

Reuse of rod spatial structures for children's playgrounds betterment

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Abstract: The disadvantage of most of children's playgrounds is the inability to fully use them during afternoon sun and in the rain. Frequently used small gazebos and canopies only allow you to hide from the rain or the sun. A full-fledged game is impossible. The optimal solution, apparently, is to build pavilions that are high enough for a full-fledged game and provide a roof over most of the playing space. An analysis of various solutions has shown that recombined elements of disassembled collapsible rod spatial structures can be used for this purpose. These widespread structures used in large-span buildings and usually fail after several cycles of operation. The proposed continuation of their use increases their asset turnover. Pavilions built from these structures provide an opportunity to continue the games in the afternoon sun and in the rain. The strength and spatial rigidity of these structures makes it possible to attach various amusement rides and lighting equipment to them. The article presents a conceptual design solution. This solution solves some of the problems of ensuring sustainable development by saving energy and reducing costs, as it ensures the reuse of dismantled structures. The solution is almost universal for different regions. The proposed solution should be seen as a conceptually new application of existing systems.

Keywords: children's playground; play environment; an inclusivity; rod spatial structures; sustainable development

1. Introduction

In a modern city, a children's play environment is a necessary part of the improvement of urban space. With proper organization, it forms the child's personality, promotes his physical development, socially adapts through communication with peers. Depending on the location in urban-planning structural formations, areas allocated for children perform certain functions. Small playgrounds on house plots intended for physical development and mainly designed for young children. A public area of a residential area located in the city in a square and park, as a rule, offers conditions for spending time with a much larger number of people, with thematic equipment for younger, middle and older children. Playground equipment includes devices for physical exercise, semantic and informational.

The topic under study is new. Therefore, these references are indirect. Authors have identified a large number of different studies indirectly related to the topic under consideration. No research has been identified on the topic under consideration. The paper highlights the most important studies indirectly related to the issue under consideration.

The general theoretical aspect formation of play spaces for children is considered in the works of R.C.Moore (1990), J.Goldstein (2012), S.G.Eberle (2014), J.F.Jacques (2015), M.Anbari, H.Soltanzadeh



(2015), [C.Sentieri Omarrementeria](#) and [E.Fernández-Vivancos González \(2024\)](#) which describe an interesting experiment when “conditions are created that distance themselves from the construction of a specialized object or place and offer children alternatives to the duality between free and protected subjects about play and the city, with a progressive approach towards a more inclusive and participatory society”.

Many works are devoted to the combinatorial possibilities of rod spatial structures and their application for various purposes. Including, for example, [D.J.Steigmann, M.G.Faulkner \(1993\)](#), [J.Dzwierzynska \(2018\)](#), [S.Klyuev, A.Abakarov, R.Lesovik, K.Muravyov, R.Tatlyev \(2019\)](#), [A.A.Kalinina, A.I.Kurbanov, N.G.Tsaritova \(2021\)](#), [K.Samoilov, B.Kuspangaliyev, G.Sadvokasova, N.Kuanyshbekov \(2022\)](#), [P.Feng, J.Zhao, Q.Wang, J.Zhai, P.Zhou \(2024\)](#) and other. However, studies on the possibilities of reuse of unused rod structures have not yet been conducted. However, the topic of integrated assessment of carbon emissions over the life cycle in construction has a number of interesting interpretations, for example, [A.Al-Habaibeh, E.Manu, T.Clement, B.Shakmak, J.Selvam, T.-H.Lin \(2025\)](#).

The historical aspect of the genesis and evolution of children's play areas considered by [B.Biondo, S.Solomon, D.Hammond \(2014\)](#), [J.Frost \(2012\)](#) and other (for example, [Play-world® Blog, 2022](#)). Interesting data is if “although 71% of parents played outside as a child, only 21% of their children play outside today” and the need for outdoor play is emphasized.

Various aspects, including interactivity, of the formation considered by [J.Jacobs \(1967\)](#), [A.Brett, R.C.Moore, E.Provenzo \(1993\)](#) and other. Thus, [R. Poppe, R. Van Delden, A. Moreno and D. Reidsma \(2014\)](#), emphasize, “Interactive playgrounds are installations that combine the benefits of traditional playgrounds with advances in technology. To provide rich and engaging game experiences, they are designed to sense, learn, and adapt to the players' behavior”. The idea of adding educational attractions with agricultural themes to children's playgrounds is peculiar – [I.Ostapenko, E.Schneider, L.Nurkusheva, B.Kuspangaliyev, K.Samoilov \(2025\)](#).

Inclusive spaces are of particular interest. The aspect of inclusivity is very important: [L.Nabors, M.Lang, K.Welker \(2018\)](#), [A.Brischetto, F.Tosi, A.Rinaldi \(2019\)](#), [A.Moore, H.Lynch, B.Boyle \(2020\)](#) and other. A very important conclusion made that “a truly inclusive playground doesn't have areas off to the side for children with disabilities, or designated spaces for special needs playground equipment. Inclusive means everyone is a part of play with peers of all abilities. Inclusive playgrounds create an atmosphere where every-one can interact with each other, explore, imagine and play together”. The issues of adequate landscaping of children's playgrounds have a certain importance: [R.C.Moore \(1993\)](#), [A.Habibe \(2013\)](#) and other. Kazakhstan's practice of developing playgrounds summarized by [E.Shneider \(2022\)](#). The analysis did not reveal any studies on improving the comfort of using children's playgrounds in the afternoon sun and in the rain. However, there is a study on the creation of translucent roofs over the entire courtyard – [A.Carbonari, M.Scarpa, F.I.M.Plaza \(2025\)](#). By themselves, such local planning decisions become part of the ideology of sustainable development – [D.Batchelor & L.Bremner \(2026\)](#).

These studies show a deep understanding of the specifics of children's play space. However, the problem of creating comfortable conditions for playing in rainy weather or hot noon practically not emphasized.

This problem solved by the installation of a roof over a part of the playing space. The practice of design and construction shows numerous examples of such gazebos, outdoor pavilions, etc. However, these buildings, in fact, are independent objects, simply added to the gaming equipment. The novelty of the solution proposed by the authors lies in the transformation of the shadow canopy into an organic part of the game space. The canopy design becomes an additional element of the gaming equipment. At the same time, the issue of reuse of decommissioned structures is being resolved. This is important from the standpoint of saving energy costs. The proposed solution for the use of decommissioned rod spatial structures for pavilions on children's playgrounds not been put forward before, either theoretically or practically. Accordingly, this proposal is a new application of existing systems. Humans and animals did not participate in the study, so ethical approval was not required for the study.

2. Materials and Methods

The aim of the study is to determine the possibility of improving the performance of children's playgrounds by building pavilions that allow playing in the afternoon sun and in the rain.

Research plan:

- Analysis of the specifics of children's playgrounds in multi-floor building complexes;
- Identification of shortcomings in the organization of the game space (the main identified drawback is the lack of space that provides the opportunity to play in the afternoon sun and in the rain);
- Analysis of geometric features of rod structures;
- Analysis of the possibilities of reuse of disassembled rod structures;

- Determination of the possibilities of reuse of rod structures for the construction of pavilions on playgrounds;
- Suggestions on the shapes and sizes of pavilions on children's playgrounds using the example of one of the most commonly used rod structures.

The research methodology based on a comprehensive method and includes an analysis of the formation of a playground, the study of the specifics of the categories of games and equipment of children's playgrounds, considering inclusivity. The research methodology also includes the study and systematization of world experience in designing playgrounds (according to literary sources, electronic resources and field surveys).

An important issue is to identify the disadvantages of modern children's playgrounds and identify ways to eliminate these disadvantages. The main disadvantage is the inability to continue playing games in the afternoon sun and in the rain. Accordingly, there is a need to analyze the possibilities of solving this problem. In this context, it is important to study the features of spatial-rod structures. These constructions can be adapted to solve the problem.

Play activity on the playground has three functions: physical play, sensory play, social play. Together, they help to form various behavioral skills in a non-family context.

The genesis of a publicly accessible children's playground, as an independent element of the urban environment, is associated with very multi-floor residential construction and with the development of automobile traffic on city streets. The courtyards of the first multi-floor urban residential buildings practically excluded the possibility of games inside due to their small size and lack of constant sunlight. Accordingly, almost all of the children's leisure time was concentrated at nearby streets. This, due to the increasing intensity of first horse-drawn and then motor transport, led to a large number of road accidents involving children. Under these conditions, a public understanding been formed that in areas of multi-floor residential development it is necessary to allocate special areas isolated from the streets for children.

However, these playgrounds with piles of sand, swings of various types, ladders, slides, etc. only partially solved the problem of organizing children's leisure. Having a significant size and designed for a large number of children to play at the same time, these left some of the issues unresolved. The main problem was that the child had to go to this playground on purpose, moving away from home. This caused concern to parents. In addition, on such a large and massively used playground, it was necessary to constantly maintain order and monitor the safety of children playing. Accordingly, there should be constantly present staff with professional communication skills with children of various ages – personal babysitters and relatives accompanying some of the children playing could not fully solve this task.

The transition from a small-quarter residential development to a large-quarter one, as well as the appearance of a micro district-type development, significantly increased the comfort of the living environment in general and provided the opportunity to create a special playground in the courtyard of almost every multi-floor residential building, in particular.

This solved the security problem, since it almost completely excluded the child playing from entering the area of city streets. The end-to-end view of the courtyard from most of the windows of adjacent residential buildings significantly reduced the natural concern of the relatives of the playing child about his location and behavior. The almost constant presence of elderly people living in these houses resting in the fresh air in the courtyard provided a sufficient level of control over the safety of children playing. Even in the absence of family ties with children playing, the very presence of adults ensured compliance with elementary behavioral standards and the adoption of prompt measures in the event of conflicts between the players or when children were injured. A significantly smaller number of children on the local playground (compared, for example, with the district playground) solved another problem – the queues that caused numerous conflicts for playing on this or that attraction practically eliminated.

The addition of mini-sports grounds for team games, gymnastic equipment and simulators to playgrounds made it possible to differentiate the majority of children playing by age, further increasing the usability of the playground. Some variety in the organization of children's leisure in the yard, their acquisition of some skills in the field of nature protection has made the involvement of children in the care of trees, bushes and flowers growing in green areas of yards.

An important stage in the development of children's playgrounds in the courtyards of multi-floor residential buildings was the standardization and unification of gaming equipment, as well as special coatings, developed in the middle of the twentieth century, which began mass-produced by industrial enterprises. This made it possible to ensure guaranteed compliance with safety standards, maintenance and repair regulations, as well as the service life and replacement of equipment. An important role here played by the emerging unification of the attachment units of various elements. There are also corresponding standards for the minimum range of playground equipment that ensure the harmonious physical and mental development of children of various ages. Industrial enterprises quickly mastered the production of gaming equipment for thematically different children's playgrounds. At the same time, the

set of the main attractions has not changed functionally – only the shape and color of the finish corresponding to a particular theme differs.

However, contrasting thematic differences of children's playgrounds in the courtyards of nearby residential buildings are impractical. The child may find it more interesting to play in the neighboring yard, and he will go there, causing concern to relatives. This is critical when a child spends his leisure time in the yard without an accompanying tutor or relative.

Some originality given to children's playgrounds by the use of mobile and collapsible elements that allow children to transform the playing space independently.

Modern close attention to the needs of children with special needs has expanded the range of game elements. These elements provide for the possibility, for example, of using a wheelchair on slides and ramps, special mounts on swings, the possibility of a child and an accompanying adult swinging together, ring fences around ladders, low-lying therapeutic bars and rings, long speaking tubes, balancers, etc. The presence of an accompanying adult next to the playing child has necessarily led to the appearance of more furniture and equipment that allows you to monitor the child in a comfortable position, change the child's clothes or arrange a short rest.

The weakening of children's interest in "monotonous" playgrounds recorded in some studies is most likely caused by age-related changes and the lack of playground equipment in the yard of their house corresponding to primary school age. It is the presence in the complete set of playground equipment of attractions for various age groups that ensures its full functioning. Attractions for two-three-year-olds, of course, are not interesting at the age of five, since the child has already "played enough" with these attractions.

It is especially important that the child has already physically grown up and simply "does not fit" into the cells intended for toddlers. According to numerous observations, kids look with interest at the "high" swings, slides, ladders, and wait for themselves to be able to use them. A six-year-old child is already beginning to try on gymnastic equipment and team games and, of course, no longer plays with the kids. Accordingly, he stops using the children's playground, switching his interest to sports grounds. For two- to three-year-olds who have just started to consciously use the playground, a standardized set of equipment is sufficient. The desire to use some new, different attraction does not arise in such children, since they have not yet mastered all the available attractions. By the time of confident development of the existing attractions, the child has already grown physically and naturally proceeds to the development of new attractions for him, parametrically corresponding to his formed physical and mental needs.

Several factors influence the formation of a modern children's playground. The function of a children's playground is to educate, form interpersonal and collective communication skills, the cognitive aspect in general and awareness of the importance of environmental protection in particular. The location in the urban environment determines the possibility of interaction with natural factors. This is reflected in the texture, color and relief of surfaces made of various materials. Materials, in turn, characterized by such parameters as naturalness, decorativeness and the degree of uniformity. The main means forming the composition are: the concept of space; layout; plastic forms; features of spatial or semantic partitioning of surfaces; geo-plastics; parametric data on height limitation, absence of sharp corners, rounded protruding elements; texture of the material, maximally reducing injury and pollution; color, multi-tone and graphic compositions; light-plastic solutions. Being an integral part of the urban improvement system aimed at meeting public needs, the problems of improving the quality of life and positive changes in the subject-spatial environment being solved.

One of the significant problems of children's playgrounds is the complexity of their operation in the afternoon sun and in the rain. The solution to this problem is to create a large enough canopy over part of the playing area. To do this, it is possible to reuse de-commissioned, dismantled rod spatial slabs.

In general, spatial rod structures of coatings used for more efficient industrial production of building structures, which reduces costs due to their mass production, specialization of production and rationality of design solutions. The most rational design forms are those that, with their manufacturability and low material consumption, provide the possibility of wide unification of structural elements, taking into account industry and intersectoral requirements, allow for the organization of in-line production of a limited range of similar elements, from which a wide variety of flat and spatial structures or buildings in general with high architectural and aesthetic properties can be created.

The development of systems of metal cross-rod spatial structures was based on the following fundamental architectural and structural prerequisites: a single unified assortment of elements with maximum compositional capabilities; the use of rolling profiles optimal in shape; the use of high-strength materials; full industrialization of production based on the use of high-performance automatic equipment, casting, stamping, etc.; compactness of system elements and the possibility of their transportation by any type of transport; high reliability, speed of assembly and installation of elements, including conveyor assembly and large-block installation; wide possibilities of spatial composition. The

highest achievement in the development of these systems is an almost unlimited variety of structural forms based on a limited set of initial types of elements used for the construction of buildings and structures for industrial, civil and agricultural purposes.

In the world practice of using structures, there are more than a hundred different systems (for example, “Mero”, “MArchI”, “Octaplatte”, “Octa-S”, “Triodetic”, “Berlin”, “Du Chateau”, “TSNIISK”, “Unistrut”, “Weimar”, “Kislovodsk”, “Module”, “Varitek”, “Premit”, “Sokol”, “Iset”, “Tagil”, “Space Dek”, “K.T.”, “Cross”, “Disk”, “NS”, “Var-itet-sistem” and others). The objects of typing in these systems are a rod and nodal elements, optimized for the weight of the bearing capacity and typed according to the geometric dimensions of the initial elements (rods, nodal elements and joints).

Cross-rod spatial structures, or spatial structures, are systems of vertical cross trusses or, most often, regular structures built on the principle of multi-connectivity, composed of regular and semi-regular polyhedra with two important properties: the possibility of dense filling of space and one length of a modular rod within a single structure. These properties are possessed by the tetrahedron and octahedron and a number of Archimedean bodies – semi-regular polyhedral.

In the world practice of designing spatial systems, constructions based on the tetra-cubo-octahedral group have become the most widespread, due to spatial geometric immutability and equal length of edges.

Tetrahedron and octahedron (or semi-octahedron) in combination with each other completely fill the space, being interchangeable bodies. The space, completely filled with tetrahedra and octahedra, is the initial matrix in which all possible spatial frameworks in the system formed. The frames formed by cutting the lattice with planes, each of which belongs to one of the faces of a tetrahedron, octahedron or semi-octahedron.

Spatial systems of regular structure based on the principle of multi-connectivity. This determines a number of their advantages in comparison with traditional structures made up of rafter and sub-rafter trusses, girders. The material in such a system distributed relatively evenly. When moving and unevenly applied loads applied to the system, a large number of rods are included in the work, which makes it possible to create sufficiently light structures of load-bearing coatings with multi-support suspended transport and other effective systems. The reserve of survivability of multi-connected systems lies in the possibility of redistributing efforts after failure or transition to the plastic stage of deformation of individual overloaded elements. The regularity of the structures determines the repeatability of the sizes and, as a result, the maximum unification of the rods and assemblies, which makes it possible to organize in-line highly mechanized production, which significantly reduces the specific labor costs for manufacturing. Accordingly, the “carbon footprint” of production is significantly reduced, which is important in terms of environmental protection.

Such plates with parallel belts been massively used to cover large spaces since the second half of the last century. These plates have different sizes of geometric solutions. The designs of nodal elements and rods differ. It is here that the main features of the manufacturing and assembly technology of the structure are concentrated, which determine the differences between some systems from others. For example, the node of the “Mero” and the “MArchI” systems consists of a cast spherical, hemispherical or polyhedral connector element with holes drilled in it for bolts according to the number of adjacent rods. Sometimes connectors are made of rod blanks of a polyhedral (for example, hexagonal) section. The bolt passed through the hole of a flat cylindrical liner pressed into the end of a tubular rod and welded to it. A hexagon-shaped lead sleeve with a bolthole equipped with a pin lock placed between the ends of the connector and the liner.

The bolt screwed into the connector using a sleeve until it touches tightly between the sleeve and the end surfaces, which ensures the transmission of compressive forces through the sleeve and the contact area, and tensile forces through the bolt. The rods of this system have a high compensating capacity, which facilitates assembly. The compensating ability is the ability to assemble, despite the inaccuracies of the manufacture of rods. The structures based on the use of unified rods and nodal connectors. The total number of cross-section types of unified rods usually does not exceed ten. As a rule, no more than four or five types of sections used in one plate. The plates, if necessary, provide consoles by shifting the support structures from the edges of the plate to the center. The section of the connectors in the plan is an octagon.

In the “Octaplatte” system, the nodal element made in the form of a hollow ball of two stamped halves welded on lining rings. Pipe rods cut at right angles welded to the ball element during installation. In the “Triodetic” system, a nodal cylinder with slots used to connect tubular rods with flattened ends. The flattened ends of the pipes subjected to special treatment in accordance with the slots. All pipes converging at the node fixed in the slots of the cylinder with a single clamping bolt. The system designed for structures made of aluminum alloys, which made it possible to use the extrusion method to obtain a rod blank of a special profile and manufacture nodal cylinders by simply cutting pieces from this blank.

In the “Berlin” system, wedge-shaped calibrated tips welded to the flattened ends of the tubular rods,

forming a cylinder with a hole inside when assembled into a node. The ends of the cylinder closed with steel covers with sides along the outer contour and tightened in a knot with studs. The node of the “Du Chateau” system uses nodal stamped shapes. Six semicircular recesses provided in each of the two shapes, which, after connecting the shapes, form a nodal element with holes for tubular rods. The shapes welded together along the outer lines of the touch pads. The rods inserted into the holes and welded, thus forming an upper or lower network. Braces and struts welded to the outer surfaces of the nodal element (one of the shapes).

There are no additional elements in the “TSNIISK” node. The ends of the pipes flattened and cut off at the right angle in the braces. The rods fixed in a special retainer during assembly so that a free space formed between their ends, which filled with molten metal during the bath welding process. The “Unistrut” system is also based on the use of stamped shapes, characterized in that eight planes are created during stamping (according to the number of adjacent rods), where holes are made for fixing rods from rolled or bent profiles (corners, brands, channels, etc.).

The “Varitek” nodal part consists of two mounting elements. Paired ribs of the nodal part cover the tips of the tubular rods, made in the form of a flat plate with a hole coaxial with the rod. In this case, centering of the core elements and adjustment of the thickness of the bearing sheets is achieved both from the side of the nodal part and from the side of the core element. The “Sokol” system consists of six identical sheet-stamped pyramid-shaped parts with protrusions around the holes for connecting parts to each other and simultaneously attaching core elements to them by means of medium bolts of normal accuracy. A bent channel profile is used here as the core elements.

The “Iset” design solution includes pyramids with a square base, staggered with their vertices down, and rods of the lower belt network connecting the vertices of the pyramids. The coupling of the pyramids at the base level provided by means of welded flange nodal elements. The main modular element is a lattice pyramid – tetrahedron. The immutability of the system ensured by loosening the upper waist mesh with profiled flooring and introducing strands into the cells of the lower waist mesh, which dissect the main hexagonal cells into triangles. The nodal element at the top is a welded cruciform connector. The overlapping connection of the rods to the nodes reduces the requirements for the precision of the elements. The lower belts are made long from a strip of solid or composite channel and bolted at the nodes. In order to reduce the number of mounting elements with a small length of compressed rods, the “Tagil” system uses a triangular-hexagonal scheme with triangular and hexagonal cells in the upper grid and with hexagonal cells in the lower grid.

Pyramids at the base level connected between bent flanged corner elements. The nodal element at the top of the pyramid solved in the form of a bent three-lobed rosette. The described constructions investigated experimentally. An example of a system where the main structural unit is a pyramid is the “Space Dek” system. The square at the base of the pyramid is made of single corners oriented inward with shelves, and the braces forming the inclined faces of the pyramid made of pipes or also from corners. The bases of the pyramids placed side by side bolted together, forming an orthogonal grid of one of the belts; the other grid formed by linear elements.

Rod spatial structures used not only for flat slabs. Extensive practice of their application in the formation of spherical, parabolic and other complex surfaces. However, in these structures there are a much larger number of types of rods of various lengths and nodal elements.

The support elements and consoles solved differently. The support of structural plates provided in various zones of the plate, both along the office and in the span of the plate, in order to unload the belt nets in the central zone. Direct support on racks or other supporting structures at a small number of points causes significant forces in the rods adjacent to the support. In order to avoid significant surges of forces in the support rods, unloading structures in the form of bundles of rods, spatial rod supports or beam elements are used. With a limited number of columns, a rational distribution of forces provided by distribution support structures in the form of contour trusses, frames, arches or using shrouds and rope suspensions. In order to ensure the frequent arrangement of suspensions with a small number of columns, hanging systems with load-bearing support cables used, which created by elastic support systems.

With the help of structural plates, a lightweight roof arranged. The supporting element of the roof here is a metal profiled flooring along the girders. Due to the limited size of the cells of the belt grids, it is sufficient to use light girders based on the nodes of the plates directly or through special tables. In coatings with plates made of rolled profiles and in some systems with belts made of closed curved profiles of rectangular cross-section, the profiled flooring supported directly on the upper belt, which in this case works not only with longitudinal forces, but also on local bending.

These spatial plates are most widely used in temporary, prefabricated pavilions for trade and exhibition or industrial purposes. The collapsible solution ensures their repeated use. The complexity of assembly and disassembly of these structures ranges from 0.2 to 0.5 person-hours per square meter of the overlapped area. Bolted structures are the most convenient for disassembly and subsequent assembly

elsewhere.

3. Results and Discussion

However, in most cases, after 1-2 cycles, these structures lose their operational prospects. This is usually due to breakage or deformation of individual elements. It is almost impossible to replace these elements, since manufacturers usually do not sell individual parts (only the new design as a whole). Accordingly, only small modules can be assembled from the disassembled structure. This is not happening in reality. All disassembled core structures either go to metal remelting or are stored due to the futility of further use.

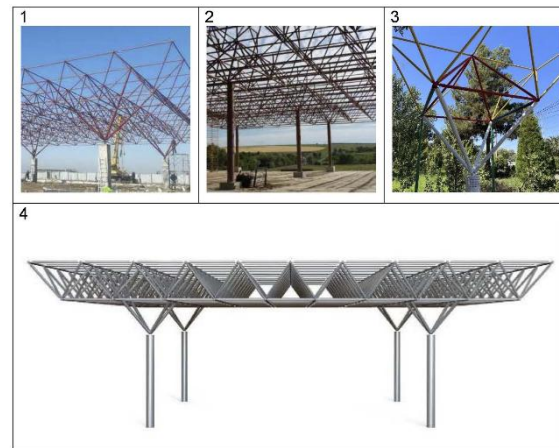


Figure 1. A rod spatial slab: 1 – The slab with a pyramid support, Almaty; 2 – The slab with a belt support, Tashkent; 3 – The fragment of a pyramid support, Tashkent (The advertising stand); 4 – A module 30.0 x 30.0 m (3D model).

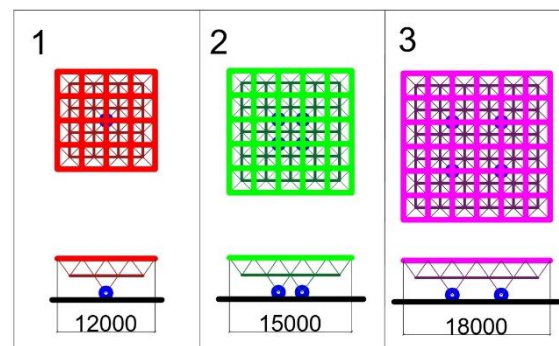


Figure 2. Suggested spatial modules for children's playgrounds (dimensions are given in millimeters): 1 – The Module "A" (12.0 x 12.0 m); 2 – The Module "B" (15.0 x 15.0 m); 3 – The Module "C" (18.0 x 18.0 m).

In this situation, it seems expedient to create smaller spatial modules from the existing nodal and rod elements. These new modules retain all the advantages of the basic design, providing one or more additional cycles of operation.

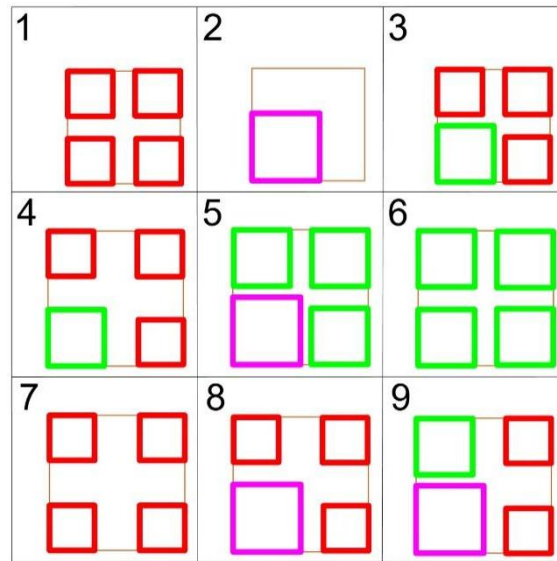


Figure 3. The possibilities of creating the proposed modules “A”, “B”, “C” based on the basic structures of 30x30 m and 36x36 m: 1 – four modules “A” based on the base of 30x30 m; 2 – module “C” based on the base of 30x30 m; 3 – three modules “A” + module “B” based on a base of 30x30 m; 4 – three modules “A” + module “B” based on a base of 36x36 m; 5 – three modules “B” + module “C” based on a base of 36x36 m; 6 – four modules “B” based on a base of 36x36 m; 7 – four module “A” based on the 36x36 m base; 8 – three modules “A” + module “C” based on the 36x36 m base; 9 – two modules “A” + module “B” + module “C” based on the 36x36 m base.

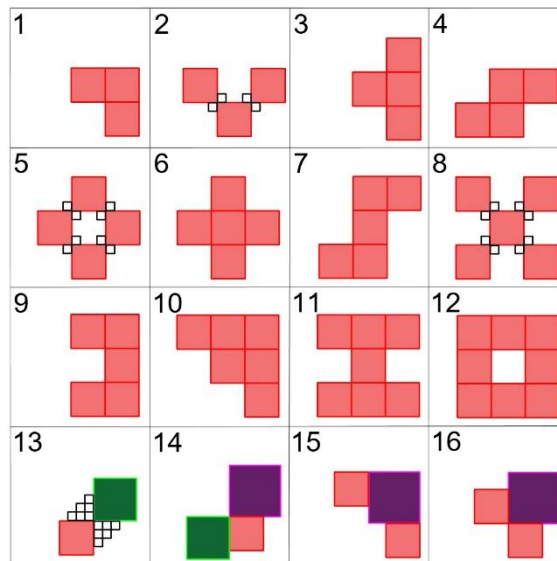


Figure 4. Suggested combinations of spatial modules for children's playgrounds: 1 – three modules “A” in the “L”-shaped layout; 2 – three modules “A” in the chess layout; 3 – four modules “A” in the “T”-shaped layout; 4 – four modules “A” in the “Z”-shaped layout; 5 – four modules “A” in a cross layout; 6 – five modules “A” in a cross layout; 7 – five modules “A” in the “Z”-shaped layout; 8 – five modules “A” in the “X”-shaped lay-out; 9 – five modules “A” in the “C”-shaped layout; 10 – six modules “A” in the “L”-shaped layout; 11 – seven modules “A” in the I-beam layout; 12 – eight modules “A” in a ring arrangement; 13 – The module “A” and the module “B” in the diagonal arrangement; 14 – The module “B”, the module “A” and the module “C” in the diagonal arrangement; 15 – two modules “A” and the module “C in the “L”-shaped layout; 16 – two modules “A” and the module “C” in the “L”-shaped layout.

A possible way to reuse these structures is the construction of outdoor pavilions on children's playgrounds. This will significantly increase the comfort of this important part of residential development. It protects most of the playing area from precipitation and so-lar overheating. Allows providing reliable

fastening of various equipment and inventory. Retains full visual control of the space from the adjacent territory.

The structure “Kislovodsk”, developed in the 1970s (The 1.466-2 Series. Spatial lattice structures made of pipes, [Seriya_1973_36](#) 1973), is widely used in the different countries of Eastern Europe and Central Asia.

This rod-shaped spatial lattice structure with an orthogonal grid of belts with a cell of 3.0x3.0 m and a height along the axes of the belts of 2.12 m. The nodes of the upper and lower belts are pyramidally connected by rods.

All rods of the system have the same nominal length and consist of steel pipes with washers welded at the end. Rods of high-strength bolts with hexagon couplings attached to them passed through the holes of the washers. To connect the rods into a spatial structure, a nodal element used, which is a steel polyhedron with threaded holes. The threaded holes are oriented in the direction of the belts and braces converging at the node. The faces of the nodal element are normal to the axes of the holes. The nodal element has threaded holes for mounting girders, suspended ceilings and process equipment.

The hinge bearing of the rod plate on the support carried out through the nodes of the upper or lower belt, as well as through the supporting capitals.

Often the reasons are improper operation, causing corrosion of the nodal elements, or violation of the technology of disassembly and reassembly, causing deformation of the rod elements.

Replacing individual damaged elements with new ones can be problematic due to the complexity of contacts with manufacturers who are not interested in the supply of individual parts. Independent repair of damaged elements in the absence of special equipment on the construction site is not promising. An attempt to use elements from another similar kit for replacement completely eliminates the possibility of its further use. As a result, the disassembled structure remains without prospects for further use.

Capitals are pyramids of rods structurally identical to the rest of the rods of the structure. The base of the supporting capital is the cell of the lower belt, and the top rests on a steel or reinforced concrete structure ([Figure 1](#)). This structural system designed for single-floor single- or multi-span buildings. Two types of module: 30.0 x 30.0 m (a span 18.0 m) and 36.0 x 36.0 m (a span 24.0 m).

Based on these modules, it seems advisable to form three main elements: module “A” – 12.0 x 12.0 m, module “B” – 15.0 x 15.0 m, module “C” – 18.0 x 18.0 m ([Figure 2](#)). Modules 15.0 x 15.0 m and 18.0 x 18.0 m are independently stable, having four supports. The 12.0 x 12.0 m element with one central support does not have independent stability. It used in several combinations depending on the configuration of the site.

Three combinations formed from the 30x30 m base module: four “A”-modules; or the “C”-module; or three “A”-modules and the “B”-module. Six combinations can be formed from the 36x36 m base module: three “A”-modules and the “B”-module; or three “B”-modules and the “C”-module; or four modules “B”-modules; or four “A”-modules; or three “A”-modules and the “C” module; two “A”-modules, the “B”- modules and the “C”-module. The possibilities of creating the proposed modules “A”, “B”, “C” based on the basic structures of 30x30 m and 36x36 m shown in the [Figure 3](#).

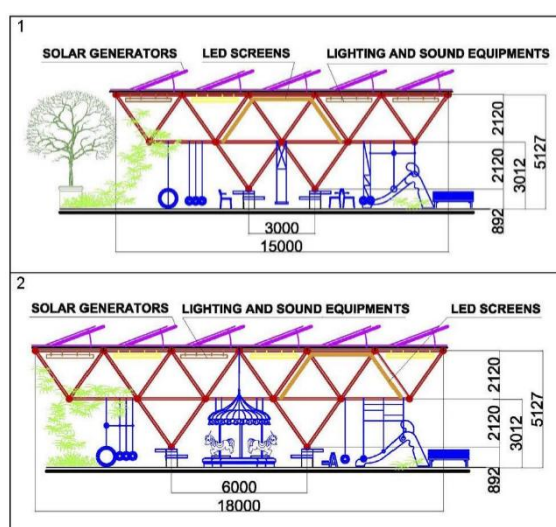


Figure 5. Suggested characteristic sections of children’s playground pavilions (dimensions are given in millimeters): 1 – The pavilion based on module “B”; 2 – The pavilion based on module “C”.

Some options for blocking this are shown in [Figure 4](#) (in variants, 2, 5, 8 and 13, additional rods are

required in the area of corner joints): 1 – three modules “A” in the “L”-shaped layout (~24.0 x 24.0 m); 2 – three modules “A” in the chess layout (~24.0 x 36.0 m); 3 – four modules “A” in the “T”-shaped layout (~24.0 x 36.0 m); 4 – four modules “A” in the “Z”-shaped layout (~24.0 x 36.0 m); 5 – four modules “A” in the cross layout (~36.0 x 36.0 m); 6 – five modules “A” in the cross layout (~36.0 x 36.0 m); 7 – five modules “A” in the “Z”-shaped layout (~36.0 x 36.0 m); 8 – five modules “A” in the “X”-shaped layout (~36.0 x 36.0 m); 9 – five modules “A” in the “C”-shaped layout (~24.0 x 36.0 m); 10 – six modules “A” in the “L”-shaped layout (~36.0 x 36.0 m); 11 – seven modules “A” in the “I-beam” layout (~36.0 x 36.0 m); 12 – eight modules “A” in the ring arrangement (~36.0 x 36.0 m); 13 – the module “A” and the module “B” in the diagonal layout (~27.0 x 27.0 m); 14 – the module “B”, the module “A” and the module “C” in the diagonal layout (~33.0 x 33.0 m); 15 – two modules “A” and the module “C” in an “L”-shaped layout (~30.0 x 30.0 m); 16 – two modules “A” and the module “C” in an “L”-shaped layout (~30.0 x 30.0 m).

Systems, geometrically made based on a square pyramid with a side of 3.0 m, has advantages. The height between the belts of 2.12 m allows, with a foundation protruding from the ground by 0.8 m, to get free space up to a height of almost 3.0 m. (If you use a system, for example, based on a tetrahedron, the distance between the belts will be 1.42 m. That is, it will be necessary to raise the supporting part of the foundation to a height of 1.5 m. This is a greater consumption of materials for foundations).

In the system based on a square pyramid in combination with a 0.8 m high foundation support, a table for adults (a table top at a height of 0.85 m) and a table for kids (a table top at a height of 0.45 m) are formed. This eliminates the possibility of injury when a person passes in the area of the inclined rod of the support capital.

The rod structure in question initially designed for the use of suspended technological equipment that creates a dynamic load. Thus, it is possible to mount swings of various types, ropes, roller coasters, ladders, etc. to the lower belt of the structure. This is an important addition to the lower fastening of these elements. As a result, the solution to the problem of ensuring the unconditional stability of equipment during active operation is simplified.

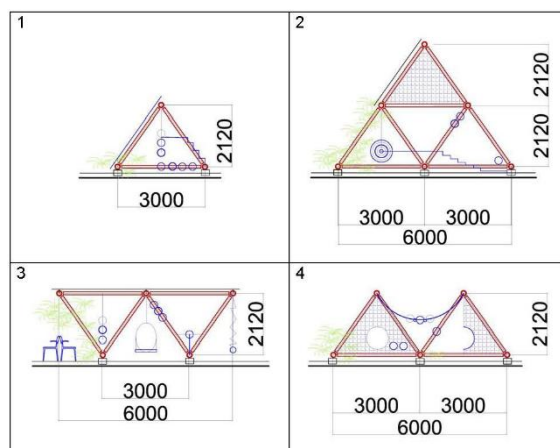


Figure 6. Suggested examples of ground structures from unused elements of the basic structure for the formation of game attractions (dimensions are given in millimeters): 1 – A small pyramid; 2 – A large pyramid-gazebo; 3 – A small pavilion; 4 – A paired pyramid.

Fixed or dynamic lighting fixtures, demonstration screens, sound-reproducing systems, video surveillance equipment attached to the upper belt and struts of the structure. Solar generators installed on the roof, providing a significant part of the electricity consumption of lighting devices. The structural elements located in the game area are equipped with special porous covers to ensure that accidental contact does not cause injury. Sections of canopies on children's playgrounds made based on modules of type “B” and “C” shown in [Figure 5](#).

From the remaining elements of the basic structure (depending on their number), it is possible to form pyramidal supports for ground-based play structures in the open space of a children's playground ([Figure 6](#)). At the same time, it is advisable to perform a roof on some parts of these elements.

The proposed design solution is almost universal for different regions. The calculated strength characteristics of this structure allow it to be used in regions with a snow load of up to 240 kg per square meter; with a wind load of up to 48 kg per square meter; installation and operation at temperatures up to -40 degrees Celsius; the possibility of using overhead crane equipment is provided; the seismicity of 7 points (with strengthening of connections of 9 points) – (The 1.466-2 [Series. Spatial lattice structures](#)

made of pipes, 1973). The weight of the structure is 14 kg per square meter.

The basic structure designed to withstand significant natural, climatic, and technological loads, both stationary and dynamic. Loads from the installation and operation of the suspended playground equipment are negligible compared to the technological loads for which the basic structure designed. The basic structure includes overhead cranes and hoists with a lifting capacity of up to 3 tons. The overhead tracks attached directly to the lower chord nodes of the rod structure.

Determining the degree of protection from climatic specifics of the space under the canopy based on the calculation of the following parameters: the size of the shadow from the canopy at midday and the area protected from rain. Due to the lack of direct sunlight, the air temperature in the shade feels about 15 degrees lower - this provides a kind of thermal comfort when playing under a canopy. For example, for 43°15' N (Almaty), the maximum height of the sun is 70.3° in summer. That is, the shade from the canopy provides protection for approximately 85% of the area under the canopy. The modules provide protection of the playing space from sun on an area of $\sim 144 \times 0,85 = 122,4$ sq.m (Module 12x12 m), $\sim 225 \times 0,85 = 191,3$ sq.m (Module 15x15 m), and $\sim 324 \times 0,85 = 275,4$ sq.m (Module 18x18 m). In case of normal rain, the entire area under the canopy is protected, and in case of oblique rain, it is also 85% protected. With an average normalized playground area per child of 5.0 sq.m, about 20 children can play in the 12x12 m Module, about 40 children can play in the 15x15 m Module, and about 60 children can play in the 18x18m Module.

The cost of a 36x36 meter module is approximately £14,775 (\$20,000). Here and below, average prices on the Kazakhstan market for May 2026 are given. The weight of the module is 18144 kg. This means that metal structures cost £821 per ton (\$1,111). The installation cost is £ 3,990 (\$5,400). This means installation costs £222 per ton (\$300). The cost of dismantling is £2,660 (\$3,600). This means that dismantling costs £150 per ton (\$200). The cost of recycling steel structures is £150 per ton (\$200).

The modules offered for playgrounds have the following parameters:

- Module 18x18 m – weight 4536 kg: Dismantling - £675 (\$900); Metal structures - £675 (\$900); Installation - £1,005 (\$1,361); Total cost of an 18x18 m module on a playground - £2,355 (\$3,161).

- Module 15x15 m – weight 3130 kg: Dismantling - £465 (\$620); Metal structures - £465 (\$620); Installation - £694 (\$939); Total cost of a 15x15m playground module - £1,624 (\$2,179).

- Module 12x12 m – weight 2016 kg: Dismantling - £301 (\$402); Metal structures - £301 (\$402); Installation - £447 (\$605); Total cost of a 12x12 m playground module - £1,049 (\$1,409).

When ordering a new structure, the cost will be: new structure £821 per ton (\$1,111); installation £150 per ton (\$200); total £971 (\$1,311). That is, a new 18x18 m module will cost £4,370 (\$5,900); a 15x15 m module – £3,010 (\$4,064); a 12x12 m module – £1,942 (\$2,622). This means that using new structures instead of reused ones is approximately twice as expensive.

All elements have a factory-made anti-corrosion coating. The resulting corrosion damage eliminated after dismantling the main structure before reassembly. Due to the low loads on the structure, when reusing it on the playground, the effect of "material fatigue" of the structure can be ignored. Humidifiers and fans installed in hot regions. Regional cultural and ideological preferences do not influence a constructive solution. These aspects affect the rides themselves.

Based on the analysis of carbon footprint data in the steel industry – [World Steel Association \(2025\)](#), [SteelWatch \(2025\)](#) [Steelonline \(2023\)](#), [J. Zhang and all \(2023\)](#) – the carbon footprint of producing a ton of steel is approximately 2.1 tons per ton; the production of metal structures gives a carbon footprint of 0.3 tons per ton. That is, the production of steel core structures yields a carbon footprint of approximately 2.4 tons per ton. This means that the reuse of the 18x18 m module reduces the carbon footprint by 10.8 tons; the use of the 15x15 m module reduces the carbon footprint by 7.4 tons; the use of the 12x12 m module reduces the carbon footprint by 4.8 tons.

4. Conclusions

The analysis of the current situation on children's playgrounds and the proposed solution allows us to draw the following conclusions:

1. An obvious disadvantage of modern children's playgrounds in the courtyards of multi-floor residential buildings is the lack of a roof over most of the play area. This does not allow you fully use the playground in the rain and bright midday sun. Small gazebos and pavilions do not solve the problem; as they only provide shelter for people from the rain and sun without the opportunity fully continue the game.

2. One of the ways to solve the problem of improving children's playgrounds in the courtyards of multi-floor residential buildings is the construction of sufficiently large outdoor pavilions.

3. The basis of their design can be reusable elements of collapsible rod spatial slabs, which for various reasons decommissioned after one or more disassembly and assembly cycles.

4. These structures, originally designed for large-span buildings, have sufficient spatial rigidity due

to the geometric solution of the cells. Accordingly, it is possible to complete a stable structure of smaller size.

5. From unused elements for modules, simple structures made that are included as supports for small attractions.

6. Depending on the specific size and configuration of the children's playground, one or more different modules are used. These modules have an easy-to-manufacture foundation, are easy to install, and allow you to fix various game attractions, audio and video equipment.

7. It is possible to place solar generators on the roof, which increase the energy efficiency of the facility operation.

8. A side effect is the continued use of structures that are not in use and require certain disposal costs.

9. The proposed design solution for reusing structures reduces the cost of constructing special pavilions from similar new structures by approximately half.

10. The reuse of core structures leads to a reduction in the carbon footprint from 4.8 to 10.8 tons, depending on the structure used.

The proposed design solution is conceptual in nature. Dismantled rod-shaped spatial structures still sometimes used as exhibition stands. The authors of the article suggest actively using them on playgrounds. These structures eliminate the disadvantage of most modern children's playgrounds: the lack of a canopy that allows you to fully continue playing in bad weather. The relevant project proposals considered, for example, by municipal services in Almaty.

Thus, the improvement of the operating conditions of children's playgrounds is possible through the construction of pavilions providing shade from the midday sun and a roof from rain. The size of these pavilions makes it possible fully continue the game during rain and in the afternoon sun. The structural basis of these pavilions are reusable elements of collapsible spatial lattice slabs. The structural rigidity and strength of these elements allow them to use for mounting gaming equipment, audio and lighting equipment, as well as solar generators. The proposed solution has economic and environmental advantages in several ways. The concept of reuse of unused core structures extends not only to flat slabs, but also to spherical structures. This determines the prospects of this area of research.

The reuse of rod structures for buildings of other purposes has not yet been studied in detail by anyone. The definition of the possibility of reuse of rod structures for the construction of pavilions on playgrounds is new (from the point of view of theory and practice). Accordingly, there are no scientific papers or practical examples to refer to yet. This study may be the beginning of further work clarifying the possibilities of reuse of various types of rod structures.

The result of the research are innovative proposals for the reuse of rod structures. The possibilities of their repeated mass use on children's playgrounds demonstrated. Currently, the practice of reuse of rod structures is minimal. Disassembled rod structures are recycled. In rare cases, parts of these structures used in exhibition stands. The reuse of rod structures has prospects and has a number of financial, organizational and environmental advantages.

Author Contributions

Conceptualization, E.S., L.N., T.U., B.K., K.S.; methodology, E.S., L.N., K.S.; software, E.S., T.U., K.S.; validation, L.N., T.U., B.K.; formal analysis, E.S., L.N., K.S.; investigation, E.S., L.N., T.U., B.K., K.S.; resources, E.S., L.N., T.U.; data curation, B.K., K.S.; writing—original draft preparation, E.S., L.N., T.U., B.K., K.S.; writing—review and editing, E.S., L.N., T.U., B.K., K.S.; visualization, E.S., T.U., K.S.; supervision, E.S., B.K., K.S.; project administration, B.K., K.S.; funding acquisition, E.S., L.N., K.S. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement

The raw data supporting the conclusions of this article will be made available by the authors on request.

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