.3 Russian Approaches and Practices of Designing School Environments

1.3.1 Adherence of educational initiatives in Russia to Sustainable Development Goals

As the SDG indicators provide requirements only for basic infrastructure, Voluntary National Review covers the issues of the accessibility of schools for children with disabilities and accessibility to the Internet.

The Voluntary National Review in 2019 revealed that 98.8% of disabled children in Russia had access to quality primary, basic, and secondary general education. In line with global inclusivity goals, Russia has planned initiatives, including the implementation of the Social Lift technology and the development of inclusive education under the "Education" National Project (2019–2024) [3].

Within the national project "Education", 800 new schools, were constructed providing a total capacity of more than 498,000 places, that reflects a commitment to expanding educational opportunities and infrastructure. 637 schools exclusively offering adapted educational programs for children with disabilities. Additionally, over 37% of general education organizations are equipped with the necessary infrastructure for digital educational environments.

Furthermore, there have been improvements in facilities for physical education in 4,223 schools in rural areas and small towns. The establishment and operation of 97 "Quantorium" children's technoparks within schools general education organizations showcase in promoting technological education

In a dedicated effort to align more closely with Sustainable Development Goals, the Federal State Statistics Service of Russia has formulated a set of indicators to assess the country's achievements. Among these indicators, the focus on school infrastructure centers on the accessibility of the internet in educational institutions.

The provided table delineates the percentage of schools equipped with internet access for educational purposes, covering the period from 2018 to 2022 in the Leningrad region. Despite a marginal decrease in the figures over the years, goal is to ensure a consistently high level of access to quality education, and the overall level in Russia stands at 94.1%.

Table 3 – The share of schools provided with Internet access for educational purposes (%) [43]

	2018	2019	2020	2021	2022
Leningrad region	95.8	95.4	95.7	94.9	94.7

The "Decade of Action" Civil Society Review does not focus directly on school infrastructure but highlights two important issues related to it.

First, it discusses the challenges of combining schools and increasing the number of students in each class. This could go against the principles of Child Friendly Schools, as it may affect both the quality of education and students' well-being, raising concerns about whether these changes create a supportive learning environment.

Second, the review points out that education funding is not enough. This lack of funding can make it difficult to improve or maintain school buildings and create a good learning environment for students.

The overview indicates that Russia has made significant progress in achieving Sustainable Development Goal 4, particularly in school internet accessibility. However, fundamental challenges, such as contradictory structural changes and inadequate education expenditures, pose risks to the sustainable development of schools. The need for a more nuanced, child-centric approach and a comprehensive exploration of deeper issues beyond physical infrastructure criteria is evident. To ensure sustained progress, addressing these challenges is crucial for a comprehensive and effective approach to educational development in Russia.

1.3.2 Current Practice

Russian researchers emphasize that the 21st-century learning environment is dynamic, fostering quick visual comprehension and stimulating visual thinking. This recognition calls for a new approach, integrating mandatory semantic and spatial elements into the design concept. The learning space undergoes a transformation, assuming a broader meaning and functional load, effectively replacing traditional school classrooms [34].

The impact of the learning environment on the educational process is evident, with the absence of artistic elements hindering students' creative thinking. In such conditions, the learning process becomes less effective, diminishing the desire to explore and slowing down the development of independent thoughts. The research underscores that in an uninspiring educational environment, students lose two crucial components – curiosity and the opportunity to engage in discussions about learning processes and outcomes.

Lebedev Studio, in collaboration with the Moscow Architecture Institute, has produced a comprehensive guideline for designing school interiors. However, external environments are not explicitly covered. Educational spaces like *'Quantorium'* and *'Tochka rosta'*, created under the national projects, also have their own design guidebooks. These guidelines align with the child-friendly schools initiative and reflect research recommendations, emphasizing the importance of creating environments that prioritize student well-being and holistic development.

Analyzing scholarly works on the architectural and environmental organization of schools, key factors influencing the evolution of school building typology include [39]:

– Modularity in the volumetric and planning design of the structure.

– Flexibility, universality, and adaptability of educational spaces.

– Flexibility and universality of public communicative spaces.

– Aesthetic significance and the promotion of psychological comfort in the design.

– Public socio-cultural significance, contributing to the broader community and cultural context of the facility.

Russian scientists claim that the development of modern educational institutions in Russia is at an early stage of conceptual formulation. Despite their emergence, there is a reliance on foreign architectural firms for construction. They highlight the need for a reevaluation of construction practices in Russian regions, emphasizing the importance of incorporating specified criteria for contemporary educational institutions in the planning and design of new facilities [36].

The importance of the school territory is explained in the manual "How to design a schoolyard" by Le-van T., Filatova B. and Yakshina A. [38]. They state that the schoolyard reflects the values and relationships within the school community. Despite being a valuable yet underutilized educational resource, it holds the potential to broaden opportunities for addressing pedagogical tasks. Collaborative design of the educational environment involving students, educators, and parents is a intricate process demanding time and specific competencies. However, it offers substantial advantages to all participants. Co-participation primarily transforms relationships within the school, laying the groundwork for intentional changes in the environment.

Despite the acknowledgment by scholars and designers of the pivotal role that a conducive school environment plays in educational outcomes, challenges manifest at the governance level, particularly in regions governed by educational frameworks that emphasize academic achievements. The Leningrad Region, as an illustrative case, places substantial emphasis on the assessment of academic results and monitoring of core values among schoolchildren, reflective of a paradigm that prioritizes scholastic accomplishments.

Within this context, a notable initiative was undertaken by the Leningrad Region Institute of Education Development in 2020. The institute authored a guidebook titled "Methodological Recommendations for Creating and Developing the Infrastructure of a Modern School." [42]

Significantly, the guidebook's treatment of physical infrastructure design was cursory, with a particular emphasis on the classroom environment. The recommendations provided therein mirrored the principles articulated in the manual produced by the Lebedev Studio. The document further integrated insights pertaining to classroom decoration.

This analysis underscores the apparent disjunction between the nuanced understanding of environmental design's impact on education held by researchers and designers and the prevailing governance structures. The emphasis on academic outcomes and the limited treatment of comprehensive infrastructure development in official guidelines reflect a potential misalignment between the acknowledged

importance of a conducive educational environment and the practical policy considerations at the regional level. Addressing these challenges necessitates a more integrative approach, wherein scientific insights on educational environment design are seamlessly incorporated into the governance frameworks to foster holistic educational development.

1.3.3 Schools in the Leningrad Region

The schools of the Leningrad Region are represented in the map in Figure 4.
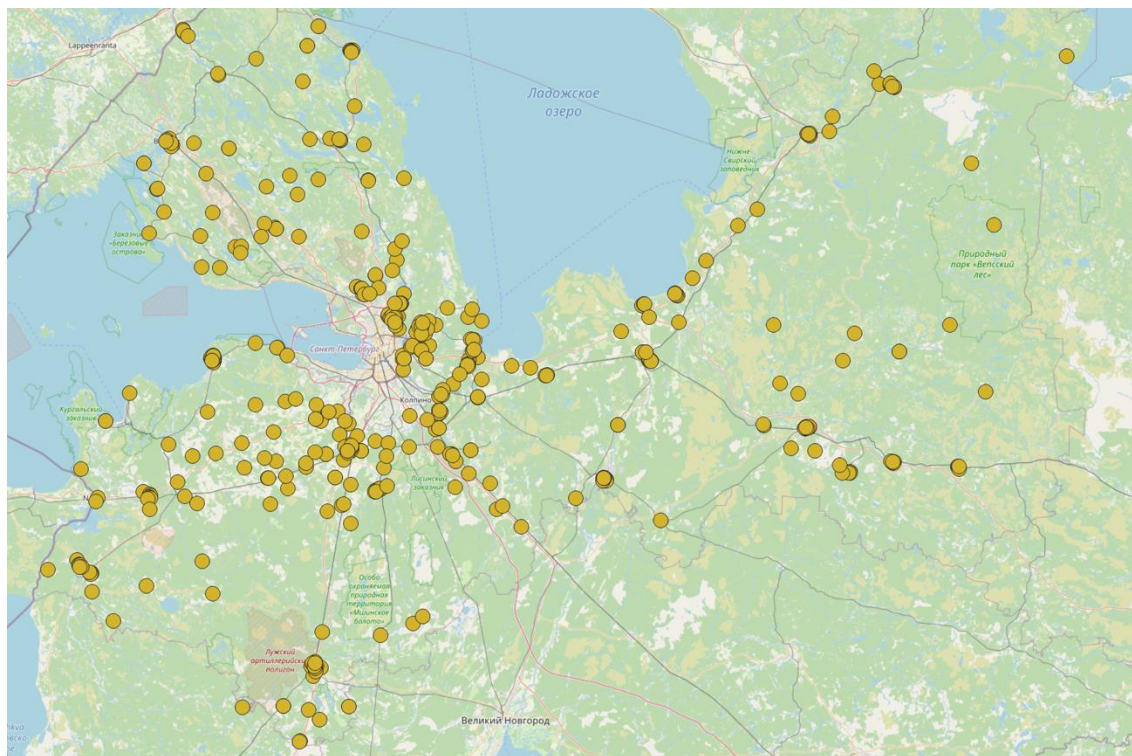
Figure 4 — Schools of the Leningrad Region
(Source: created by author)

The number of schools is increasing in cities near Saint Petersburg, driven by urbanization and population growth. Murino serves as a notable example where new schools are constructed using modern materials and design approaches. In contrast, cities like Kirishi primarily have school infrastructure inherited from the Soviet period, resulting in a relatively high average year of construction and a substantial need for rebuilding infrastructure.

Table 4 – Number of schools and students in the Leningrad Region [44]

Average Construction Year	Average Year of Last Renovation	Number of Buildings in Need of Renovation
1976	2009	62

The regional government provides statistics on the number and attendancy of schools that is presented in Tables 5 and 6.

Table 5 – Number of schools and students in the Leningrad Region [45]

Indicator	Year	Urban Areas	Rural Areas	Total
Number of Schools	2022	176	160	336
Number of Students	2022	143,342	46,271	189,613

In 2022, there was an increase in the number of general education schools by 4 units, resulting in a corresponding growth in the number of students by 10,624 individuals. In urban areas, with the addition of 4 schools, the number of students increased by 8,317 individuals. This indicates an increase in both the number of classes and their enrollment in urban areas [37].

Table 6 – Number of students in 1 classroom [45]

Indicator	Year	Urban Areas	Rural Areas	Total
Primary Education	2021/2022	27/27	19/20	24/25
Middle Years	2021/2022	26/26	18/18	23/24
High School	2021/2022	21/22	12/12	19/19

The analysis of educational data in the Leningrad region for the year 2022 reveals an increase in the number of general education schools and students, particularly in urban areas near Saint Petersburg. The occupancy of classrooms in the institutions shows a tendency to grow, with a specific emphasis on primary education in rural areas and secondary education in urban settings.

Despite compliance with federal and regional construction requirements, the provided indicators only cover basic criteria for infrastructure size and safety. Importantly, there is a lack of assessment based on the principles of Child Friendly Schools for the schools in the Leningrad region.

In conclusion, while there is a positive trend in the expansion of educational facilities, especially in urban centers, schools in more remote areas face challenges with outdated infrastructure. Future research will focus on evaluating both school types against the principles of a child-friendly school to ensure a comprehensive understanding of their educational environments.

2 Research Methodology

2.1 Review of the existing methods

The majority of existing methods for evaluating school environments either study the internal environments or emphasize the interconnection between internal and external school environments. However, these methods include various approaches to assess different domains of school environments: the academic, social or physical environments.

In the external environment, researchers tend to focus on a range of factors such as ecological, economic, social, and safety elements, all of which have a significant influence on student outcomes. Primarily, researchers study social and economic factors, such as levels of income and the socioeconomic status of the surrounding community, that impact the quality of the academic setting.

The review of the existing studies showed that the most common methods of the assessment of school environments are statistical modelling, interview method, spatial analysis, case studies, spatial analysis, meta-analysis and participatory action research. These methods can be combined in the studies to provide more profound evaluation of the object.

This part of the research will cover different approaches to evaluating school environments focusing on the interrelations between internal and external environments.

2.1.1 Socio-economic Statistical Analysis

The method suggested by L.D. Ruiz, S. D. McMahon and L. A. Jason in the study titled "The Role of Neighborhood Context and School Climate in School-Level Academic Achievement" uses a statistical analysis to explore the interplay between community violence, socio-economic status (SES), and academic outcomes in public elementary schools [22].

The study uses location-based data from public sources to explore how different factors around schools affect student success. It looks at things like family income, education levels, jobs, safety, crime, and how students feel about their school.

The researchers use GIS tools to demonstrate how school performance connects to the conditions in the neighborhoods. They compare local community data with school data to see how things like poverty and crime may be linked to school results.

The study also shows that a good school environment can help students do better in school, even if they live in neighborhoods with difficult socio-economic conditions.

2.1.2 Qualitative Meta Synthesis Approach

An approach suggested by Hanne Mikkelsen and Rita Agdal provides a critical systematic review of qualitative studies from the Nordic countries [17].

The research began with a scoping and systematic search of Nordic studies. The search strategy combined terms related to "neighborhood" and "education," along with other relevant keywords. A literature review was then conducted across multiple databases aiming at the inclusion of studies from both educational and social science perspectives.

The search provided a large number of texts, which were screened to remove duplicates. Initial screening involved reviewing titles and abstracts based on specific inclusion and exclusion criteria. The final selection included several articles published in peer-reviewed journals that examine various aspects of how neighborhoods influence educational achievement.

Quality assessment of the included studies was carried out using a specific rating tool that evaluated elements such as engagement and ethics. The analysis involved reading of the articles to identify themes related to the influence of neighborhoods on educational achievement, leading to the development of overarching themes based on the findings.

The analysis resulted in a study that explores the impact of the socio-economic environment on educational outcomes, with the search criteria specifically aimed at excluding quantitative research.

2.1.3 Remote sensing and statistical modelling for evaluation of the level greenness and academic performance

The study by S. B. Rakowska, K. L. Lutz, and M. D. Adams from the University of Toronto used remote sensing and statistical modelling to examine the relationship between green space and school performance in elementary schools in Ontario, Canada [19]. Green space was measured using three spatial boundaries: the school property, a 1.6 km neighborhood, and a 5 km neighborhood area.

Data on green space within these areas was collected and analyzed in relation to standardized test scores in reading, writing, and mathematics to assess school performance. Property boundary polygons were created for each school to more closely examine green space accessibility during outdoor activities.

This method allowed for a more focused assessment compared to earlier studies, which often used broader geographic areas. Spatial analysis techniques were applied to evaluate the distribution and accessibility of green space in relation to the test scores.

2.1.4 Responsive Analysis Method for Surrounding Urban Spaces

Not many studies have explored how the areas around schools impact students. However, one important work by S. Mahmoud, A. Elshater, and S. Afifi looks into this topic. Their study, titled "Investigating Pupils' Responses to Urban Spaces Around Schools: Actions for a Responsive Environment," examines how nearby urban spaces affect students' daily routines and whether these spaces meet their needs [16].

The study is divided into three main parts. First, the researchers reviewed existing literature to understand how urban spaces and variety help meet students' needs. Second, they spent eight months conducting surveys and observations to see how well the areas around schools supported student activities. They observed students sitting, talking, eating, and also interviewed them to learn more. Finally, they used the Space Syntax method to study how the areas were connected and how students moved through them.

The study provides a detailed look at how public spaces around schools are used. However, it has some limitations when it comes to suggesting ways to improve these spaces. It also highlights the difference in how internal and external spaces are used. Additionally, the study focuses on the quality of activities supported by these spaces from the students' perspective.

2.1.5 Spatial Analysis Method

The methodology developed by A. Abulibdeh's team in Qatar provided a framework for analyzing the spatial distribution and accessibility of public and private schools in the country [2].

The research focused on gathering and organizing data about school locations, land use, area boundaries, and road networks. This data was divided into different layers: point layers for schools, polygon layers for land use and administrative divisions, and line layers for road networks. The point layers were used to calculate how accessible schools are, while the road network data helped measure travel distances and times to schools. Population data was also included to assess school accessibility for different groups.

The spatial analysis followed several steps. First, data was collected about school locations, land use, road networks, and petrol stations at both national and local levels. Then, different spatial techniques were used to analyze school distribution, patterns, clustering, spatial differences, and how close schools were to hazards. These methods measured accessibility and showed how different factors affected school distribution and access.

Although the primary focus was on school accessibility, some methods were also employed to assess the safety of the external environments surrounding schools.

2.1.6 Interview Analysis Method for External Environments

A study by Russian researchers Elena V. Ivanova, Alsu R. Aizatulina, Irina A. Vinogradova, and Ivan A. Klimov focused on evaluating the availability and quality of neighborhood services and facilities of schools [13].

The research was framed by the "15-minute city" concept, emphasizing the importance of having essential services within a short walking distance. The aim

was to evaluate the comfort and usability of public spaces around schools, recognizing their role as social hubs frequented by students, parents, and teachers.

The study involved 996 participants, including students, parents, and teachers from different districts in Moscow. Data were collected using an online questionnaire that focused on two main factors: the presence of infrastructure like educational centers and cafes, and participants' views on public spaces, including their satisfaction with sports facilities and overall use. Public space comfort was measured by looking at social infrastructure, informal meeting spots, safety, versatility for different activities, and how accessible the spaces were for pedestrians.

This method helped evaluate the quality of public spaces around schools and provided useful insights for urban planning. However, the study did not specifically focus on the unique needs of children or their interactions with the school environment.

2.1.7 Multilevel Statistical Modelling Method for Internal School Environments

A British research team led by P. Barrett conducted a study across 27 schools in the UK with 3,766 students to explore how school environments impact student outcomes [4]. The term "environment" included both ecological and physical factors (like air quality and available open space per student) as well as emotional and behavioral aspects important for psychological comfort.

The researchers used a statistical model based on three main design principles: naturalness, individualization, and stimulation. Each principle was broken down into ten specific design factors. Elements like natural light, air quality, personalization, flexibility, and visual stimulation were found to significantly improve students' academic performance.

The results showed a strong link between the comfort of the learning environment and student success. This approach highlights key environmental factors that affect educational outcomes, making it easier to target improvements.

However, the study mainly focused on the indoor environment of schools, limiting its broader application. Still, some factors, such as natural light, air quality, and physical activity opportunities, could be applied to outdoor school environments, suggesting that the findings can be expanded beyond just indoor settings.

2.1.8 Empirical Method based on Participation

The research by Katie Richards-Schuster, Laura J. Wernick, Maren Henderson, Matthew Bakko, Miguel A. Rodriguez, and Eric Moore uses the Youth Participatory Evaluation (YPE) method to study key aspects of school climate, such as racial disparities, disciplinary practices, and student-teacher relationships. This approach actively involves students in the evaluation process, making their perspectives central to understanding these issues.

In a multi-year collaboration between researchers and practitioners, the YPE method focuses on continuous improvement and reflection within the school district. It addresses challenges like managing power dynamics, tackling racial inequities, and ensuring authentic youth participation. The goal is to create meaningful and lasting changes in school environments.

In their article "Children's Participation in Urban Planning and Design: A Systematic Review," Ö. Ataol, S. Krishnamurthy, and P. Van Wesemael emphasize that co-production is the best way to involve children in urban planning. Unlike traditional methods, where children typically just offer their opinions, co-production allows them to take part in every stage of the process. This approach gives children a sense of involvement and responsibility. They can make decisions and put ideas into action with guidance from an adult moderator. As a result, they see real outcomes and feel a genuine sense of contribution and ownership.

The table 7 below provides the summary of the methods observed, defining the approach, input data, method description and the outcomes.

Table 7 – Summary of methods for evaluating school environment

Method	Description	Outcomes
Socio-economic Statistical Analysis	The study examines the relationship between socio-economic variables—including income, education, employment, socio-economic status, violent crime, safety, and school climate—and their impact on academic performance.	The results indicated that students from lower socioeconomic backgrounds generally achieve lower academic performance, which is partially influenced by the prevalence of violent crime.
Qualitative Meta Synthesis Approach	The study employs a critical systematic review methodology that incorporates elements of qualitative meta-synthesis. The search specifically focused on Nordic studies and utilized a search string combining keywords related to "neighborhood" and "education," along with other pertinent terms.	The study identified three key factors that affect educational achievement: neighborhood social support, community attachment and reputation, and the influence of policies on daily life.
Remote sensing and statistical modelling for evaluation of the level greenness and academic performance	This method investigated the relationship between green space and academic performance in elementary schools. Green space was identified using remote sensing techniques and the Normalized Difference Vegetation Index (NDVI) at the school	The results indicate that higher levels of greenness within a 5 km radius of schools in Ontario are linked to lower academic performance among Grade 3 and 6 students. Increased greenness in the

Table 7 (continued)

	boundary, as well as within 1.6 km and 5 km neighborhood buffers. Academic performance was measured through standardized test scores in reading, writing, and mathematics.	5 km and 1.6 km buffers, as well as within school boundaries, showed no positive impact on academic achievement.
Responsive Analysis Method for Surrounding Urban Spaces	The methodology includes three main components: a literature review on urban spaces and their impact on responsive school environments, a questionnaire and eight months of discreet observations and the Space Syntax method to analyze spatial connections and predicts movement patterns around the school.	The results emphasized that variety is essential for creating responsive spaces, as areas offering diverse activities can repeatedly engage different individuals. However, the school's surroundings do not sufficiently meet students' needs and expectations.
Spatial Analysis Method	The method assessed school accessibility across various demographic groups. The spatial analysis began with data collection on school locations, land use, road networks, and petrol stations at national and local levels. Spatial techniques were employed to evaluate school density, clustering patterns, and distances to schools and potential hazards.	The analysis reveals that public schools are primarily situated in residential areas. It proves the necessity for ongoing investment in urban educational facilities to accommodate the growing population. Additionally, the proximity of schools to

Table 7 (continued)

		high-speed roads and petrol stations within 75 meters raise safety concerns.
Interview Analysis Method for External Environments	The method included interviews with participants from educational institutions to gather their views on the objective features of public spaces and their overall satisfaction. The analysis is focused on such criteria as safety, pedestrian access, ecology, health, social infrastructure, and the idea of "third" places.	Public spaces around schools are crucial for leisure activities and social interactions. Most respondents expressed high satisfaction with the overall safety of their school district and the conditions for safe pedestrian movement, as well as areas for leisurely walks.
Multilevel Statistical Modelling Method for Internal School Environments	The method involved analyzing the individual effects of naturalness, individualization, and stimulation on learning. After identifying the relevant measures, a multi-level analysis was conducted to evaluate their combined impact on learning outcomes.	The naturalness design principle accounts for approximately 50% of the impact on learning, while individualization and stimulation contribute about 25% each. Seven key design parameters—Light, Temperature, Air Quality, Ownership, Flexibility, Complexity, and Colour—collectively

Table 7 (continued)

		explain 16% of the variance in academic progress. This research underscores the significance of "inside-out design."
The empirical method based on participation	The approach involved the organization of participatory events with children to gather their insights and engage them in the decision-making process.	Modern megacities face significant challenges in creating child-friendly spaces, including limited resources for adapting public areas, a lack of strategic planning that prioritizes children's needs, and the exclusion of certain age groups from urban environments.

These methods provide valuable insights into the design of school environments and their connections to nearby neighborhoods. They highlight how these factors impact educational outcomes and student well-being.

However, there is a lack of research on the provision of facilities and services in external school environments, especially regarding child-friendly city design principles. Studies focus more on internal aspects like classroom layouts and natural lighting and do not consider how external amenities, such as parks, playgrounds, community centers, and safe walking routes, contribute to children's experience. It is essential to understand how external environments interact with school settings, as they significantly influence children's socialization, physical activity, and overall well-being.

The current research will examine how on-premises and external facilities can enhance the school experience. It will include the study of the availability of safe green spaces, recreational opportunities, and community engagement initiatives that align with child-friendly design principles.

2.2 Method Design

2.2.1 Factors for school assessment in accordance to CFC principles

The Child-Friendly City framework sets clear goals for city governance to create a supportive environment for every child.

One key goal is to make sure children have access to good social services, such as healthcare, education, nutrition, early childhood development, justice, and family support.

Another objective is to create a safe, clean, and secure environment where children are protected from harm, including exploitation, violence, and abuse. It also includes access to clean water, sanitation, and hygiene. Urban design should focus on child safety and make it easy for children to move around.

A third goal is to provide every child opportunity for family time, play, and leisure. This means providing access to social and cultural activities where children can play, interact with friends, and explore their surroundings.

These goals together provide a clear approach to urban planning and governance. They aim to make cities safer, more inclusive, and enriching for children and young people. They also help identify factors that affect children's social and emotional growth in urban areas.

The factors are split into two general groups for the purpose of this research. Internal factors evaluate the facilities situated within the school territory and external factors demonstrate the provision of facilities and services within the 500 meters to the school.

2.2.2 Internal factors

The presence of **sports grounds** on school premises is an important factor. These spaces promote physical fitness, teamwork, and friendly competition. Students can use them both during lessons and after classes.

Another key factor is the availability of **playgrounds**. Playgrounds improve physical activity, creativity, and social interaction. They are especially important for younger students in developing their physical and cognitive abilities.

Additionally, **greenery** plays a crucial role. It improves air quality, provides shade, and creates a pleasant environment to learn and relax. Greenery also helps reduce stress and improves focus among students.

2.2.3 External factors

The first external factor is the provision of **public spaces.** Parks and community areas near schools help kids to connect with each other. These spots are often used for gatherings between students.

External playgrounds in parks or community spaces is another factor that gives students more opportunities to play and communicate. The access to these playgrounds promotes interaction and collaboration between students.

Leisure points like cafes, cinemas, fast-food places, and malls provide students with places to socialize, offering a break from their usual school routines.

The next factor is the provision of **sports facilities**, that include gyms, pitches, dance schools, and swimming pools. These are spaces for physical activity, team sports, and extracurricular activities, that promote fitness and well-being of children.

Cultural and educational objects like art centers, language schools, libraries, museums, and theaters is another important factor that diversifies students' learning experience by fostering creativity, cultural awareness, and critical thinking.

Healthcare facilities is another significant factor key for supporting both the physical and mental health of students and contributing to a safer environment.

Safe **pedestrian crossings and traffic lights** are essential facilities that are required near schools to help kids travel to and from school safely. Traffic lights help to create safer spaces in streets and protect children on their ways to school

Bus stops, where public transport picks up and drops off students, is the final factor for the assessment. They make the way to school easier for those who live farther away and ensure that education is accessible for everyone.

The information is presented in a table format (Table 8) that summarizes each factor, along with its scoring system and description. All evaluations are standardized to a uniform scale, ranging from 0 to 1. A score of 0 indicates insufficient provision, while a score of 1 reflects optimal provision.

Table 8 – Factors that influence child development

Factor	Score	Description
Internal Factors		
Sports Grounds	0 - No, 1 - Yes	Dedicated areas for sports like football and basketball pitches that promote physical fitness and teamwork among students.
Playgrounds (internal)	0 - No, 1 - Yes	Safe outdoor spaces with play infrastructure that promotes physical activity and social interaction essential for children.
External Factors		
Greenery	Ratio of greenery to school area (0 to 1)	Areas with grass, trees, and plants that improve air quality and provide a calming environment for learning and relaxing.
Public Spaces	Proximity (0 to 1)	Accessible community areas, such as parks or plazas, that inspire social interaction.
Playgrounds (External)	Proximity (0 to 1)	Recreational areas outside the school that offer additional opportunities for play and physical activity.
Leisure Points	Proximity (0 to 1)	Locations for informal activities, such as cafes and cinemas for relaxation and social interaction among students.

Table 8 (continued)

External Factors		
Sports Facilities	Proximity (0 to 1)	Facilities like gyms and swimming pools that promote fitness and well-being.
Cultural & Educational Objects	Proximity (0 to 1)	Local spaces, such as arts centers, libraries, and museums, that improve the educational and cultural experience.
Healthcare Amenities	0 - No, 1 - Yes	Health services, that are vital for supporting students' physical and mental well-being.
Pedestrian Crossings and Traffic Lights	Ratio between controled crossings and the total number of crossings	Traffic control measures that provide safety for students in school environments.
Bus Stops	Proximity (0 to 1)	Designated areas for public transport pickups that ensure safe and efficient travel for students to and from school.

2.3 Method

Based on the factors described in the previous section the following approach has been designed. It is shown in Figure 5.
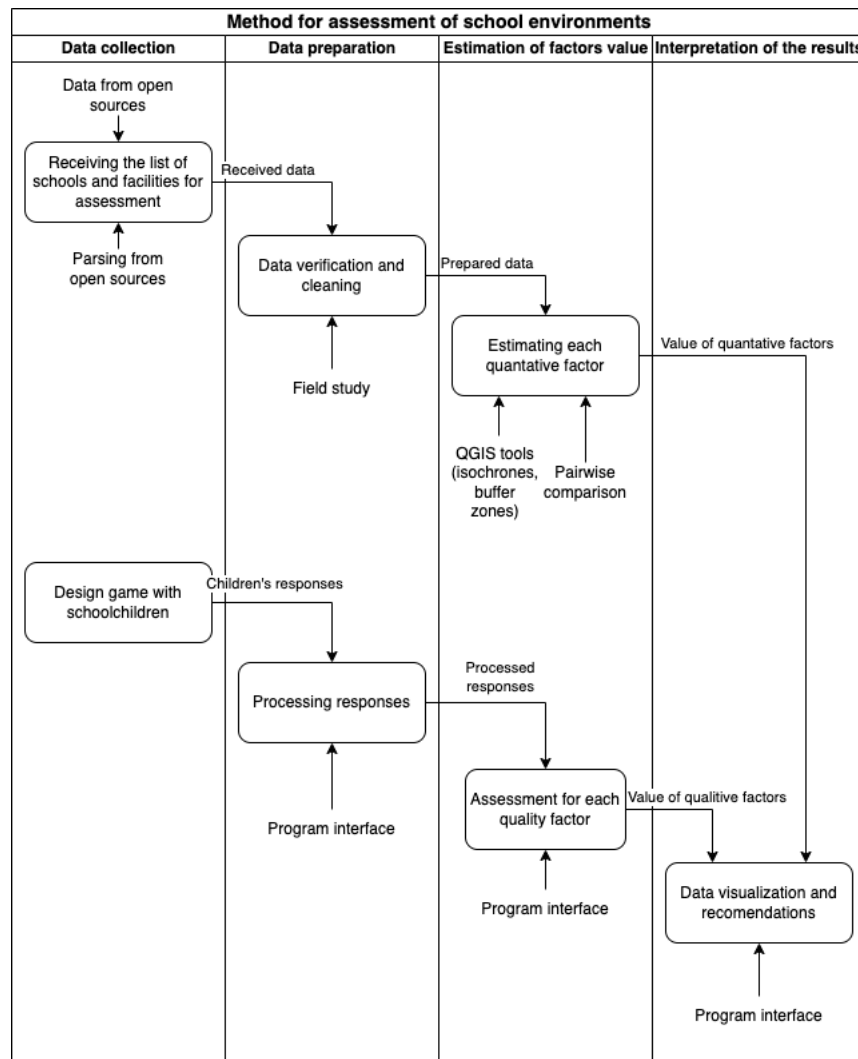
Figure 5 — Method for assessment of school environments

The diagram presents a method for assessing the internal and external school environments through a structured and multi-step approach. This structured approach ensures that both quantitative and qualitative aspects are evaluated, providing an understanding of the school setting.

The method is divided into four stages: Data Collection, Data Preparation, Estimation of Factors Value, and Interpretation of the Results. Each stage involves specific tasks that provide a detailed analysis of the internal and external school environments.

The steps for implementing the method are described in detail below.

2.3.1 Data collection

In this stage, the data is being gathered for the analysis to provide a complete view of the school environment. There are two main sources, where the data is taken from, are open-source information and design game conducted with schoolchildren.

Data from open sources

The open-source data is obtained through public databases and government resources. It serves as the foundation for the evaluation of factors impacting the school setting. The required data includes information on playgrounds, traffic lights and pedestrian crossings, green, public transport stops, road network, sports infrastructure, public spaces and health amenities.

Design Game for School Children

The workshop is conducted to understand how students see and use spaces inside and outside the school. It is a 1.5 hour event that includes activities to involve everyone into joint design. The main activity is mental mapping, where students can share their thoughts on the school and its surroundings to understand how students interact with the school environment.

The event outline is shown in Table 9.

Table 9 – Design game outline

Stage	Description
Introduction and Warm-up (10 minutes)	The participants take part in a conversation about how they use different spaces within and around the school. The concept of a "child-friendly city" is introduced. Key questions include: How do you spend your time at school outside of lessons? What activities do you enjoy during your free time? Which places do you visit most frequently before and after school? Where do you spend the most of your free time?

Table 9 (continued)

Explanation of Game Rules and Objectives (10 minutes)	Each team designs a district that includes both the internal and external spaces of the school. Decisions should reflect children's needs. Participants will be divided into 5 teams, each representing different needs and priorities for the district.
Brainstorming and Decision-Making (10 minutes)	Teams list and discuss potential infrastructure elements for their district, prioritizing up to 10 essential objects. They must justify the importance of these objects for their design and community and can create unique objects if necessary.
Round 1 Presentations (15 minutes)	Each team briefly present the objects they chose and explain the reason for selecting them. Teams are encouraged to explain how their design supports a child-friendly city concept.
Round 2 Discussion and Voting (10 minutes)	Teams review all the projects and vote on which proposals they believe should be prioritized. They must provide reasons for their votes and emphasize the benefits of the chosen projects.
Final Voting and Debate (15 minutes)	Each team votes for the top three projects they feel should be implemented, based on the needs of the community.
Reflection and Feedback (20 minutes)	The activity involves group reflection and open discussion. Discussion questions include: Were all teams satisfied with the final outcomes? Would you enjoy using these designed spaces? What is missing from this vision of the school environment? Did the design create spaces that serve the interests of all students? How does this design differ from the real environment?

2.3.2 Data preparation

At this stage is the collected information is checked for correctness, consistent, and prepared for analysis. This includes checking and cleaning the data, conducting field studies, and processing the results from design games.

2.3.2.1 Field studies

At this stage, the school surroundings are reviewed to verify the information available online. The focus is on assessing the condition of the infrastructure and identifying any missing or inaccurate details. Field studies help correct any errors and provide a clearer understanding of how the infrastructure functions in practice to ensure that the data is more accurate and up-to-date.

2.3.2.2 Data verification and cleaning

The process of data verification involves comparing field-collected data with information from public sources like databases and GIS. This helps identify discrepancies, such as outdated infrastructure details or incorrect locations, and correct them.

After verification, the data is cleaned by correcting errors, removing duplicates, and filling in missing information. To ensure consistency, the data is then standardized, aligning geographic data to a common format..

2.3.2.3 Processing the results of a design game

The feedback from school children will be organized into categories based on on the factors that affect the school environment, both inside and outside. This will help understand what students need and think about their surroundings. A summary table will then be made to show their needs for different types of environments.

2.3.3 Estimation of data

2.3.3.1 Multi-criteria analysis

The quantitative assessment focuses on objective, numerical data, utilizing advanced tools and statistical methods to measure the physical attributes of the school environment.

Analytic Hierarchy Process

The factors were compared pairwise, placing more value to the internal factors that are governed by school authorities (Table 10).

Table 10 — Judgment Matrice

#	Criterion	1	2	3	4	5	6	7	8	9	10	11
1	Sports Ground	1.00	1.00	2.00	4.00	4.00	5.00	5.00	6.00	4.00	4.00	4.00
2	Playground	1.00	1.00	2.00	4.00	4.00	5.00	5.00	6.00	4.00	4.00	4.00
3	Greenery	0.50	0.50	1.00	4.00	4.00	4.00	5.00	5.00	4.00	4.00	4.00
4	Public Spaces	0.25	0.25	0.25	1.00	1.00	3.00	3.00	2.00	1.00	1.00	1.00
5	Playgrounds (External)	0.25	0.25	0.25	1.00	1.00	2.00	2.00	2.00	1.00	1.00	1.00
6	Leisure Points	0.20	0.20	0.25	0.33	0.50	1.00	2.00	1.00	1.00	1.00	1.00
7	Sports Facilities	0.20	0.20	0.20	0.33	0.50	0.50	1.00	1.00	0.33	0.33	0.33
8	Cultural & Educational Objects	0.17	0.17	0.20	0.50	0.50	1.00	1.00	1.00	0.50	0.33	0.33
9	Healthcare Amenities	0.25	0.25	0.25	1.00	1.00	1.00	3.00	2.00	1.00	0.50	0.50
10	Traffic Lights	0.25	0.25	0.25	1.00	1.00	1.00	3.00	3.00	2.00	1.00	1.00
11	Bus Stops	0.25	0.25	0.25	1.00	1.00	1.00	3.00	3.00	2.00	1.00	1.00
	Total	4.32	4.32	6.90	18.17	18.50	24.50	33.00	32.00	20.83	18.17	18.17

The values for each factor were normalized and assessed for consistency. The results are presented in Table 11.

Table 11 — Normalized Judgment Matrice

#	Criterion	1	2	3	4	5	6	7	8	9	10	11
1	Sports Ground	0.23	0.23	0.29	0.22	0.22	0.20	0.15	0.19	0.19	0.22	0.22
2	Playground	0.23	0.23	0.29	0.22	0.22	0.20	0.15	0.19	0.19	0.22	0.22
3	Greenery	0.12	0.12	0.14	0.22	0.22	0.16	0.15	0.16	0.19	0.22	0.22

Table 11 (continued)

4	Public Spaces	0.06	0.06	0.04	0.06	0.05	0.12	0.09	0.06	0.05	0.06	0.06
5	Playgrounds (External)	0.06	0.06	0.04	0.06	0.05	0.08	0.06	0.06	0.05	0.06	0.06
6	Leisure Points	0.05	0.05	0.04	0.02	0.03	0.04	0.06	0.03	0.05	0.06	0.06
7	Sports Facilities	0.05	0.05	0.03	0.02	0.03	0.02	0.03	0.03	0.02	0.02	0.02
8	Cultural & Educational Objects	0.04	0.04	0.03	0.03	0.03	0.04	0.03	0.03	0.02	0.02	0.02
9	Healthcare Amenities	0.06	0.06	0.04	0.06	0.05	0.04	0.09	0.06	0.05	0.03	0.03
10	Traffic Lights	0.06	0.06	0.04	0.06	0.05	0.04	0.09	0.09	0.10	0.06	0.06
11	Bus Stops	0.06	0.06	0.04	0.06	0.05	0.04	0.09	0.09	0.10	0.06	0.06

Maximum Eigenvalue (λmax) was evaluated with Wolfram Alpha math analysis tool.

$\lambda max \approx 11.38$

Consistency Index (CI) was calculated according to the formula 1.

$$CI = \frac{n-1}{\lambda max - n} \tag{1}$$

where:

n is the number of factors;

λmax is Maximum Eigenvalue.

The value of n equals to 11. Then, the CI is evaluated:

CI=(11−1)/(11.38−11)≈0.0382

Random Index (RI) for n=11 according to Satty pairwise comparison analysis method:

$RI \approx 1.51$

Consistency Ratio (CR) wa calculated by the formula 2.

$$CR = \frac{RI}{CI} \tag{2}$$

Where:

RI is Random Index;

CI is Consistency Index.

The CR equals to 0.0253.

CR= ≈0.0382/1.51≈0.0253

Since the CR is less than 0.10, the level of consistency in the pairwise comparisons is considered acceptable.

After calculation and verification the following factor weights were obtained (Table 12).

Table 12 — Normalized weights of the factors

Criteria	Normalized weight of the factor
Sports Ground	0.2150
Playground	0.2150
Greenery	0.1742
Public Spaces	0.0632
Playgrounds (External)	0.0567
Leisure Points	0.0423
Sports Facilities	0.0274
Cultural & Educational Objects	0.0294
Healthcare Amenities	0.0508
Traffic Lights	0.0630
Bus Stops	0.0630

The school performance will be assessed using the following formula (3):

$$\text{Performance} = \sum_{i=1}^{11}(f_i \times W_i), \tag{3}$$

- where:

- f_i – weight of the factor

- W_i – normalized weight of the factor

2.3.3.2 GIS analysis tools

Geographic Information Systems (GIS) tools are used to map and analyze data related to schools. Isochrones create travel time maps, showing how long it takes students to get to parks, recreational areas, and public transport stops.

Another tool, buffer zones, creates visual boundaries around schools, usually set to 500 meters—the maximum distance considered walkable by Russian law. This

helps accurately measure how close schools are to amenities, safety features, and services.

2.3.3.3 Qualitive factors estimation

Qualitative assessment will gather opinions from students and stakeholders to understand their experiences with the school environment. Methods like content analysis and thematic coding will be used to review open-ended survey responses and find common themes in the feedback.

2.3.4 Results interpretation

The final step in the process is interpreting the results, where both quantitative and qualitative data are combined to provide valuable insights. This stage involves analyzing the data, visualizing the findings, and offering recommendations for improving the school environment.

Mapping and spatial techniques are used to examine the factors impacting the school environment, providing a clear view of the current conditions. The quantitative and qualitative results are summarized in a single table, giving a complete picture of each school. These findings will then be used to create specific recommendations for each location.

Finally, the results and recommendations are shared with school administrators, the Education Committee of the Leningrad Region, and policymakers. This approach ensures a thorough assessment of each school's strengths and areas for improvement, offering a comprehensive analysis of their surrounding environments.

3   Study of School Spaces in the Leningrad Region

3.1 Quantitative analysis of schools in the Leningrad region

Primarily, 4 schools in Gatchina, Leningrad Region, were selected. Their locations are shown in Figure

The test data set was obtained from multiple open data sources, mailnly OpenStreet Maps, Data from IDU laboratory and 2GIS. These data is assessed with QGIS software according to the factors.

The buffer zones of 500 meters were marked around each school centroid. This is demonstrated in Figure 6.
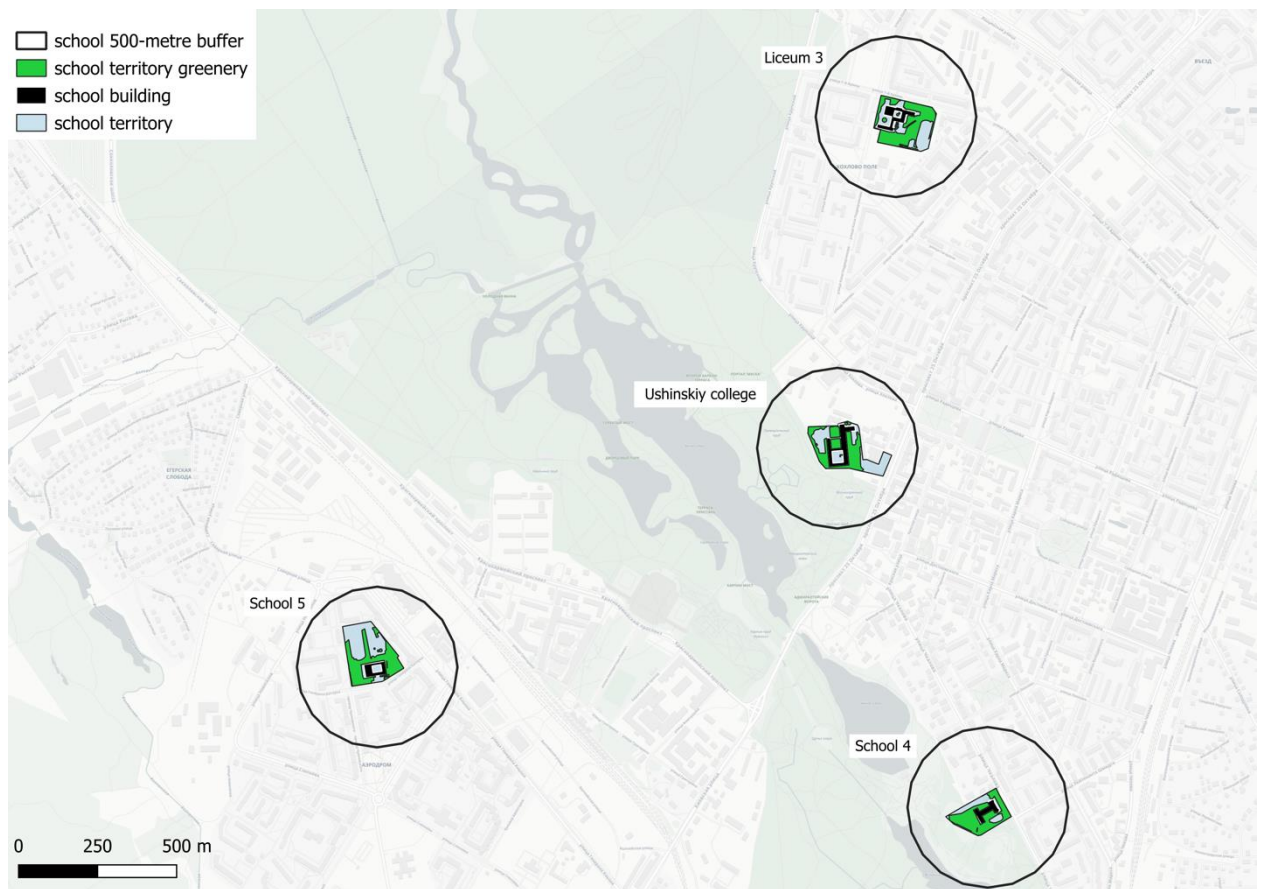

Figure 6 — Test schools with buffer zones

The Figures 7–10 below show the examples of location of amenities around the selected schools.
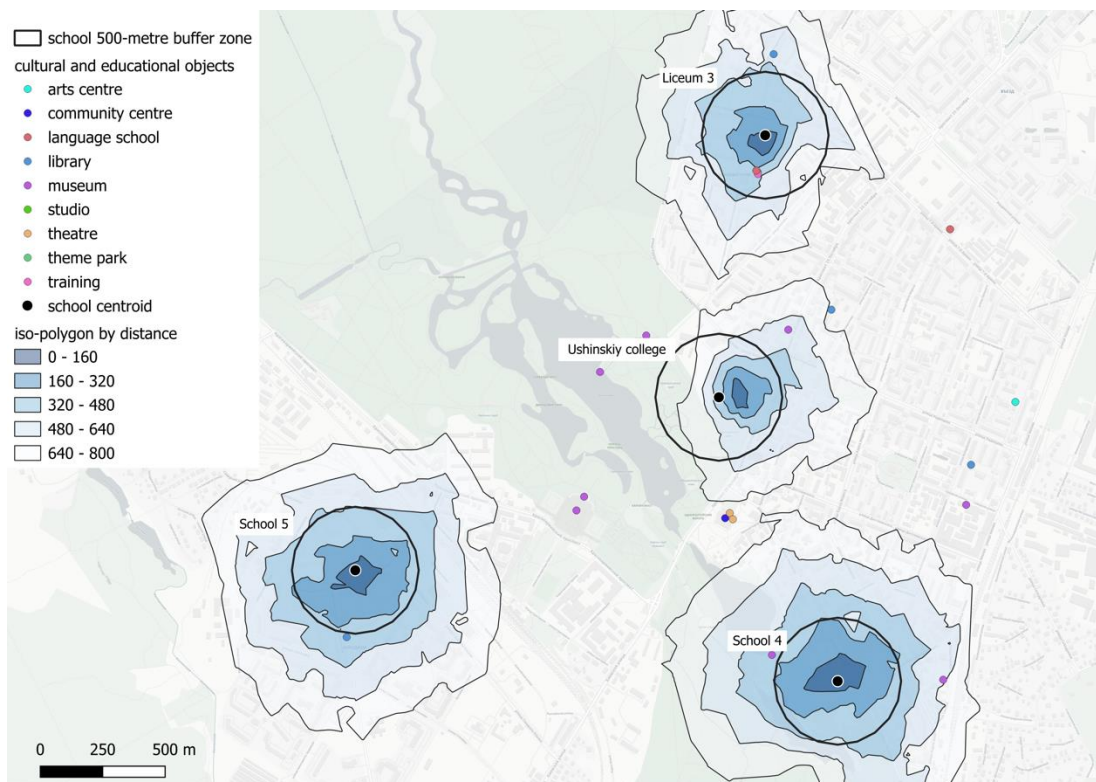
Figure 7 — Cultural and educational objects provision
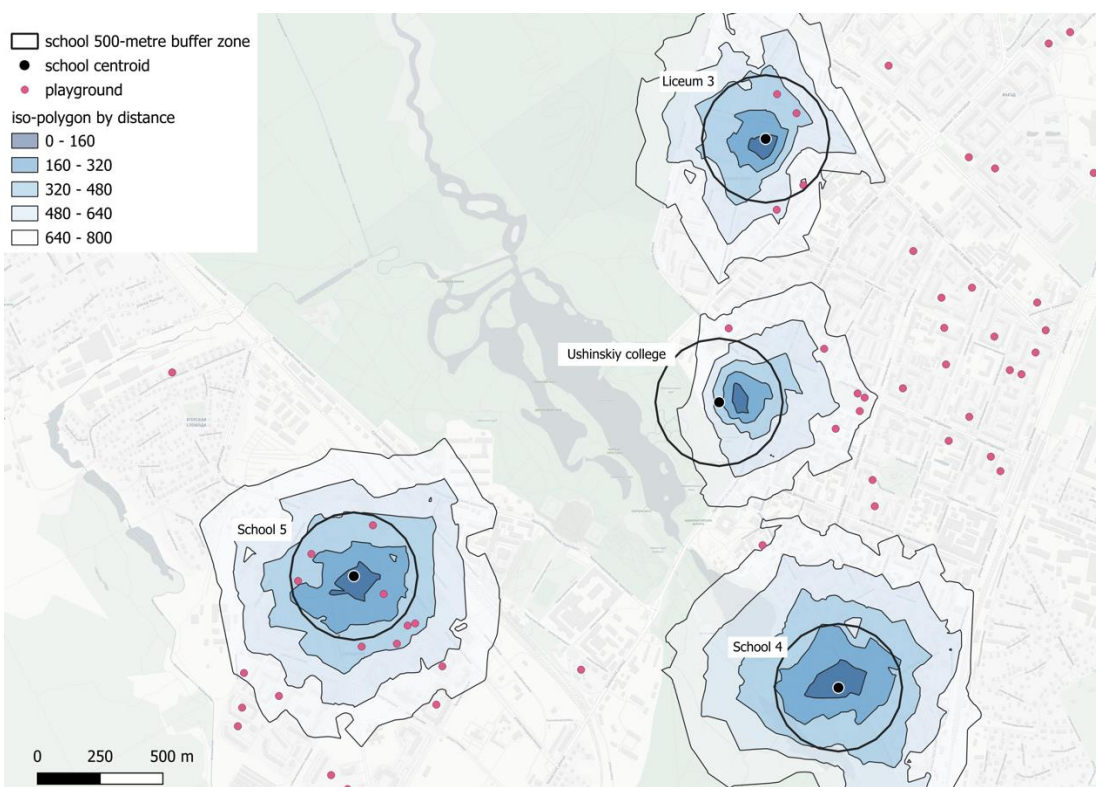
Figure 8 — Playgrounds provision

55
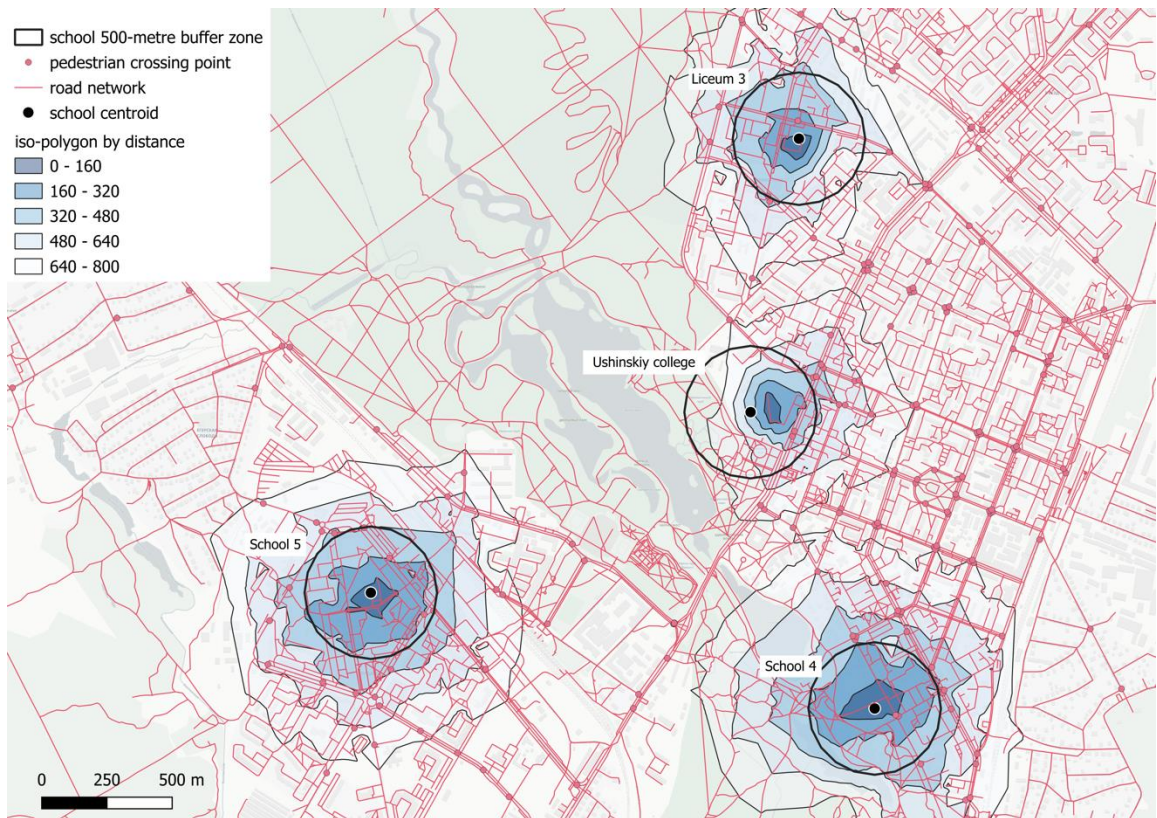
Figure 9 — Road network and pedestrian crossings
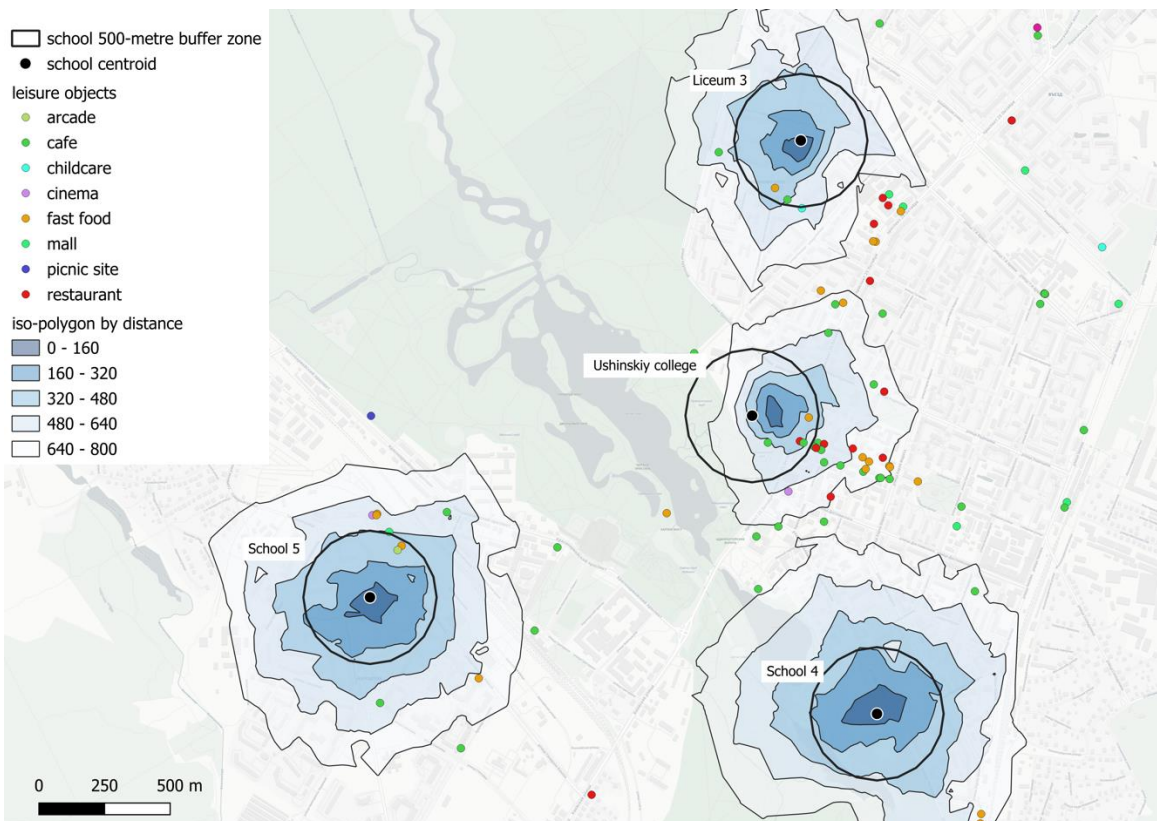
Figure 10 — Leisure points provision

The values for factors Sports Grounds, Playgrounds (Internal), Healthcare Amenities and Traffic Lights were assessed based on their presence or absence. The scores for other factors were assessed by creating iso-areas with QNEAT3 tool.

The Greenery factor was evaluated by calculating the ratio for the areas of school green zones and school territories, as demonstrated in the example in Figure 11.

Figure 11 — Greenery provision

The following values for test schools were obtained (Table 13).

Table 13 — Assessment of factors for schools in Gatchina

Factor	School 5	School 4	Ushinsky College	Liceum 3
Sports Grounds	1	1	1	1
Playgrounds (Internal)	1	0	0	0
Greenery	0.48	0.72	0.51	0.58
Public Spaces	0.2	1	0.6	0.4
Playgrounds (External)	0.8	0	0.2	0.6
Leisure Points	0.6	0.2	0.6	0.6
Sports Facilities	0.8	0.2	0.6	0.4
Cultural & Educational Objects	0.6	0.6	0.6	0.6
Healthcare Amenities	1	1	1	1

Table 13 (continued)

Traffic Lights	0.8	1	0.6	0.8
Bus Stops	0.8	0.6	0.6	0.6

3.2 Qualitative analysis of schools in the Leningrad region

Seven design games were conducted with schoolchildren from Gatchina, Leningrad Region, involving participants from three age groups: primary school students (Years 3–4, ages 9–10), lower secondary school students (Years 6–7, ages 12–14), and upper secondary school students (Year 10, ages 16–17). Each game included approximately 25 participants.

The children were divided into five groups and provided with a map of their city (Figure 12). Their task was to reimagine the city's design from scratch, except for homes and schools. They had to populate the city with facilities and locations essential for their daily lives outside of school.

Figure 12 — Map layout for the design game

The game consisted of two rounds to help prioritize children's needs. Each group could choose only three locations in each round to place on the map. After every round, they voted to decide which locations were the most important for theь. Figures 13–15 capture the process of the game.

The results were different for each age group. Younger children preferred playgrounds and sports fields because they live close to school and like to play outside. They also marked shopping malls as their priority since outdoor spaces are not as good in winter, and malls give them a warm place to spend time.

They also mentioned that fast-food restaurants and bakeries are important because they can buy affordable snacks. Grocery stores and delivery pick-up points were also a popular response. In the second round, they added cultural, sports and outdoor facilities, such as parks, libraries, theaters, museums, and sports centers like swimming pools to their list.

Figure 13 — Design game process with lower secondary schoolchildren

Lower secondary school students emphasized the need for privacy and spaces where they could interact with peers without disruptions.

Their top priorities included shopping malls, fast-food restaurants, and entertainment locations such as amusement centers and water parks. They also expressed interest in isolated and extreme, like abandoned buildings, as gathering spots. Through discussion, they stated that existing playgrounds were boring and

unappealing for their age and they prefer spaces wit more dynamic and engaging attractions.

In the second round, they included transportation infrastructure, sports and cultural facilities, and parks in the city layout. Additionally, some students highlighted a lack of high-quality public spaces near waterfronts.

Figure 14 — Design game process with upper secondary schoolchildren

Upper secondary school students also valued leisure spaces the most. However, in the first round, they also highlighted the need of good bus routes and road infrastructure since many of them commute to school.

In the second round, they placed more attention to cultural and educational institutions. They suggested places for work, vocational training, and community activities, like the "Movement of the First." They saw these places as opportunities for learning and extracurricular activities.
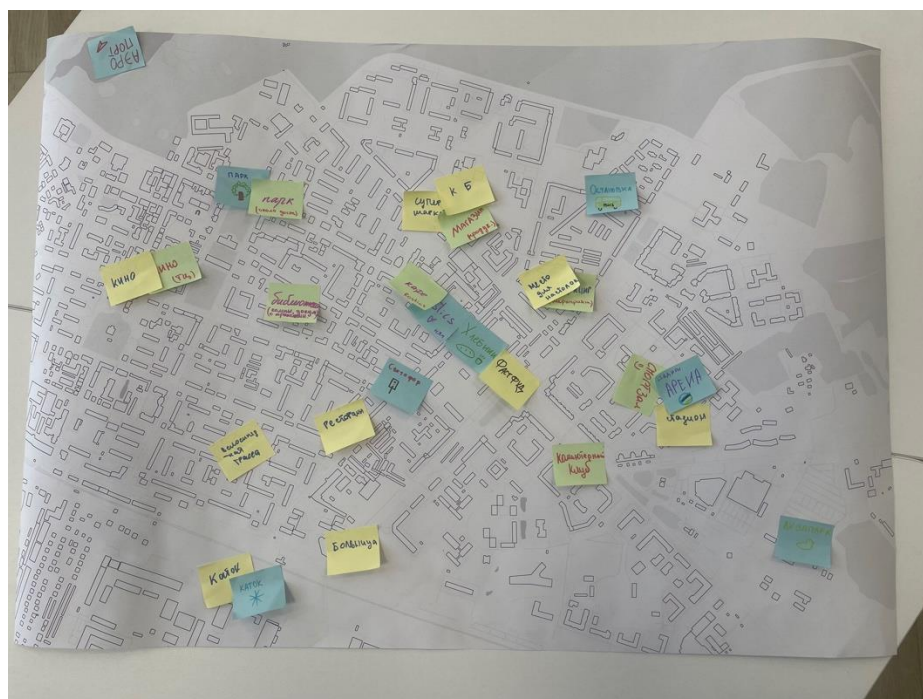
Figure 15 — Locations suggested by a group of upper secondary schoolchildren

The responses from the schoolchildren were collected into a ranking matrix, which demonstrates the importance of each factor based on the outcomes of the children's voting. This matrix provides a prioritized list of the facilities that the children considered most essential for a systematic analysis of their preferences and needs (Table 14).

Table 14 – Factor ranking based on the outcomes of the design games

#	Factor	Primary School (ranking)	Lower Secondary (ranking)	Upper Secondary (ranking)	Sum	Aggregate ranking
1	Sports Grounds	5	3	5	13	3
2	Playgrounds (Internal)	1	5	11	17	5
3	Greenery	7	7	7	21	8
4	Public Spaces	4	2	4	10	2

Table 14 (continued)

5	Playgrounds (External)	2	6	10	18	6
6	Leisure Points	3	1	2	6	1
7	Sports Facilities	6	4	6	16	4
8	Cultural & Educational Objects	9	8	8	25	10
9	Healthcare Amenities	11	11	9	31	11
10	Traffic Lights	10	10	3	23	9
11	Bus Stops	8	9	1	18	6

The results show that children value leisure spaces the most, such as malls and cafes, where they can meet friends outside school. Their next priorities are sports facilities, playgrounds, and bus stops. In contrast, they ranked pedestrian crossings, cultural institutions, and healthcare facilities lower.

Safety factors were not a major concern for most children. Only older students who commute to school emphasized the need for bus stops and good road infrastructure. Cultural and healthcare facilities were also ranked lower since they are not part of daily routines.

Although children may not fully understand the importance of these factors, they are essential for a safe and well-functioning city. To balance this, a harmonized judgment matrix was created, adjusting their rankings to reduce the gap between leisure spaces and safety-related factors (Table 15).

Table 15 – Harmonized ranking

Number	Factor	Aggregate ranking	Harmonized ranking
1	Sports Grounds	3	2
2	Playgrounds (Internal)	5	3

Table 15 (continued)

3	Greenery	8	4
4	Public Spaces	2	2
5	Playgrounds (External)	6	3
6	Leisure Points	1	1
7	Sports Facilities	4	3
8	Cultural & Educational Objects	10	4
9	Healthcare Amenities	11	6
10	Traffic Lights	9	4
11	Bus Stops	6	4

A judgment matrix was created based on the rankings to calculate the factor weights. This matrix turned the children's subjective preferences into measurable weights. The weights were determined by comparing the relative importance of each factor, ensuring that safety, infrastructure, and overall urban quality were properly considered, even though they were ranked lower by the children. The matrix provided a balanced approach that combined both the children's preferences and broader urban planning needs (Table 16).

Table 16 – Judgement matrix based on harmonized ranking

№	Factor	1	2	3	4	5	6	7	8	9	10	11
1	Sports Grounds	1	2	3	1	2	0.5	1	2	5	3	3
2	Playgrounds (Internal)	0.5	1	2	3	1	0.33	1	2	4	2	2
3	Greenery	0.33	0.5	1	0.33	0.5	0.25	0.5	1	3	1	1
4	Public Spaces	1	0.33	3	1	2	0.5	1	3	5	3	3
5	Playgrounds (External)	0.5	1	2	0.5	1	0.33	1	2	4	2	2

Table 16 (continued)

6	Leisure Points	2	3	4	2	3	1	3	4	6	4	4
7	Sports Facilities	1	1	2	1	1	0.33	1	2	4	2	2
8	Cultural & Educational Objects	0.5	0.5	1	0.33	0.5	0.25	0.5	1	3	1	1
9	Healthcare Amenities	0.2	0.25	0.33	0.2	0.25	0.17	0.25	0.33	1	0.33	0.33
10	Traffic Lights	0.33	0.5	1	0.33	0.5	0.25	0.5	1	3	1	1
11	Bus Stops	0.33	0.5	1	0.33	0.5	0.25	0.5	1	3	1	1

The principal eigenvalue for the provided matrix (λmax) is 11.347, and the Consistency Ratio (CR) is 2.3%, which indicates highly reliable comparisons. This low CR value suggests that the comparisons made in the judgment matrix are consistent, ensuring that the results are credible and the priority weights derived from the matrix are valid.

The weighted criteria for the following factors, based on matrix harmonization were calculated (Table 17).

Table 17 – Normalized weights of the factors

Number	Factor	Normalized weight
1	Sports Grounds	0.1335
2	Playgrounds (Internal)	0.1103
3	Greenery	0.0496
4	Public Spaces	0.1238
5	Playgrounds (External)	0.0876
6	Leisure Points	0.2241
7	Sports Facilities	0.0981

Table 17 (continued)

8	Cultural & Educational Objects	0.0516
9	Healthcare Amenities	0.0223
10	Traffic Lights	0.0496
11	Bus Stops	0.0496

3.3 Null scenario

The results from qualitative analysis for schools in Gatchina were applied to the normalized weights of factors. The values obtained are presented in Table 18.

Table 18 — Weighted values for the analysis of schools in Gatchina

Factor	School 5	School 4	Ushinsky College	Liceum 3
Sports Grounds	0.133	0.133	0.133	0.133
Playgrounds (Internal)	0.110	0.000	0.000	0.000
Greenery	0.024	0.036	0.025	0.029
Public Spaces	0.025	0.124	0.074	0.050
Playgrounds (External)	0.070	0.000	0.018	0.053
Leisure Points	0.134	0.045	0.134	0.134
Sports Facilities	0.078	0.020	0.059	0.039
Cultural & Educational Objects	0.031	0.031	0.031	0.031
Healthcare Amenities	0.022	0.022	0.022	0.022
Traffic Lights	0.040	0.050	0.030	0.040
Bus Stops	0.040	0.030	0.030	0.030
Performance	**0.708**	**0.490**	**0.557**	**0.561**

The results of the analysis demonstrated the following key insights into the provision of essential facilities across the schools in Gatchina.

School 5 scored the highest because it has internal playgrounds and is close to sports facilities, which students really appreciated. These facilities are important for both recreation and physical development.

School 4 received the lowest score, even though it is centrally located. It is far from key places like playgrounds, leisure spaces, and sports facilities. However, its proximity to a large park helped improve its score for public spaces.

Overall, schools have moderate access to key services. Most important amenities, such as sports grounds, leisure areas, and bus stops, are located 300 to 800 meters from the schools. While access to basic services is adequate, there's still room for improvement in providing students with more of the services they value.

Playgrounds and leisure spaces, like malls and cafes, were the most valued by students. Schools that had these nearby, like School 5, scored higher, highlighting the importance of spaces for socializing and recreation outside of school.

Public spaces and greenery were also important, with some schools benefiting from being near parks. For example, School 4 did better because of its proximity to a large park. However, some schools lacked diverse outdoor areas for recreation, showing a need for improvement.

Healthcare and cultural facilities, like libraries, theaters, and museums, were ranked lower. This shows they are not as important in students' daily lives, though they are still needed for a well-rounded urban environment. The low values suggest more attention may be needed to make these amenities more accessible near schools.

Bus stops and road infrastructure were more important for older students who rely on public transport. Improving these facilities could help make schools more accessible and improve their overall performance.

3.4 Experiment scenarios

3.4.1 Description of Experiment Scenarios

In the first experimental scenario, the criteria weights are adjusted based solely on the responses from children. This helps determine whether the harmonized judgment matrix accurately reflects the needs of children, as shown during the design game. By recalculating the weights based on the factors ranked highest by children, the matrix is tested for how well it captures their priorities.

A new comparison matrix is created from the aggregated rankings of children, allowing for an assessment of how well the harmonized judgment matches their

preferences and whether the current weighting system responds to those preferences. The goal is to determine if the harmonized assessment method, combining both qualitative and quantitative elements, accurately reflects the factors children consider most important in their daily lives.

In the second experimental scenario, the methodology is applied to schools in other cities within the Leningrad region, specifically Kingisepp and Volkhov. This helps assess whether the method can be applied consistently across different cities, demonstrating that it works in a standardized way and is not location-specific.

Data for these cities is collected using the same approach as the initial experiment, relying on OpenStreetMap and other trusted sources for quantitative data. The data is analyzed using QGIS tools to ensure consistency across cities.

The same qualitative analysis is applied, considering children's preferences from design games in these cities to determine the appropriate factor weights for each location. Testing the method in these additional cities evaluates its flexibility and effectiveness, ensuring it works consistently while accounting for regional differences. This confirms the method's broader applicability in assessing school environments across various urban settings.

3.4.2 Experimental Scenario 1

Based on the children's opinions, expressed in the participatory design game (Table 14), a comparison matrix was created. It is represented in Table 19.

Table 19 – Judgement matrix based on children's ranking

#	Factor	1	2	3	4	5	6	7	8	9	10	11
1	Sports Grounds	1	3	5	0.33	2	0.2	3	6	8	6	4
2	Playgrounds (Internal)	0.33	1	3	0.25	2	0.17	3	6	7	4	2
3	Greenery	0.2	0.33	1	0.25	0.33	0.17	0.5	3	5	2	0.33
4	Public Spaces	3	4	4	1	4	0.33	3	6	8	6	4
5	Playgrounds (External)	0.5	0.5	3	0.25	1	0.14	0.5	4	6	3	1
6	Leisure Points	5	6	6	3	7	1	4	7	9	6	4
7	Sports Facilities	0.33	0.33	2	0.33	2	0.25	1	4	6	4	2

Table 19 (continued)

8	Cultural & Educational Objects	0.17	0.17	0.33	0.17	0.25	0.14	0.25	1	4	0.5	3
9	Healthcare Amenities	0.12	0.14	0.2	0.12	0.17	0.11	0.17	0.25	1	0.25	0.2
10	Traffic Lights	0.17	0.25	0.5	0.17	0.33	0.17	0.25	2	4	1	0.33
11	Bus Stops	0.25	0.5	3	0.25	1	0.25	0.5	0.33	5	3	1

The comparison matrix analysis yielded a principal eigenvalue (λ max) of 12.497 and a Consistency Ratio (CR) of 9.9%. The principal eigenvalue indicates that the matrix is reasonably consistent, with values close to the expected value for a consistent matrix. The CR of 9.9% is below the 10% threshold, confirming that the pairwise comparisons are consistent and reliable. These results ensure that the factor weights derived from the matrix are dependable for decision-making.

The normalized weights based on matrix harmonization were calculated (Table 20).

Table 20 – Normalized weights of the factors (Children's opinion)

Number	Factor	Normalized weight
1	Sports Grounds	0.1355
2	Playgrounds (Internal)	0.0953
3	Greenery	0.0406
4	Public Spaces	0.1773
5	Playgrounds (External)	0.0617
6	Leisure Points	0.2849
7	Sports Facilities	0.0747
8	Cultural & Educational Objects	0.0346
9	Healthcare Amenities	0.0128
10	Traffic Lights	0.0294
11	Bus Stops	0.0532

The results from qualitative analysis for schools in Gatchina were multiplied by the normalized weights of factors. The following values were obtained (Table 21).

Table 21 — Weighted values for schools in Gatchina (Children's opinion)

Factor	School 5	School 4	Ushinsky College	Liceum 3
Sports Grounds	0.135	0.135	0.135	0.135
Playgrounds (Internal)	0.095	0.000	0.000	0.000
Greenery	0.019	0.029	0.021	0.024
Public Spaces	0.035	0.177	0.106	0.071
Playgrounds (External)	0.049	0.000	0.012	0.037
Leisure Points	0.171	0.057	0.171	0.171
Sports Facilities	0.060	0.015	0.045	0.030
Cultural & Educational Objects	0.021	0.021	0.021	0.021
Healthcare Amenities	0.013	0.013	0.013	0.013
Traffic Lights	0.024	0.029	0.018	0.024
Bus Stops	0.043	0.032	0.032	0.032
Performance	**0.665**	**0.509**	**0.574**	**0.557**

The results show that leisure points and public spaces scored the highest across schools in Gatchina, meaning that children prefer areas where they can relax and socialize outside of school.

Leisure points were especially important at three schools, with a score of 0.171 for places like malls, cafes, and fast-food restaurants. Parks and other public spaces were also important. School 4 stood out because it's close to a large park, which helped improve its overall score.

This focus on leisure and public spaces, rather than sports or cultural facilities, shows that children value places where they can hang out and have fun. These spaces are important for their daily lives and overall happiness with their environment.

The children's preferences have slightly shifted the values of factors compared to previous assessment, placing more emphasis on leisure points and playgrounds.

Schools with better access to these facilities perform much better according to the children's preferences. In contrast, schools like School 4, which lack such amenities despite being near public spaces, scored lower.

3.4.3 Experimental Scenario 2

The quantitative analysis for seven schools in Kingisepp and Volkhov were additionally conducted.

The data for the analysis was collected from OpenStreetMap, IDU Laboratory, and 2GIS, then processed with QGIS software to assess various factors. A 500-meter buffer zone was created around each school to evaluate nearby amenities. The locations of cultural and educational facilities, playgrounds, roads, pedestrian crossings, and leisure points were mapped. Factors like sports grounds, internal playgrounds, healthcare amenities, and traffic lights were evaluated based on their presence, while others were assessed using iso-areas through the QNEAT3 tool. The greenery factor was calculated by determining the proportion of green space within the school's territory. Below provided some of the visualisations of analysis steps (Figures 16–19).
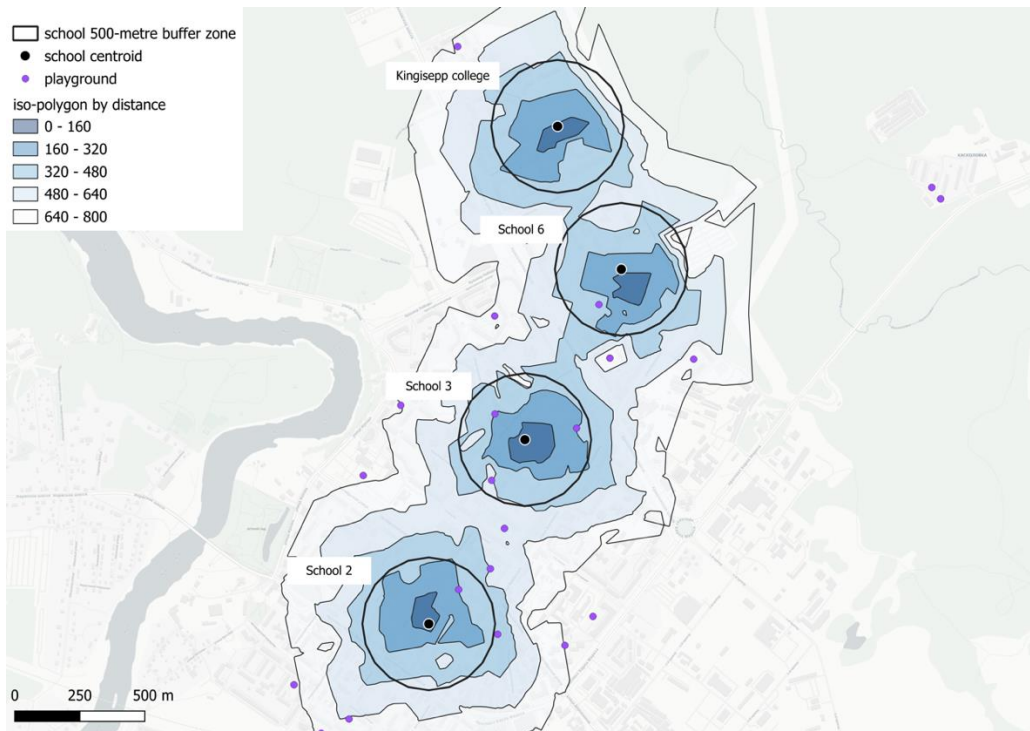

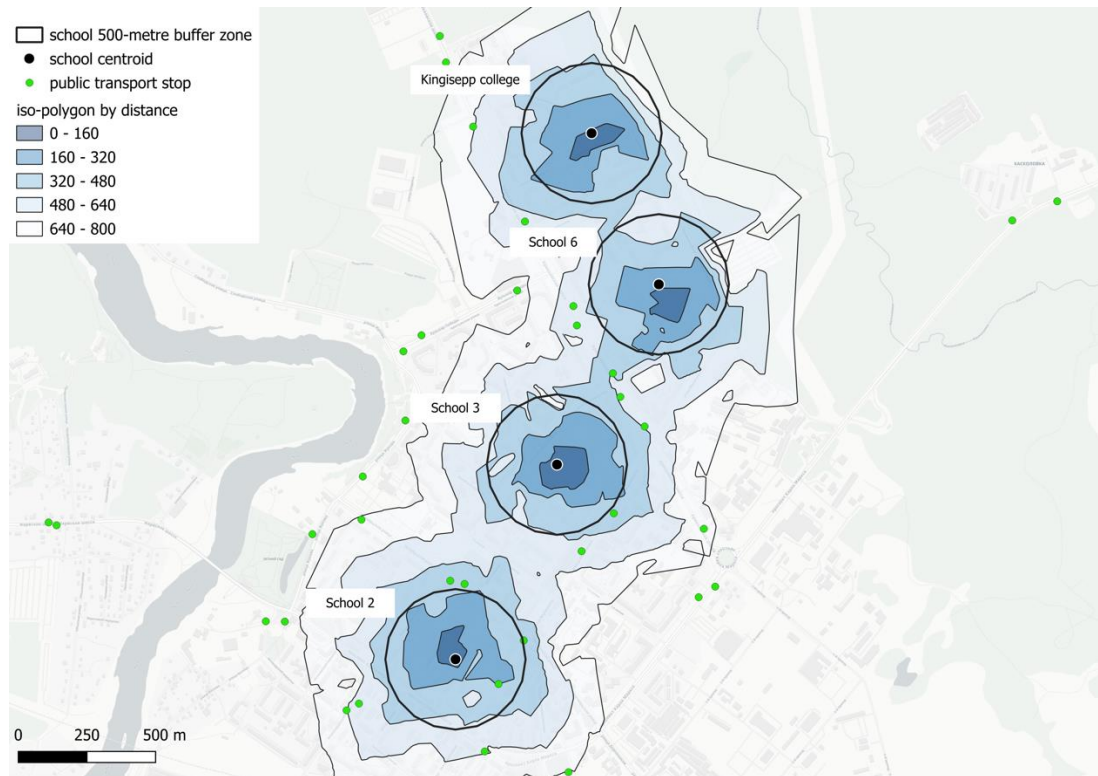Figure 16 — The analysis of playground proximity for schools in Kingisepp

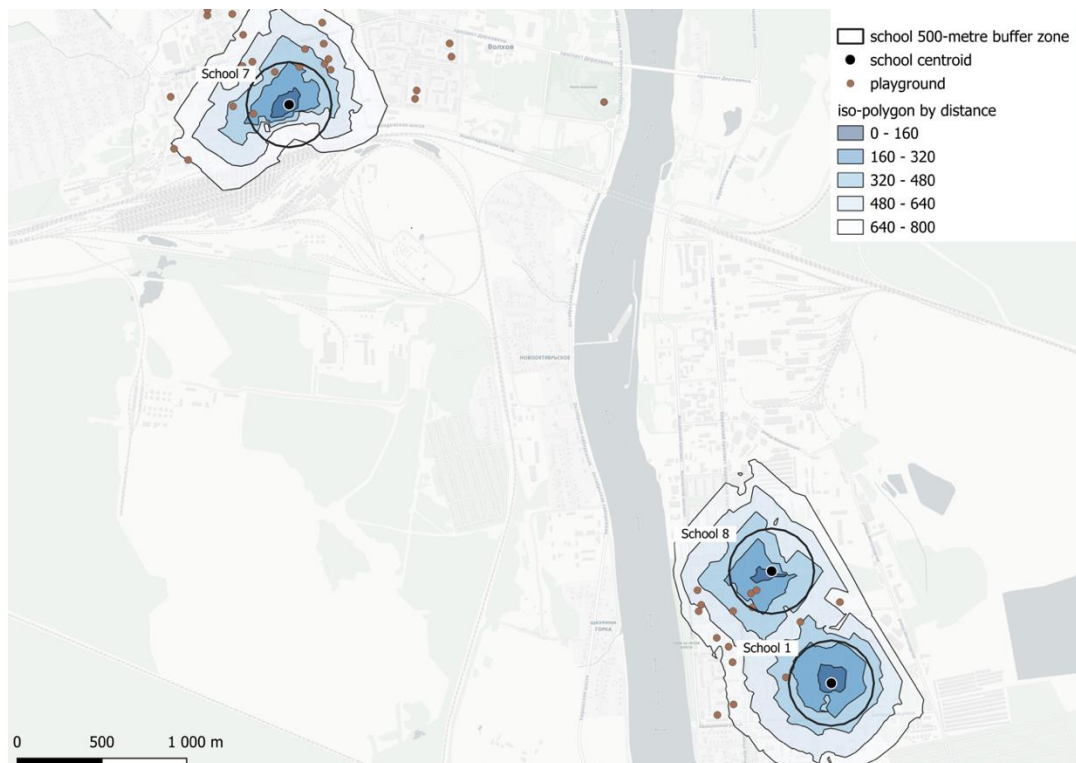Figure 17 — The analysis of bus stops proximity for schools in Kingisepp

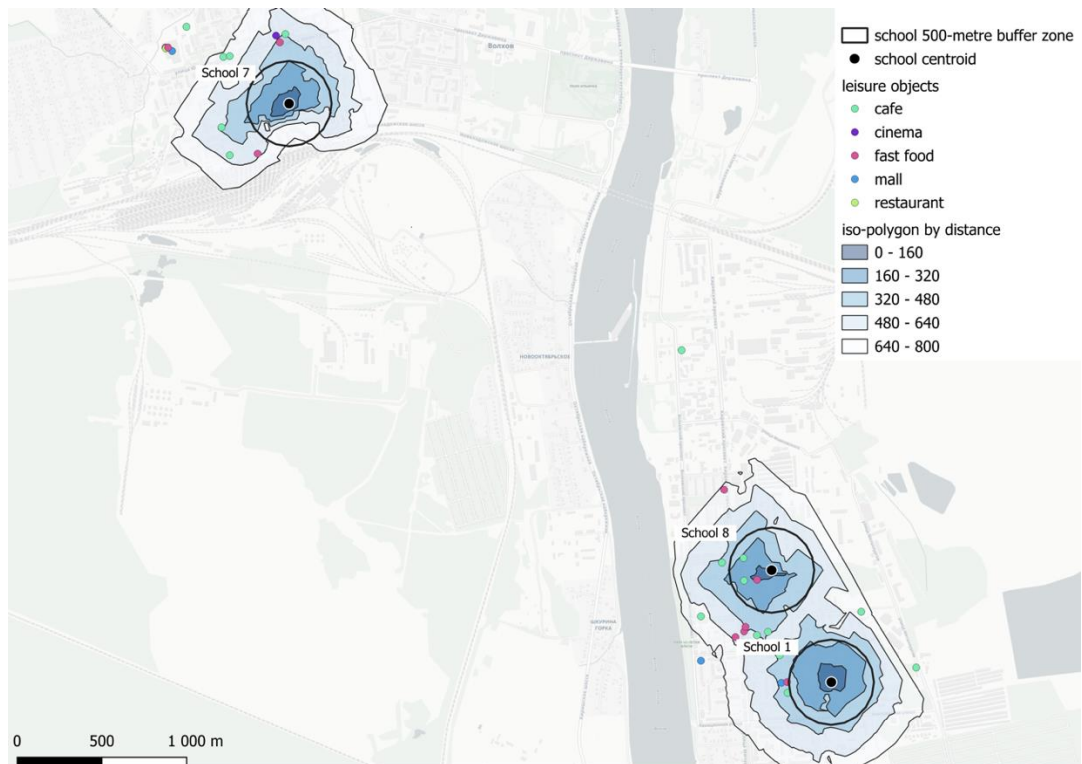Figure 18 — The analysis of playground proximity for schools in Volkhov

Figure 19 — The analysis of leisure points proximity for schools in Volkhov

The results of the analysis of quantitative factors assessment are shown in the Table 22.

Table 22 — Assessment of factors for schools in Kingisepp and Volkhov

	Kingisepp				Volkhov		
Factor	Sch. 2	Sch. 3	Sch.6	Kingisepp College	Sch.1	Sch. 8	Sch.7
Sports Grounds	1	1	1	1	1	0	1
Playgrounds (Internal)	0	0	0	0	0	0	0
Greenery	0.27	0.58	0.45	0.55	0.37	0.33	0.14
Public Spaces	0.2	0.8	0	0.6	0.2	0.4	0.6
Playgrounds (External)	0.8	0.8	0.6	0.2	0.6	0.8	0.8
Leisure Points	0.8	0.6	0.6	0.8	0.6	1	0.4

Table 22 (continued)

Sports Facilities	0.6	0.8	0	0	1	0.4	0.4
Cultural & Educational Objects	0.2	0.4	0.4	0	0.8	0.4	0.8
Healthcare Amenities	1	1	0	1	1	0	1
Traffic Lights	1	0.8	0.6	0.6	0.8	1	0.8
Bus Stops	0.6	0.6	0.6	0.4	0.6	0.8	0.6

The obtained results were multiplied with normalized vectors to obtain evaluation of schools environments. The result is demonstrated in Table 23.

Table 23 — Weighted values for schools in Kingisepp and Volkhov

Factor	Sch. 2	Sch. 3	Sch.6	Kingisepp College	Sch.1	Sch. 8	Sch.7
Sports Grounds	0.135	0.135	0.135	0.135	0.135	0.000	0.135
Playgrounds (Internal)	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Greenery	0.011	0.024	0.018	0.022	0.015	0.013	0.006
Public Spaces	0.035	0.142	0.000	0.106	0.035	0.071	0.106
Playgrounds (External)	0.049	0.049	0.037	0.012	0.037	0.049	0.049
Leisure Points	0.228	0.171	0.171	0.228	0.171	0.285	0.114
Sports Facilities	0.045	0.060	0.000	0.000	0.075	0.030	0.030
Cultural & Educational Objects	0.007	0.014	0.014	0.000	0.028	0.014	0.028

Table 23 (continued)

Healthcare Amenities	0.013	0.013	0.000	0.013	0.013	0.000	0.013
Traffic Lights	0.029	0.024	0.018	0.018	0.024	0.029	0.024
Bus Stops	0.032	0.032	0.032	0.021	0.032	0.043	0.032
Performance	**0.585**	**0.663**	**0.425**	**0.556**	**0.565**	**0.534**	**0.537**

In terms of overall performance, School 3 had the highest score, followed by School 2 and Kingisepp College. These schools offer a balanced provision of essential factors, especially leisure points, public spaces, and sports facilities. On the other hand, School 7 and School 6 had the lowest scores due to a lack of key facilities such as public spaces, sports facilities, and internal playgrounds.

Leisure points were the most heavily weighted factor across all schools, with School 8 scoring the highest, followed by School 2, School 7, and Kingisepp College. This reflects the children's preference for spaces where they can socialize outside of school hours, like malls and entertainment venues. The schools are well provided with leisure infrastructure, piving the children room for the communication and engagement after school.

Sports grounds received a consistent weight across most schools, except for School 7, where no sports grounds were provided. The lack of such facilities at School 7 is concerning, as it may affect student engagement in physical activities.

Public spaces had varying scores, with School 3 in Kingisepp and School 7 in Volkhov scoring highest. Public spaces like parks are important for socializing and physical activity outside school. However, the score of School 6 in Volkhov shows a lack of these spaces, which could affect the overall environment for students.

Playgrounds outside the school premises scored relatively evenly across schools, with School 6 scoring slightly lower. Notably, no internal playgrounds were reported in any school. This indicates a lack of sheltered play areas near schools, which are particularly important for younger students.

Greenery was present at a moderate level in all schools, reflecting a reasonable provision of green spaces within school grounds, which support student well-being.

Sports facilities varied across schools, with Schools 2 and 5 scoring the highest. Other schools, such as Schools 3 and 6, reported little to no provision. The availability of sports facilities is essential for physical education and extracurricular activities. The lack of these facilities in some schools represents a gap in providing a supportive environment for student health and development.

Healthcare amenities were generally available, but two schools lacked sufficient provisions, which slightly affected the overall score.

Pedestrian crossings, traffic lights and bus stops were reasonably well distributed across schools, showing a good accessibility of transportation and safety infrastructure. However, some schools could benefit from better access to safe transport routes.

The analysis shows that most schools are moderately equipped with essential amenities, but there are notable gaps in sports facilities, public spaces, and leisure points. Schools that provide better access to these facilities offer a more supportive environment for students' physical and social development. To improve the overall school environment, schools with lower scores should focus on enhancing access to outdoor play areas, sports facilities, and public spaces, which would help create a more holistic, engaging, and safe environment for students across all schools.

3.5 Strengths and Weaknesses of the Method Developed

The method provides a structured assessment of school environments by combining qualitative and quantitative data. It integrates children's preferences from design games with spatial analysis, ensuring a balance between subjective experience and objective factors. Scalability is confirmed by successful application in multiple cities, proving independence from specific locations.

Reliance on open-source spatial data and GIS tools enhances objectivity. Buffer zones, iso-areas, and network accessibility analysis minimize human bias. The weighting system prioritizes real user needs, making the framework adaptable while maintaining standardized comparisons.

The method has some limitations, such as its reliance on the availability and accuracy of data. Open-source datasets may be outdated or incomplete. Some

factors, like the quality of sports facilities or public space safety, may be too simplified for a unified evaluation. The method also needs to be tested over time to track changes in the environment. The weighting system, which is based on children's opinions, can be subjective and could be improved by involving more stakeholders.

Despite these limitations, the method is still a useful tool for urban planning. By improving data accuracy, refining the factors being evaluated, and testing the method over time, it can be made even more effective.

In the Leningrad Region of Russia, key stakeholders can use the method effectively. Government bodies, like the Committee for General and Professional Education, the Transport Committee, and the Committee for Urban Development Policy, are important for aligning school projects with regional standards, managing transportation safety, and planning school facilities within the city's growth. Local governments are responsible for carrying out these projects and making sure they meet community needs.

Construction and design companies in the private sector help build schools to modern standards, while investors and developers provide the necessary funding. Working together, these groups can successfully apply the method and improve school infrastructure in the region.

4 Recommendations for School Environment Design

4.1 General Recommendations for School Environment Improvement

Based on the results of the research, the following general recommendations have been devised to improve the existing schools' performance. Moreover, they can be considered while planning the construction of new disctricts and school buildings.

First, it is essential to locate playground sports grounds on-premises and in the surrounding area within 300–500 meters from the school building. This will help to provide the infrastructure for physical development and safe play, as well as the place for communication and building social skills.

As older students require separate spaces for socializing after school, indoor and outdoor leisure points should be provided. They include spaces like cafes, malls, and outdoor areas. These spaces will provide students with opportunities to relax and socialize after school.

Nature is an essential factor for the development of child's physical and cognitive abilities, thus it's important to provide a sufficient level of greenery within the school premises. It can be also complemented by activities engaging the children into discovering the nature like on-premises school gardens. Also, green spaces act as leisure points for children especially in late spring and early autumn, thus proximity to such spaces can also provide additional possibilities for socializing and physical activities.

Another important factor is transport accessibility, thus it is important to provide schools with public transport stops within 300-meter distance from schools. Commuting students will get experience while going to school, meanwhile the overall connectivity of points of interest, like public spaces, libraries for schoolchildren will increase, creating a more interconnected city for children.

Also, students express the crave for having quality cultural and educational amenities, such as libraries, museums, and theaters where they can take part in extracurriculum activities and learn more. These facilities should be easily accessible, either nearby or through community partnerships.

While designing the spaces it is important to address the needs of different age groups. Younger students often need play areas for noisy activities, while older students might want spaces for socializing. Schools should plan environments that suit the diverse needs of all students, providing comfortable spaces for children of every age.

Finally, schools should be integrated into the wider urban landscape. Future planning should ensure that schools are situated in well-developed areas with easy access to essential services, public spaces, and recreational facilities. This approach supports the long-term development of the city and helps create a thriving community for them to grow in.

To implement the proposed methodology and results, stakeholders in the Leningrad Region can consider several key actions.

First city administration can use this method to consider the plan for prioritizing child-friendly spaces near schools, including sports grounds, playgrounds, and green areas within 500 meters. City general plan should also ensure schools are close to social and recreational spaces.

Regional Budget Committees may consider this approach to allocate funding for the development of child-friendly spaces, such as sports and recreational facilities, near schools, as they will be more demanded. This includes projects like parks and playgrounds that meet the needs of various age groups.

Education authorities can integrate the proposed methodology into school assessments to check that surrounding environments support children's development.

Community organizations can use this framework to explore the areas that require improvements the most and draw public attention to the children's needs. This would help to create a solid reasoning for the measures to be taken.

4.2 Recommendations for the Improvement of the Existing School Environment

Based on the methodology, existing school environments were analyzed to see how the outlined recommendations can be put in practice in accordance with

Child Friendly City principles. The data for schools 2 and 5 in Gatchina was collected and analyzed, as they located in a dense residential district and in close proximity to each other and their external environment areas intersect (Figure 20).
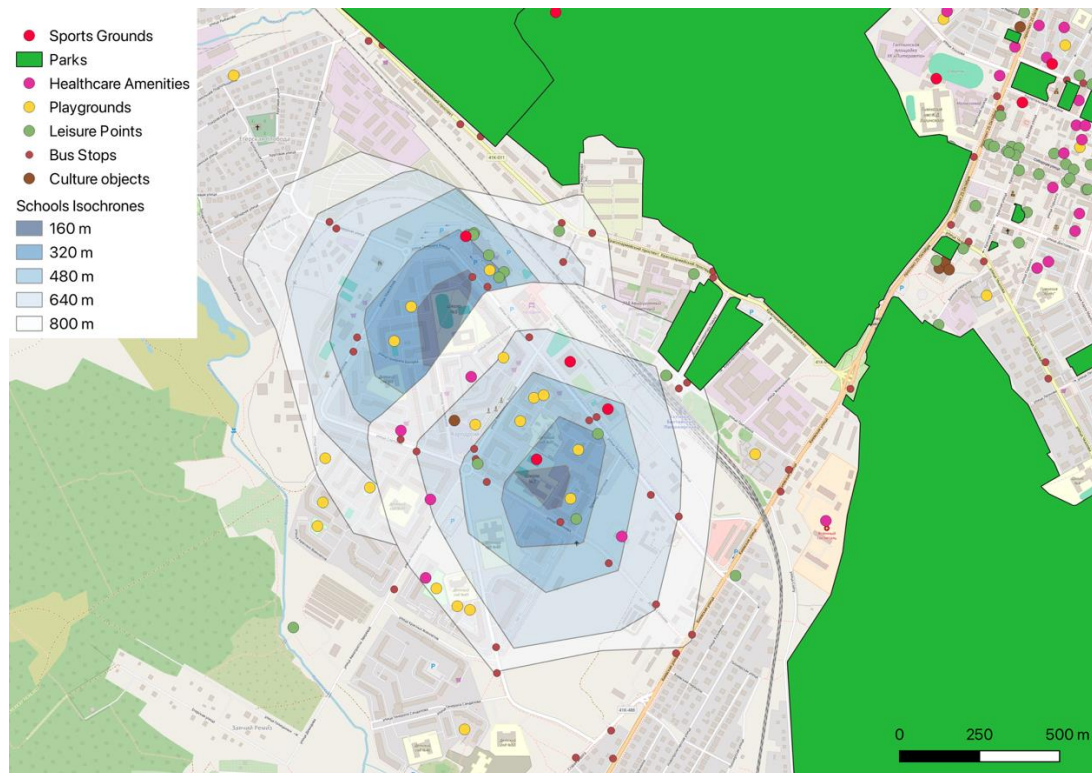

Figure 20 — Schools 2 and 5 existing environments

The following results for the school performance were obtained (Table 24).

Table 24 — Weighted values for Schools 5 and 2

Factor	School 5	School 2
Sports Grounds	0.135	0.135
Playgrounds (Internal)	0.095	0.000
Greenery	0.019	0.016
Public Spaces	0.035	0.035
Playgrounds (External)	0.049	0.049
Leisure Points	0.171	0.228
Sports Facilities	0.060	0.045
Cultural & Educational Objects	0.021	0.014
Healthcare Amenities	0.013	0.013
Traffic Lights	0.024	0.029

Table 24 (continued)

Bus Stops	0.043	0.043
Performance	**0.665**	**0.608**

The results show that schools demonstrate relatively high performance, especially in the provision of playgrounds, sportsgrounds, leisure points, transport infrastructure and healthcare facilities. However, they lack green spaces that can be quickly accessed by children and sufficient cultural facilities.

Thus, the following improvements were suggested to improve the provisioning of factors and overall school environment performance (Figure 21). Adding one more cultural object, for example, a community center for children closer to School 2 will increase this factor performance. At the same time, it is located in walking distance from School 5 can be also used by its students.

We can also observe that the district lacks green areas within it, having large parks only 20-30 minutes far from schools premises. The area only has a public boulevard with tree rows that may not be enough for children. Thus, a new green space on an empty site is suggested, that should be designed considering children as users.
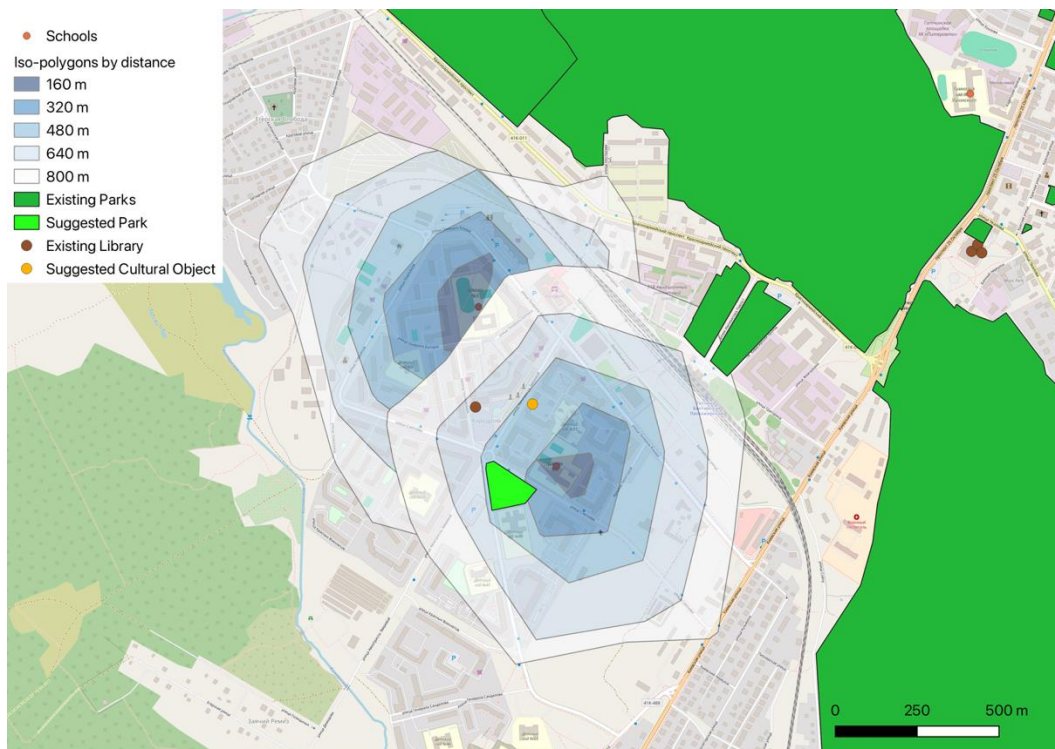

Figure 21 — Suggestion for environment improvements (Schools 2 and 5)

By introducing such changes, both schools increase performance (Table 25).

Table 25 — Weighted values for Schools 5 and 2 with improvements

Factor	School 5	School 2
Sports Grounds	0.135	0.135
Playgrounds (Internal)	0.095	0.000
Greenery	0.019	0.016
Public Spaces	0.106	0.106
Playgrounds (External)	0.049	0.049
Leisure Points	0.171	0.228
Sports Facilities	0.060	0.045
Cultural & Educational Objects	0.021	0.021
Healthcare Amenities	0.013	0.013
Traffic Lights	0.024	0.029
Bus Stops	0.043	0.043
Performance	**0.736**	**0.686**

This demonstrates that the methodology can be applied to analyze the existing gaps and ensure the optimal location for environment improvements to minimize the costs of building new facilities.

4.3 Recommendations for the Improvement of the Developing School Environment

School locations are primarily defined by the demand factors, such as number of residents in the district, proximity to residential infrastructure. Nowadays, multiple residential buildings are built that includes the necessity for plan school infrastructure. However, these facilities are considered separately, without proper attention for the surrounding environment.

In Gatchina, a new school for approximately 1200 students is to be open in summer 2025. Children will also require urban infrastructure to fulfill their needs for development, safety and leisure. Thus, the developed methodology was implemented to see how the new premises is provided by the facilities, according to child friendliness (Figure 22).
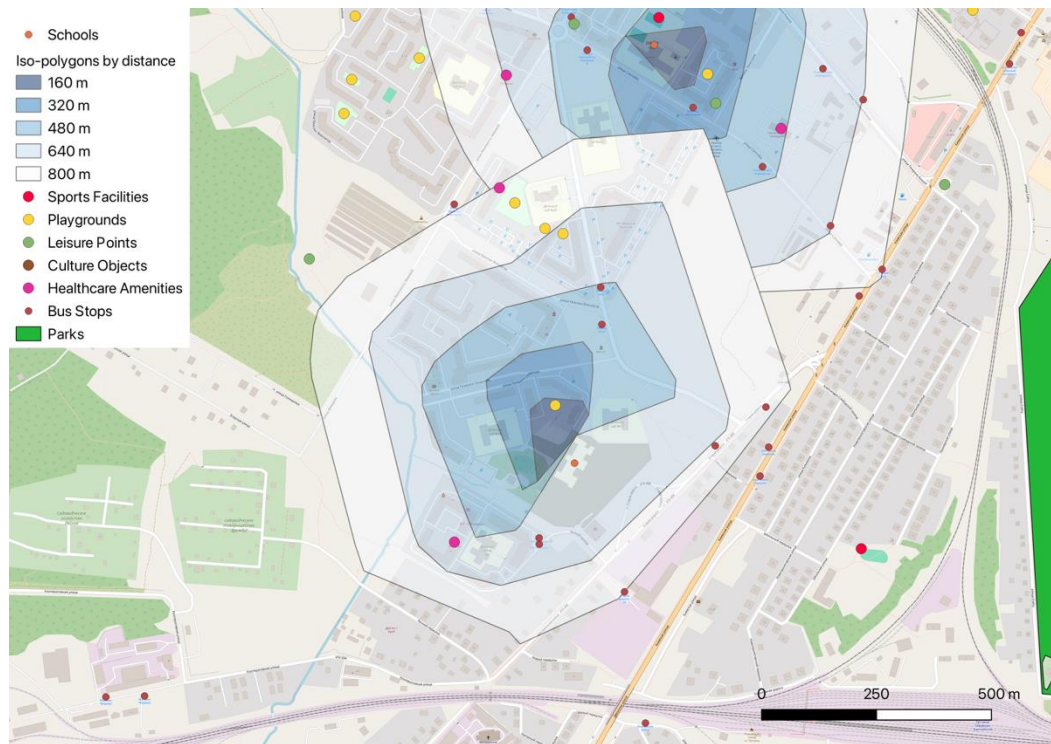
Figure 22 — Environment of new school in Gatchina

The analysis of geospatial data shows the following results (Table 26).

Table 26 — Weighted values for the new school

Factor	New School
Sports Grounds	0.135
Playgrounds (Internal)	0.095
Greenery	0.022
Public Spaces	0.000
Playgrounds (External)	0.062
Leisure Points	0.000
Sports Facilities	0.000
Cultural & Educational Objects	0.000
Healthcare Amenities	0.013
Traffic Lights	0.024
Bus Stops	0.043
Performance	**0.393**

We can observe only a good provisioning of playgrounds and transport infrastructure with a moderate accessibility of healthcare amenities. All the other

factors are poorly provided as the area is only developing. However, the future demand for the city infrastructure from children should be taken into account as the school will be open soon and children will use the surrounding infrastructure more. Considering this, the following improvements are suggested (Figure 23).
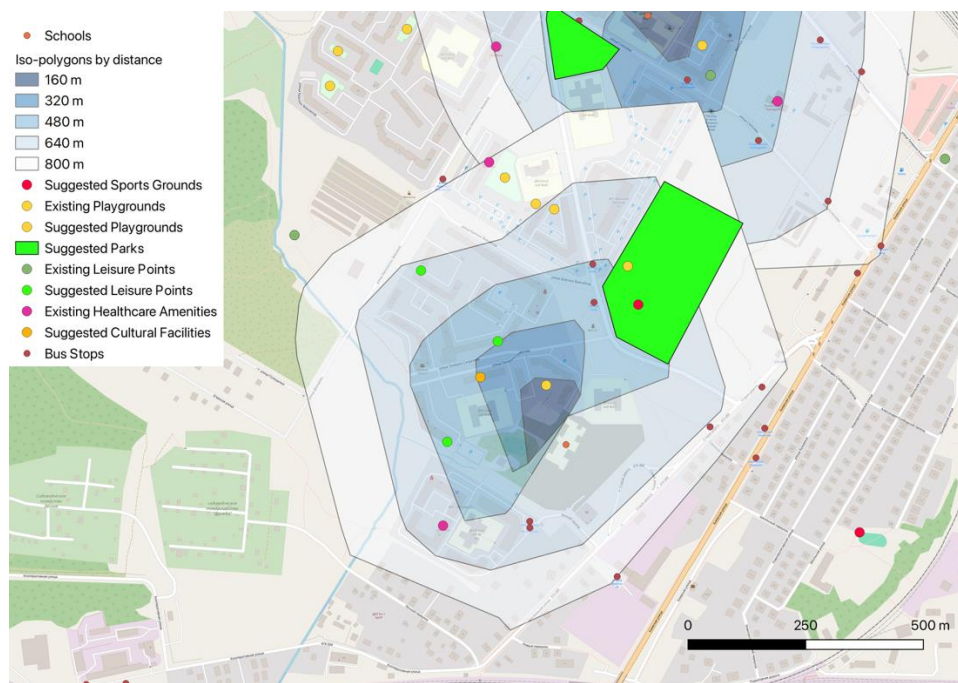

Figure 23 — Suggested improvements for new school

The residential complexes located around the school can accommodate the majority of functions, while a new green space may be built for students and residents of the district. This will significantly change the new school performance and make the developing infrastructure ready for the opening of the school (Table 27).

Table 27 — Weighted values for the new school with improvements

Factor	New School
Sports Grounds	0.135
Playgrounds (Internal)	0.095
Greenery	0.022
Public Spaces	0.106
Playgrounds (External)	0.062
Leisure Points	0.228
Sports Facilities	0.045

Table 27 (continued)

Cultural & Educational Objects	0.028
Healthcare Amenities	0.013
Traffic Lights	0.024
Bus Stops	0.043
Performance	**0.800**

The obtained results show that the methodology can be also implemented to analyze the to-be infrastructure and prevent shortages in services provisioning for children.

The results of the research were presented to the Deputy Head of the Education department of Gatchina city administration, N.V. Solovyeva. She admitted that many school premises need improvements, both internally and externally and a significant transformation is going to improve the quality of school environments. She added that nowadays more attention is paid to children's needs while developing the urban environment and more quality infrastructure appears around schools.

She highlighted that the methodology and the results of the research can be taken into account to advance the development of school environments. She also acknowledged that nowadays little is heard about Child Friendly City and Child Friendly Schools principles and they should be considered to fulfill the needs the children and provide the opportunities for their harmonious development.

CONCLUSION

The study aimed to assess internal and external school environments based on essential facilities proximity, based on the concept of a "child-friendly city." It implied the identification of the facilities influencing children's development, implementation of GIS tools to analyze the proximity of these spaces and design games with children to prioritize their needs. This helped to understand how surrounding environment affects students' experiences and views.

The assessment implied 11 factors to evaluate the environment in terms of convenience and fulfilling children needs. It compared the priorities of different age groups, showing what younger students and older students value most.

A design game format was chosen to allow children to actively participate in shaping their ideal school environment. This approach made sure that students' opinions and preferences were considered in the evaluation process.

The methodology was successfully tested in other cities, showing that it could be applied to various school environments, regardless of location.

There were four key findings from the assessment process.

Children of different ages have various priorities for the school environment when it comes to child-friendly city principles. Younger students prefer areas for safe and engaging play, while older students value places for after-school socializing.

Communication is among the highest priority for all age groups that is why it is important to create accessible facilities for independent activities within school premises as well as have public spaces, leisure points, sports and educational facilities nearby for the harmonized development and promoting social interaction.

Each school has its own predefined parameters influenced by its location and surroundings. Thus, it is important to study each school separately to identify the needs and problems. However, the results of each school analysis should be considered together as adding an extra facility can affect ls schools performance.

The methodology that includes both spatial analysis and participatory event for children helps to provide a more balanced evaluation of school environments. It

helps to combine the objective spatial data with the subjective opinions of school children and engage students in the planning process to provide spaces that cater their needs.

In conclusion, the study shows the common trends for school environments and identifies the problems that have to be addressed to create a complete and harmonious environment children's educational, physical and social development. The methodology and recommendations can be further developed and implemented in other cities to evaluate educational infrastructure in the context of child-friendliness.

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