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PRINCIPIA OF ROMAN CASTRUM PONTES –SPATIAL AND SOCIAL RELATIONS IN THE BUILDING

ABSTRACT

The decision of Roman Emperor Trajan to build this famous bridge also influenced the stone constructions of the associated castra on both sides of the Danube, in the areas of today's village of Kostol in Serbia and the town of Drobeta-Turnu Severin in Romania. For this reason, we analyse in this paper the castrum Pontes in Serbia, which we suppose was characterized by dimensional relations between the constituent elements. Certain relations noticed in the plan of castrum fortifications can also be observed in the plan of an individual building – within the main principia.

The classical plan of a Roman principia and the specific geometric relations in the case of Pontes Principia influence certain social relations of users and this building. An analysis of analogous solutions in the auxiliary castra of Limes also contributes to a better definition of the functions of certain rooms of the principia. However, by applying modern software designed for architectural analyses, we can study the above relationships more thoroughly and offer suggestions for functions that have not been determined yet.

KEYWORDS: PRINCIPIA, ROMAN CASTRUM, ANCIENT ARCHITECTURE, SPATIAL AND GEOMETRIC RELATIONS, PONTES, SOCIAL RELATIONS.

INTRODUCTION

The plan of the Pontes castrum in the area of today's village of Kostol in Serbia is a part of the whole construction that consists of Trajan's Bridge and the very similar castrum of Drobeta on the opposite bank of the Danube in today's town of Drobeta-Turnu Severin, Romania. Within the camp of Pontes, the building of the principia was partially explored during research in the period 1980-1990 (Petrović, Vasić 1996: 25; Гарашанин, Васић 1980: 7-24. Vasić, Kondić 1986:542 – 560; Гарашанин, Васић 1987: 71-116). Today's remnants of the bridge and castrum Pontes date from the time of the reign of emperor Trajan (98-117 A.D.). During Trajan's offensive against Dacia, several castra along the banks of the Danube between Moesia and Dacia were renovated or built from the foundations. The famous bridge between Pontes and Drobeta was built in the period 103-105. A.D. According to Procopius, two castra were built simultaneously with the construction of the bridge (Гарашанин, Васић 1980: 8). The purpose of these castra was obviously to control communication between the new Roman provinces of Dacia and Moesia.

Several archaeological phases are registered on the castrum Pontes and its principia. There is a possibility that the first phase of construction represented one small fortlet from the Flavian period (Vasić, Kondić 1986: 543). Below the traces of stone ramparts and stone principia, remnants of wooden constructions were discovered, which testifies to the character of the first phase construction. The next phase of fortification walls and principia, with stone walls, from the period of Trajan (103-105. A.D.) was the most significant in the sense of architectural quality. Archaeological finds from the principia show that this building had been built at the same time as Trajan's bridge, which is the same case regarding the principia building in Drobeta (Milošević 2004: 55, 58). After a period of maintenance neglect during the period of the Severan dynasty (first half of the III century), a reconstruction of castrum Pontes occurred. In this reconstruction, some of the towers lost their function and were not restored. The restoration of this phase also occurred on the building of the principia, where some of the facilites within it were not reconstructed (Petrović, Vasić 1996: 25). The last reinforcements of defenses (building of new towers, closing some of the gates) were recorded during the second half of the IV century. This building activity included the construction of a new horreum (granary) (Vasić, Kondić 1986: 554). According to documentation of the Archaeological Institute in Belgrade, the building of principia was not restored in this period, but small houses were built above its remnants. After the last restoration in the IV century, there was no new ones in the following centuries.

The research concluded that this is a building that is characterized by a symmetrical plan and is very similar to the concept of the principia in the Drobeta camp, on the opposite bank of the Danube (Marcu 2009: 279, Pl. 19). The shape of its plan is very close to a square, while the shape of the inner courtyard is a quite regular square. The appearance of squares as representatives of regular geometric shapes indicated the possibility of a certain geometric relationship between them and that this determined the plan of the entire principia.

The existence of certain geometric relations in the architecture of the principia can also impose an examination of their influence on user behavior. The spatial qualitative impacts of architecture on their users (visibility and movement within that space) can be considered through certain modern software (Varoudis 2014: 298), providing an integral observation of several dimensions of the architectural space. By applying specific software, researchers gain direct insight into the location of each point when perceiving one type of impact at a certain moment. Through a group of operations in this software, the relationship between individual spaces, angles, obstacles, individual distances, maximum and minimum values of action (e.g., in the form of movement) is analyzed. One of the examples of the direct effect of the space of an architectural building on people is the movement that space imposes on them. Depending on this movement and the degree of visibility of certain spaces, the spaces of basic communication and those that were characterized by greater secrecy stand out.

In the architecture of the period of late antiquity, , the separation of the functions of certain spaces according to the place concerning the communication of users appeared for the first time. In military architecture, we can notice this shift within the fort layout with its main roads, and special spaces for the principia and the shrine within it, the commander's building (praetorium), economic buildings (granaries), hospitals, barrack blocks for living etc. For this reason, analyses of qualitative influences on user behavior using certain graph methods of modern software can indicate the functions of parts of the building. Archaeological research in the case of the Pontes Principia has so far yielded no results, since the destruction of the level from Trajan's period on the whole surface of principia was significant.

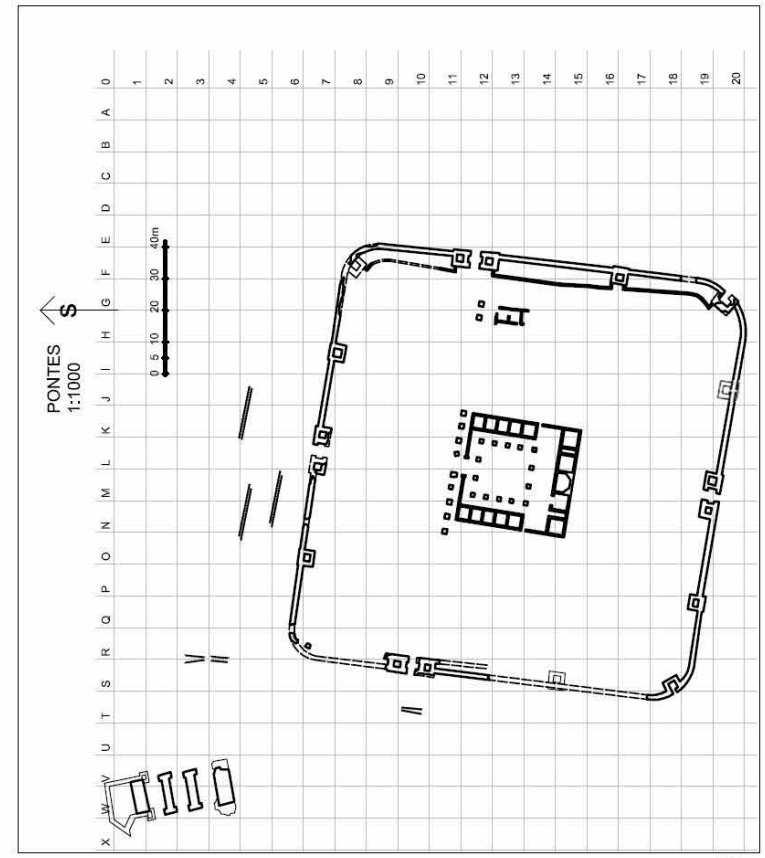

Fig. 1 a) The aerial footage of the archaeological site of Pontes; b) Plan of castrum (Trajan's phase) after archaeological investigation (Doc. of the Institute of Archaeology, Belgrade).

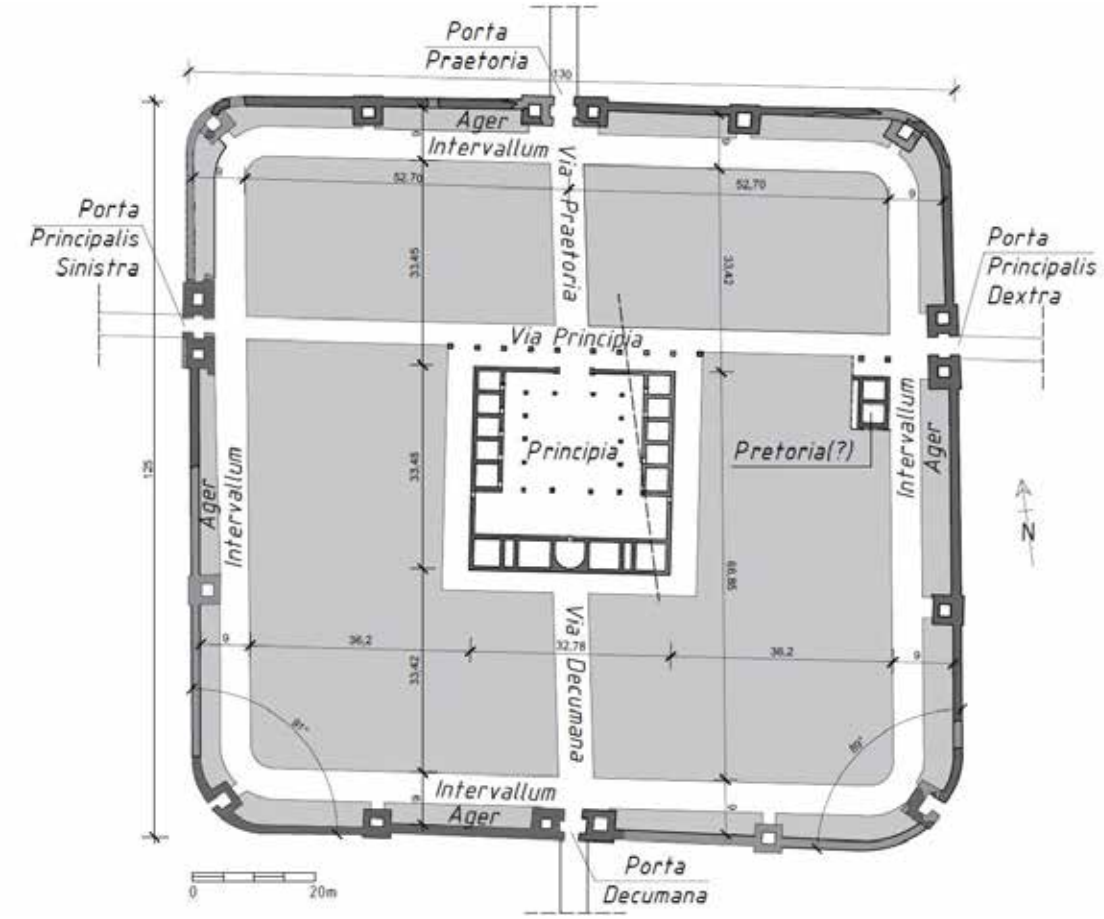

Fig. 2 The plan of the Pontes castrum with the positions of gates, towers, ramparts, associated ager and intervallum, main roads through castrum, the building of principia and discovered part of the officer's building (pretoria ?).

GEOMETRY OF CASTRUM PONTES

In the analysis of the shape of the Pontes castrum and the principia building, technical documentation from the archaeological research was used, as well as aerial footages of visible remains in the field (Fig. 1). Castrum Pontes has the layout of an almost regular rectangle, which was the basic form of Roman castra from the Middle Imperial period (Cambell 2009: 32-33). During the I and II centuries A.D. the planning concept followed the earlier recommendation of ancient writers Hygianus and Polybius, with frequent deviations determined by local conditions and the requirements of specific cohorts (Petrović, Vasić 1996: 18). The basic layout of the Roman castrum refers to the rectangular plan, where distinct blocks of buildings were created. A T-shaped arrangement of roads was established where the crossroads met near to the headquarters (principia), which often occurred at the central block in a fort (Cambell 2009: 33).

If we consider the ideal north-south orientation, the direction of the eastern rampart of the castrum has a deviation at its north end of 9° to the east. We were able to define that the angle between the southern and western ramparts was determined to be 91°, which was also the case with the angle between the northern and eastern ramparts. The remaining two opposite angles were determined to be 89°. The pronounced closeness of these values to the values of a right angle and the constitution of terrain where the castrum is built indicate that there was an obvious error in the process of mea-

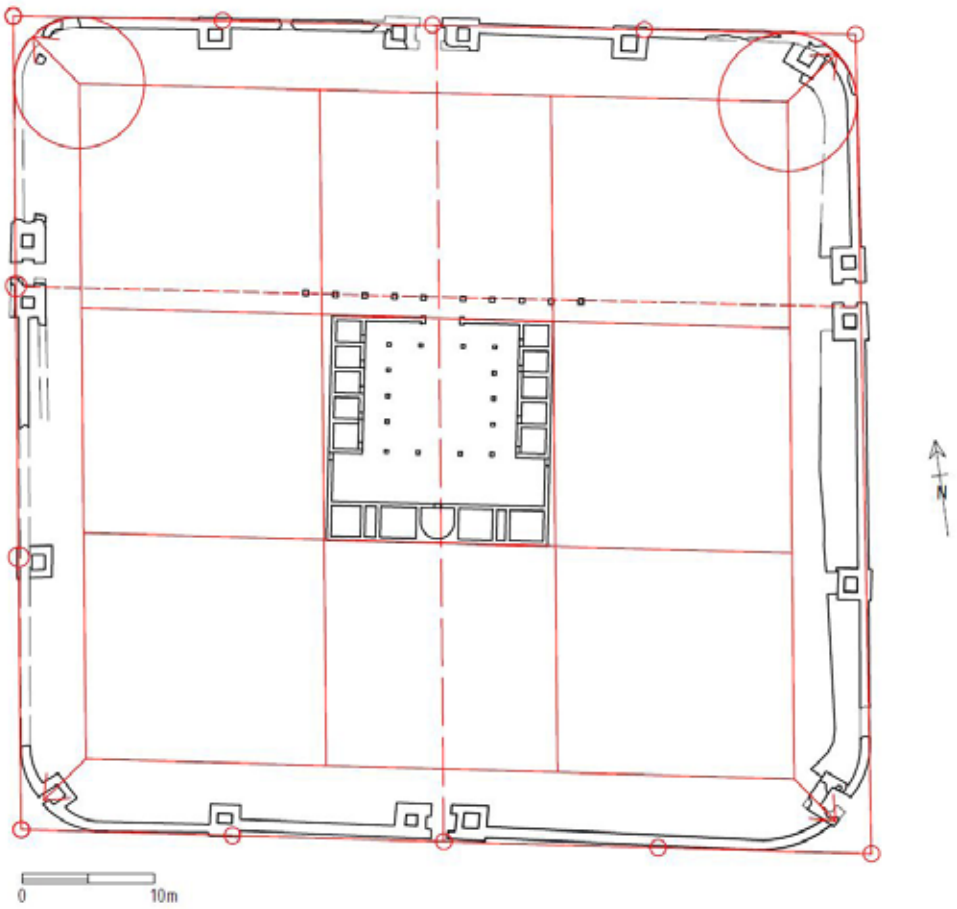

Fig. 3 The plan of castrum Pontes with the positions of fortifications and the building of principia with the geometrical relations of the castrum plan.

surement, which was a common case in the period of antiquity when using hand instruments at a great distance (Taylor 2003: 66). Therefore, it seems that castrum fortification walls were not built on an accurately rectangular plan. Also, the positions of the western gate Porta Principalis Sinistra and eastern gate Porta Principalis Dextra were determined at the same angles (Fig. 2).

Behind the fortifications of Trajan's castrum Pontes and their associated ager, there was an intervallum, unburdened by built structures. With it, the fortifications and the ager were separated from the building structures inside the camp. During research, the northeast corner of the officer's building (Pretoria?) was registered, which established that the inner border of the intervallum from Trajan's time was 9 m distant from the inner face of the ramparts (Petrović, Vasić 1996: 25; Vasić, Kondić 1986: Fig.4). Within the space enclosed by the intervallum, the buildings of the auxiliary garrison of Pontes were planned to be placed. Observing the internal arrangement of the castrum, it can be noticed that its internal space under the built structures was in the shape of a rectangle, very close to the shape of a square. Its plan can be divided along the length (in the north-south direction) into three equal parts - northern, central, and southern space. In the western-eastern direction, the camp was divided into equal halves (Fig. 3). At the current level of research of the route of the castrum ramparts, it seems that concerning the extreme corners of the rectangular interior space, the most protruding corner points of the Pontes fortifications have been determined. The distance

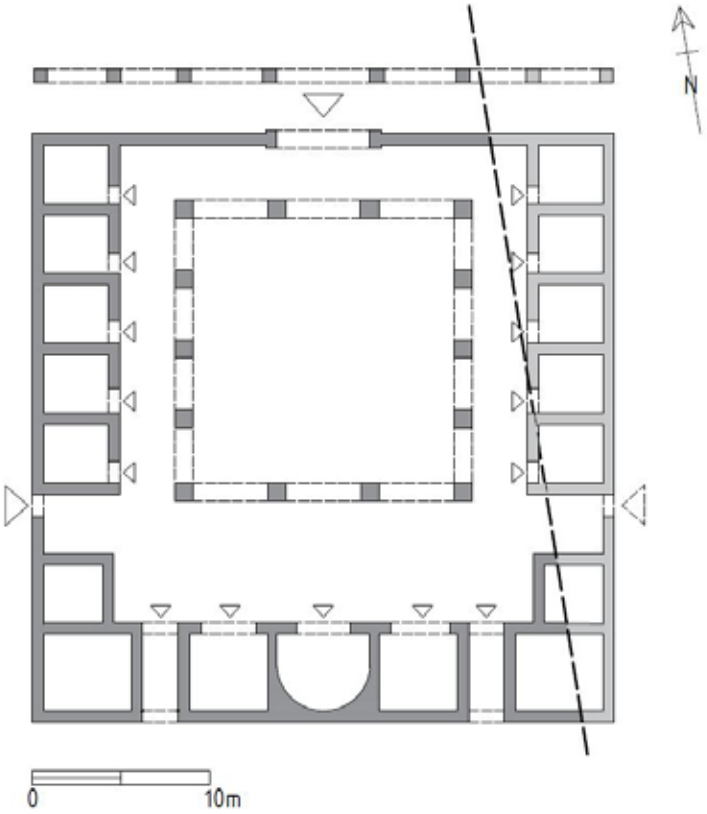

Fig. 4 The reconstruction of the plan of Principia in the castrum of Pontes (the author's drawing according to the Doc. of the Institute of Archaeology, Belgrade and Petrović, Vasić 1996. Fig 2.)

between the internal built space and the route of the outer face of the ramparts has the value of the radius of circles (Fig. 3), along which the route of the ramparts at the corners was defined, at least on the north side of the castrum.

The division of the interior into three parts was common for Roman camps but did not always imply an equal width of the mentioned areas (Campbell 2009: 32-34). The central space is divided by width into three equal squares, and the surface of the central square is occupied by the principia building (Fig. 3). The fact that the principia building occupies the area of the central square with its outer enclosing walls indicates that its position and size were determined simultaneously when planning the routes of the Pontes fortifications. The size of Roman principia at Pontes (1093, 92m2) is one fourteenth of the size of the castrum (1,51ha), i.e. it occupies 7% of the fort surface[1]. Roman castra from the period of the I-II century at the Iron Gate show a similar relationship of size towards the buildings of principia (Milošević 2004: 50, 57, 62). The same circumstance applies to forts on the territory of Roman Dacia and Britannia (Marcu 2009: 213, 227 with the ref. 1662).

DIMENSIONAL AND FUNCTIONAL ANALYSES OF PONTES RINCIPIA

The building of principia was discovered in the center of the Pontes castrum, as part of the oldest stone phase, (Petrović, Vasić 1996:24). The principia building inside the Pontes castrum has been explored for the most part (Fig. 4). Only part

1 In earliar papers, the size of castrum was calculated according to the overalll width and length of the castrum to 1,6ha. However, the size of Pontes castrum plan is a bit smaller - it is 1.5ha due to the rounded corners of its fortifications. (Гарашанин, Васић 1987: 80; Milošević 2004: 53).

of the eastern rooms remains unexplored. If we consider the ideal north-south direction, the direction of the eastern side of the principia has a deviation at its north end of 9° to the east, as is the case with the entire castrum. [2] However, the deviation of castrum ramparts is connected to the irregular shape of the castrum plan, while the deviation of the principia is connected to deviation i.e. rotation of the whole building in space, with very regular angles in the plan of the building.

The building of the principia is of a regular rectangular plan in shape. A review of the available archaeological documentation established that the size of the building was 32.86 × 33.48 m. As already mentioned, there are no deviations from the right angles in the plan of the facility, which shows that its construction was much more regular concerning the whole castrum.

The investigated (larger) part of the principia indicates that a square courtyard surrounded by a colonnade was developed in the center of its northern part. Along the lateral sides of the courtyard, a series of rooms of equal dimensions extended into the northern part of principia. At its southern part, along the south side of the courtyard, a large hall was built. Behind the hall, a series of rooms flanked the central one, which had an apse. To the east, rooms are registered at the same distance from the courtyard colonnade as those in the west. The same is the case with the layout of the southern rooms. The eastern explored part of the rooms in the south had a symmetrical arrangement like the western part of these rooms concerning the central room and the building axis of symmetry. The entrance in the principia is also placed centrally concerning the visible width of the courtyard with the associated porticoes. The width of the entrance to the principia building is 5.25 m. All the above data indicate that during the reconstruction of the principia plan, symmetry had to be taken into account in the plan of the building towards the north-south direction with the already mentioned deviation of 9° to the east.

On the west and east sides of the northern part of the building, there are five rooms planned in a row. The width of these rooms is the same - 3.65 m (Fig. 5). The other interior dimension of the room is 3.3 m. The concept according to which they are designed is uniform - the entrances to each of the rooms are designed so that one doorframe rests on the transverse wall between the observed room and the next.

Towards the interior of the rest of the northern space, a portico was planned, about 3.1 m wide, from the outer face of the room wall to the inner face of the columns. It was supported by carved columns: a base with associated toruses, trochilus, and a plinth was found of one of them. The columns of the eastern and western parts of the portico are projected in the axes of the transverse walls of the rooms along the western and eastern enclosing walls of the principia so that there are five of these on each side. However, on the north side of the portico, as well as on the south, there were four columns each.[3] The two central columns on the north and south sides are connected to the directions of the door jambs at the entrance to the building, the pillars on the outside of the porch, and the directions of the walls of the central room at the southern end of the principia. The reason for the wider distance between the columns and entrance jambs on the north and south sides was the dominant communication in the north-south direction, where the basilica and the sanctuary

2 The thickness of the above-ground parts of all walls is about 0.6 m, while the width of the foundation parts of the colonnade of the inner courtyard is about 1 m. During the research, no particularly pronounced fundamental expansion concerning the above-ground parts of the walls was noticed. On most of the walls, it was either uniform with the facades of the walls or protruded only a few centimeters. (Petrović, Vasić 1996, 25). Data on the dimensions of the walls and certain details of the Principia were obtained according to the technical and photo-documentation of the Archaeological Institute in Belgrade and the kind statements of MilojeVasić, to whom I would especially like to take this opportunity.

3 According to the technical documentation of the Archaeological Institute in Belgrade, on the north side of the porch, the eastern column of the two central columns of the porch on this side was found, which is in the axis of the eastern door jamb of the north wall of the principia.

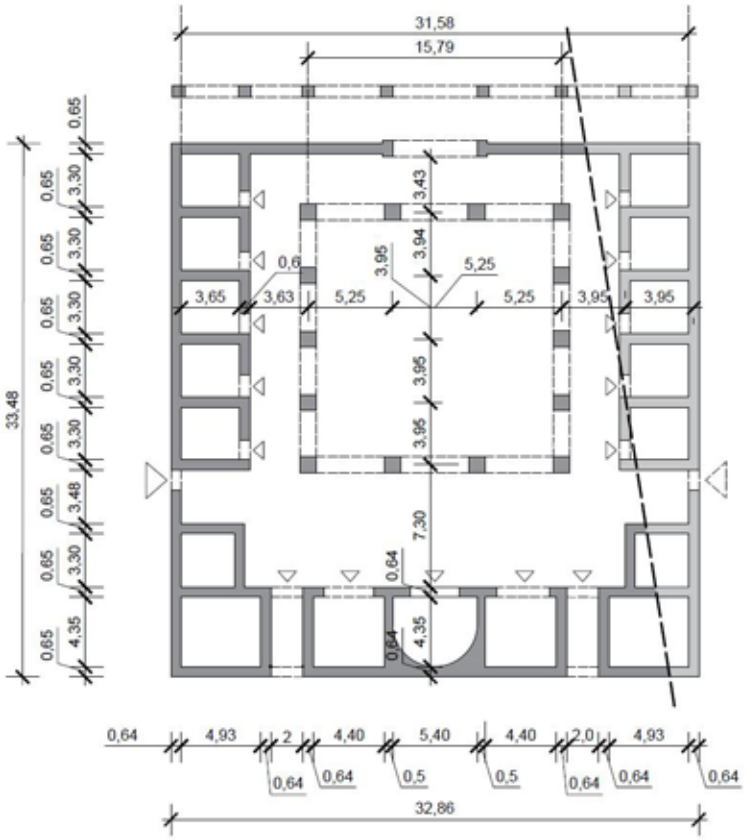

Fig. 5 The reconstruction of the plan of Principia in the castrum of Pontes with metric measurement of the plan elements (the author's drawing).

are the main focal centers on the way from the entrance to the principia. The width of this north-south communication was adapted to the width of one of the main communications within castrum – the Via Praetoria.

Within the rooms in the south, the central room stands out with its shape and position. The apse is defined on the south side of this room, while the northern half of its plan is characterized by right angles. This room is also placed on the axis of the north-south direction, as well as the entrance to the principia, which again shows its symmetry. The room is preserved at the level of its foundations, and it can be concluded with sufficient certainty that the entrance to it was placed in the axis of the north-south direction. To the left and right of this room, other rooms in a row along the south wall were spotted. According to the available technical documentation, the entrance to the room west of the central one was very wide - about 3 m (Petrović, Vasić 1996: Fig. 2).

Between the rooms along the southern facade of the building and the northern half of the building, there was a space with an impressive width of 7.30 m. The length of this space was equal to the length between the walls of eastern and western rooms of the principia turned to the portico. This area was surrounded by walls, except in the central part of the north side, where it relied on the four columns of the portico.

The functional and spatial organization of this building corresponds to the standard organization of principia buildings from the time of the I and II centuries (Johnson 1983: 104-119). According to that organization, the central part of the space is occupied by a yard that was surrounded on three sides by porticoes and rooms. On the left and right side of the yard, there were smaller rooms, which, according to older researchers, were designated as storerooms for ammunition - *armamentaria*.

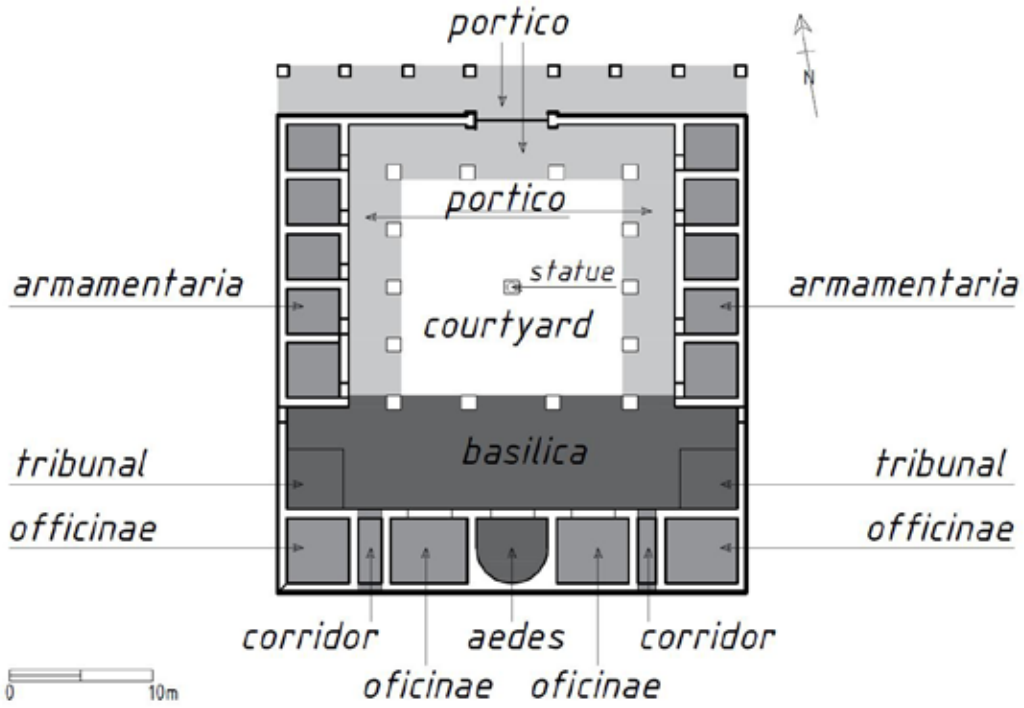

Fig. 6 The reconstruction of functions of separated rooms within Principia of the castrum of Pontes.

Recent reinterpretations in Romania regarding the functions of these rooms indicate that according to the area they occupied, they could also have served as administrative rooms or workshops in fortifications that were chronologically and structurally close to Pontes (Marcu 2009: 39, 73, 131-132, 214, 229-230). As part of a series of rooms in the south that had an administrative purpose, Vasić defined the function of the sanctuary for the central room (Petrović, Vasić 1996: 25), which fits in with the general planning pattern of the principia of Trajan's Time (Johnson 1983: 104).

In addition to the conclusions of earlier researchers regarding the functions of individual rooms, the purposes of other rooms and spaces within the principia can be determined (Fig. 6). The above-mentioned space opposite the entrance was a hall (*basilica*), a more monumental part of the principia according to the span of over 7 m. North of the western corner room within the southern row of rooms, in the area with the side passage that leads from the basilica to the street west of principia, a construction of weaker material was found on the floor. This construction corresponds to the tribunal (*tribunalia*) - the place for the commander on the raised platform. Traces of a similar construction exists on the opposite, eastern part of principia as well. Its position is identical chronologically and architecturally with close examples in Romania, as in similar examples of auxiliary principiae:Drobeta, Gilau, Racari, Slaveni, Buciumi (Johnson 1983: 111; Gyemant, Gudea 1983; Marcu 2009:73). The narrower spaces located between two wider rectangular rooms within the southern row of rooms served as corridors, which led out of the principia.[4] According to the proximity of the tribunal and the larger number of exits concerning the rooms in the southwest and southeast corner, there is a possibility that people stayed in them more often than in other rooms. It was a

4 Identical corridors were found in chronologically and constructively close examples of the prinicipiae to the auxiliary fortifications in Romania (Marcu 2009: 132, 215). Similar corridors can be observed in much larger sets of command buildings, such as in Lambaesis.

common practice in Roman principiae to plan a hypocaust system in these rooms at that position later or during construction so that the degree of comfort within these rooms was higher. For these reasons, it should be taken into account that the commander-in-chief of the garrison was housed in such a room (Marcu 2009. 39, 73, 214-215).

As was mentioned in the introduction, the investigated part of Pontes Principia indicates an almost identical solution to Principia in Drobeta. Although other examples of principiae have been explored along the Serbian bank of the Danube, their proportions in detail differ significantly from the applied plan of principiae on Pontes (Petrović, Vasić 1996: 23-25). The similarity of the principiae in Drobeta and Pontes is especially related to their internal organization. This circumstance can suggest that the plans of these buildings in the two camps that belonged to the ensemble of the bridge were part of the same concept. Here, it is difficult to distinguish if this concept was of strategic (military) nature, architectural, or if it included both of these reasons. In any case, here we do not have enough evidence to claim that either of these reasons was crucial in the building concept of two castra and theirs principae.

PROPOSED SCHEME OF DIVISION FOR THE PRINCIPIA SPACE

The symmetry of the principia building in Pontes and the pronounced similarity between it and the one in Drobeta contribute to the reconstruction of its plan. With the present symmetry in the plan, right angles, and parallel walls, the more elaborated analysis of the graphic plan according to which the building in Pontes was designed can be justified. Some details indicate a high degree of regularity, such as the square shape of the plan of the central courtyard and the position of the columns of the courtyard porticoes.

The mentioned regularities indicate the possibility that a certain type of scheme was used in the graphic design of the plan of the building. Certainly, one question is the reason for the builder's need to adopt a certain scheme as a template. The intentions of the ancient builder were manifested not only through the adoption of the scheme as a certain template but also through the process of rational adaptations which deviated from the initial scheme. That the mentioned process was current in antiquity is indicated by the unavoidable architectural manual of that time. Vitruvius explained the correctly performed ancient procedure of planning a building so that at the beginning of the process a systematic scheme based on a unit of division is created. In the second step, Vitruvius indicates that any adaptation of the plan is allowed, according to the nature of the site (i.e., minimal deviation from the given scheme), as long as it does not affect the proper appearance of the building (Vitruvius (2006): book VI, chapters 1 - 4). Therefore, in the process of analyzing the degree of regularity of the plan according to which the principia was built, we should certainly start from the most regular form and go to less regular forms in further analysis.

It is important to take precautions when the analysis of the graphic design of the plan of the building is in issue. Setting out the plan of the building on the ground was done by using graduated rods for measuring, a set square (norma) and groma for determining right angles, sweeping cords for circle segments, a longitudinally carved rod with water in its channel for determining the horizontals, etc. Although there was a standardized tool, there was no standardized Roman way of design and measuring on the ground. The archaeological and architectural evidence also shows that the importance of a project was not a guarantee of higher standards for precision and accuracy. Markets of Trajan in Rome, a plan of the mausoleum of Maxentius, and the Baths of Caracalla are just some examples of such imperfections (Taylor 2003: 66, 69, 70). Additional measurements on long distances and angles could suffer from accumulated errors. Often, according to the previous Vitruvius recommendation, the builders adopted

– changed a bit, the planned measures on-site.

To interpret the measurement of the building of principia, I applied several approaches. The first one was to take as many measurements as possible (length, width, thicknesses of the walls, axial distances) to find if there is a regularity among them. The second approach refers to taking overall long distances, since there is a greater possibility that there is an accumulated error made by the addition of small measurements. Besides this, a difference must also be made in the interpretation of the position and type of some architectural elements. It is not the same if we consider the border architectural elements or within the plan of building. Also, a difference must be made in the measurement of the walls and columns. If we assume for example the columns in the courtyard, there is evidence that their foundations were of almost a meter wide, while carved columns above the ground were much thinner in their diameter. The builder could not rely on the further measurement on the dimensions of the foundation above the ground level, so the planning of the courtyard must have been subjected to this circumstance. Therefore, if we want to interpret the measurements in the courtyard, the right dimensions would not be the widths and distances between the foundations of columns, but the axial distance between the columns.

The rectangular shape of the whole building in the plan (not counting the outer portico towards Via Principia) measuring 32.86 × 33.48 m indicates that there is a slight difference between the width and length of the building. The regular square form of the plan of the central courtyard imposes the definition of the beginning of the analysis for the plan of the principia. Concerning the enclosure of the central courtyard, the number of supporting columns of the surrounding porticoes on each of the parallel sides is symmetrically solved to the two axes of symmetry placed in the north-south and east-west directions. Such symmetrical determination of the position of the constituent architectural elements would not be related to the whole plan of the Principia, in which there is only one axis of symmetry –the north-south direction.

The width of the *armamentaria* on the east and west sides was harmonized with the mutual distance of the columns in the courtyard. The *armamentaria* rooms are of the same individual lengths and widths. The width of the *armamentaria* rooms is 3.30m, while the thickness of the walls between them is 0.6 - 0.65m. This determines the axial distance between the dividing walls of armamentaria as 3.90 - 3.95 m. The same can be applied to the length of the rooms.

It has already been emphasized that the columns of the central courtyard are precisely defined in the axes of the transverse walls between the rooms of the *armamentaria*, which means that the value of 3.90-3.95m corresponds to the distance between these columns. The length of the central yard (from the axis of one column to the axis of another one) is 15.75m (53 Roman feet). The mentioned range of values expressed in meters fits the value of 13 ¼ R, where R denotes the Roman foot, which in the metric value system would be 0.296-0.297m. Value from 13 ¼ R for the distance between columns indicates that the mentioned measure was obtained by dividing the length of the central yard of 53 feet into four parts.

Similar dimensional relations have been registered between the axes on which the porch pillars are located and the axes of the front walls of the *armamentaria*. The sum of half the width of the foundation of the pillars, the width of the porch, and half the thickness of the front wall also has a value of 3.90 m. At the same time, the sum of half the thickness of the front wall and the width of the interior space of *armamentaria* has a value of 3.95 m.

It is noticeable that the thickness of the western and eastern wall of the Principia is not included in the mentioned calcuation, because otherwise there would be a departure from the value of 3.90-3.95 m. A similar situation can be noticed in the position of the southern wall. The Roman builder must have had clear reasons for the obvious repeating

of a value of 3.95 m (13 ¼ R) within the space of the building and the departure from this value at the plan borders of the building.

The reason for this inconsistency is the deviation of the whole building within the planned central space of the principia in the Pontes castrum plan. The imperfect angles of that central space are equal to the angles between the ramparts of the castrum (89 and 91). These angles caused the difference of two Roman feet between the length of the principa plan and its width . Within borders of the imperfect central space of the castrum the outer faces of all four walls of Principia are defined (Fig. 3). That implies that builders could define the interior arrangement within a space which is smaller by the value of the thicknesses of the western and eastern walls. This explains why the thickness of the western and the eastern wall of the principia was not included in the building concept, according to Vitruvius' recommendations that any adaptation of the plan is allowed according to the nature of the site (in this case to the geometry of central space of castrum). The evidence for this building concept is the fact that the length between the inner faces of the western and eastern wall is exactly twice that of the axial length of the courtyard (Fig.5).

The mentioned division of space into a certain number of squares 3.90-3.95 m wide can be traced on the example of the axial width of the basilica. In that case, the clear width of the basilica space of 7.30 together with half the thickness of columns and room walls gives a sum of 7.90 m, which totals twice the value of the length of 3.95 m.

When it comes to the width of the rooms in the south, we must start again from the dimensional division of the square of the central courtyard. In the previous analysis, we saw that the geometric division of space along the east and west sides of the Principia depends on the distance of the axes of the columns in the central square courtyard. These axes are established on its east and west sides. There was no difference with the division of rooms in the south. Their width depended on the distance between the axes of the columns of the central courtyard on its southern side. The value of 5.25 in the modern metric system coincides with the value of 17 2/3 expressed in Roman feet, which is obtained by dividing the length of the central courtyard of 53 Roman feet by the number three. The width of the entrance to the Principia building was adjusted to a distance of 5.25 m. The depth of the southern rooms was also determined by the same value so that the route of the outer face of the south wall of the Principia was determined at a distance of 5.25 m from the axis of the south wall of the basilica.

The relationship between the width of the central courtyard and the width of the principia explains how the principia was planned (Fig. 5). According to the graphic plan defined by previous analyses, the width of the central courtyard is twice as small as the inner width of the principia. The distance between the individual structural elements in the north-south direction is defined in the value range of 3.90-3.95 m. Around the smaller square which defines the route on which the axes of the columns of the central courtyard are formed, two larger ones are formed. On the route of the first larger square, the front walls of the armamentaria and the north wall of the Principia were determined. On the route of the largest square, the width of the outer porch towards the Via Principalis was determined, then the inner faces of the eastern and western walls of the Principia and the axis of the southern wall of the basilica, i.e. its width (Fig. 7b).

From the previous analysis, a different division of the sides of the smallest square is noticeable, which defines the shape of the central courtyard. The division of the square in the plan of the inner courtyard into three parts in one direction, that is, four parts along the other direction, is not the only one in terms of the Pontes castrum. If the plan of the entire fortification is observed globally, we will notice that both the western and eastern ramparts are divided into three parts, while the northern and southern ramparts are divided into

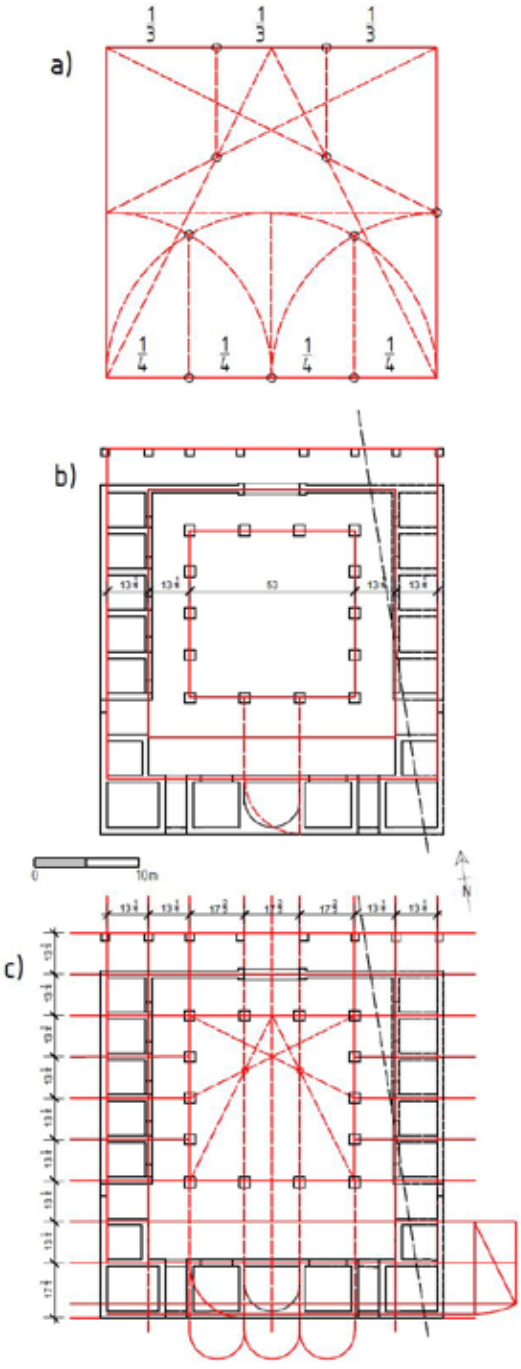

Fig. 7 Geometrical division of Principia space: a) the concept of geometrical division of square edges to its thirds and quarters; b) reconstructed initial scheme based on the geometrical relations between three squares; c) proposed initial scheme of division for the Principia space.

four parts (Fig. 3). The division was established by the positions of the main gates of the castrum and the positions of the towers. Thus, the division of the sides of the square according to the ratio of 4:3 was valid both for determining the position of fortification elements (towers) within the entire defense system of the castrum and for determining the architectural elements (columns) within the most important command building such as the principia. The geometric division of the sides of a square into a different number of parts along two directions could be done as shown in (Fig. 7a). The width of the central rooms in the south is harmonized with the spacing of the columns on the south side of the central courtyard. The depth of all the rooms on the south side is equal to the width of the intercolumnia on the south side of the basilica, as can be seen in the proportions represented in the room west of the aedes (Fig. 7c). It can be seen in (Fig. 7c) that most of the proportions within the building of the principia came from the relation 4:3. The size of the outer faces of both of the tribunals is adapted to the division of widths of armamentaria. The width of corridors is equal to the half of the width of the intercolumnia on the south side of the basilica.

The principia at Pontes, although classical in its design conception for Roman buildings of this type, is distinguished in its plan by a certain effort of its builders to achieve special relations of geometric regularity (Fig. 7c) That is why the Pontes Principia is convenient as a case study for analyzing the extent to which the regularity of its plan influenced social actions and communications within the building itself. For the needs of this type of analyzing buildings in general, special software has been developed in the field of architecture.

POSSIBLE RELATIONSHIPS BETWEEN THE SPACE OF PRINCIPIA AND ITS USERS

The space of the building of principia can be researched by applying the analytical theory of architecture, where the influence of the architecture on its user's behavior is considered (Turner 2002). In other words, we can quantitatively represent qualitative values in architecture, and thus the impact of architecture on user behavior in space (Varoudis 2012). Computer analysis of space is necessary nowadays because the human eye can consider only one position to the rest of the space in which the user operates, while modern software achieves simultaneous interaction of all points on the user in a given space. For such purposes, the analytical method of architecture implies the application of the theory of space (the so-called space syntax) and visibility graph analysis (VGA). Space syntax is defined as a set of analytical, quantitative and descriptive tools for analyzing the layout of space in buildings and cities i.e. the relationships and rules of behavior that space imposes (Hillier, Hanson 1984: 48-51). It is understood that spatial syntax is composed of elementary combinations, elementary objects, relations, and observations (Hillier, Leaman, Stansall, Bedford 1976: 151).

DepthMapX is one of the software packages specialized for the analysis of spatial syntax and the impact of space on social action (Al Sayed 2014: 30). When analyzing the software, the focus is on variables that indicate the social significance of the space, in this case of one Roman castrum principia. By integrally considering the interrelationship of individual sets of points with the rest of the space, the DepthMapX - software singles out certain regions in which the social behavior of users is more or less pronounced. Examples of such regions are communication axes, different regions in which visual communication is more pronounced, remote spaces, and those in which communication is either direct (ie. Physical) or indirect (ie. only visual).

The basic quantitative categories that define the impact of space action on social action are Isovist area, Connectivity, Visual Integration, Mean Shortest Path (Varoudis 2014: 298). A square grid in the software package divides the analyzed space into many small fields, i.e. points. During analysis, the positions of communications (doors and other openings) and obstacles (walls and pillars) must be marked. Each of the values is measured by the number of influences of individual points to the rest of the space.

The geometrically limited part of the space with which the immediate view from one point is realized concerning the visual obstacles is called Isovist. If a certain number of isovists are registered in certain areas, those areas are referred to as Isovist areas (Benedict 1979: 47). The number of physically direct connections that individual points have with the surrounding points in the considered space is considered within the category of Connectivity. This is especially important in the case of analyzing the availability of information by moving users from one space to another. If the user receives less information on that occasion, it affects his slower movement, because he has to visually look for information before moving to the next part of the space. Slower movement directly affects the reduction of the amount of user information in the next radius of action. Circular plans of space (for example conchs) offer less loss of information compared to other forms of plans since there are no corners that visually obscure any new information within a particular space. The visual connection of certain spaces between which there is no direct physical connection is defined by the size of Visual integration (Rohloff, Psarra, Wineman 2009: Ref.094: 03-05). Through the Mean Shortest Path category, the required number of steps in the movement of users is considered to achieve visual accessibility of the location with other spaces. It is directly proportional to the number of changes (i.e. the number of combinations) of the directions of action of the movement so that the number of steps is proportional to the depth

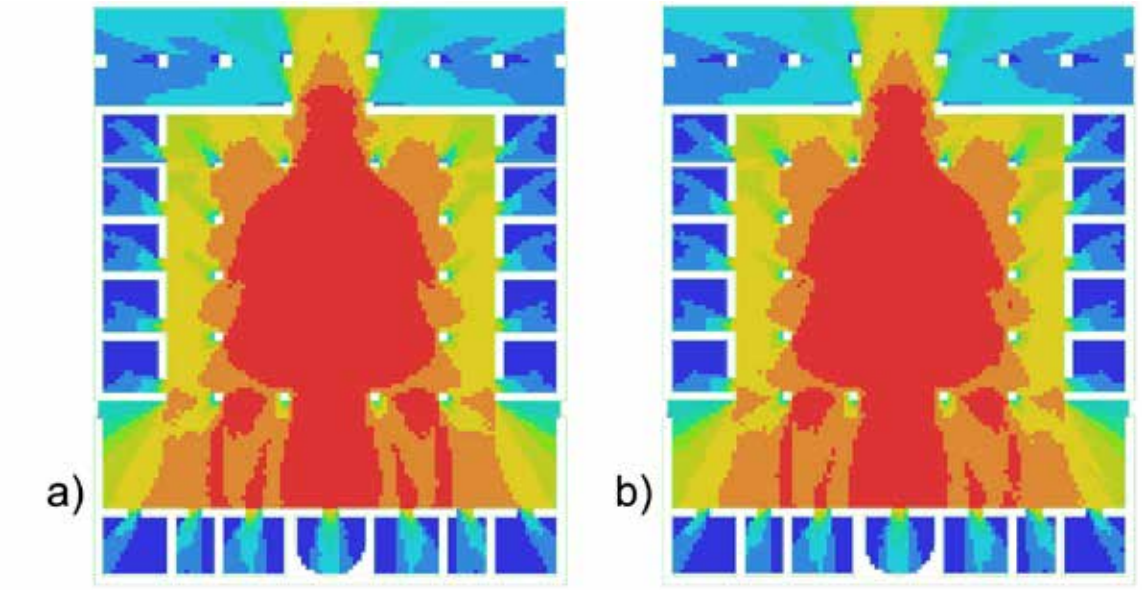

Fig. 8 The visual and physical communication graphs in the conducted state of Principia:
a) Connectivity graph; Isovist area graph.

of vision. The global relationship of one part of space to others is better considered in the case of this category than is the case with Connectivity, which defines exclusively physical contact that offers the mutual relationship between individual spaces (Varoudis 2014: 298; Turner 2003: 663).

The mentioned categories do not have certain units of measurement, because they represent the relationship between sizes of the same character. The numbers that are defined by them represent an overview of the measures of influence in the displayed space, which serves to compare the social influences in a given space. As the most suitable form of presentation for such a comparison in DepthMapX, a graph has been designed where the given color spectrum highlights spaces with more or less pronounced influences of the mentioned sizes. The color range is linearly adapted to the observed categories from its minimum to its maximum values for each point in the specific part of the building plan. Maximum values are expressed in red (the warmest), minimum values in dark blue (the coldest), while the average values are expressed in dark yellow. Other values can be easily calculated from this kind of color range in the graph representation.

The analysis of the Pontes Principia in the selected software brings with it certain specifics. Individual spaces (such as, in our case, the space of the tribunal) do not play a greater role in physical and visual communication but they are understood as an integral part of a larger space (in this case the hall/basilica). When choosing the thickness of the barriers (walls and columns), a correction in the graphical appearance for DepthMapXhad had to be made concerning the remains of the principia, which is mostly preserved at foundation level. Although the walls were almost the same thickness in the foundation and above-ground part, the thickness of the foundations for the supporting columns of the inner courtyard colonnade was much larger than the width of the columns in the above-ground part, and above all in the height of the man's field of vision. Since fragmentary parts of the columns on Pontes remained, the same width can be preliminarily adopted for their thickness as in Drobeta, which is about 70 cm (Marcu 2009: 132).

We will analyze the principia within two scenes. The first one shows the real plan of the building, while the second one is connected to the equal numbers of columns on all four sides of the inner yard as an imagined variant.

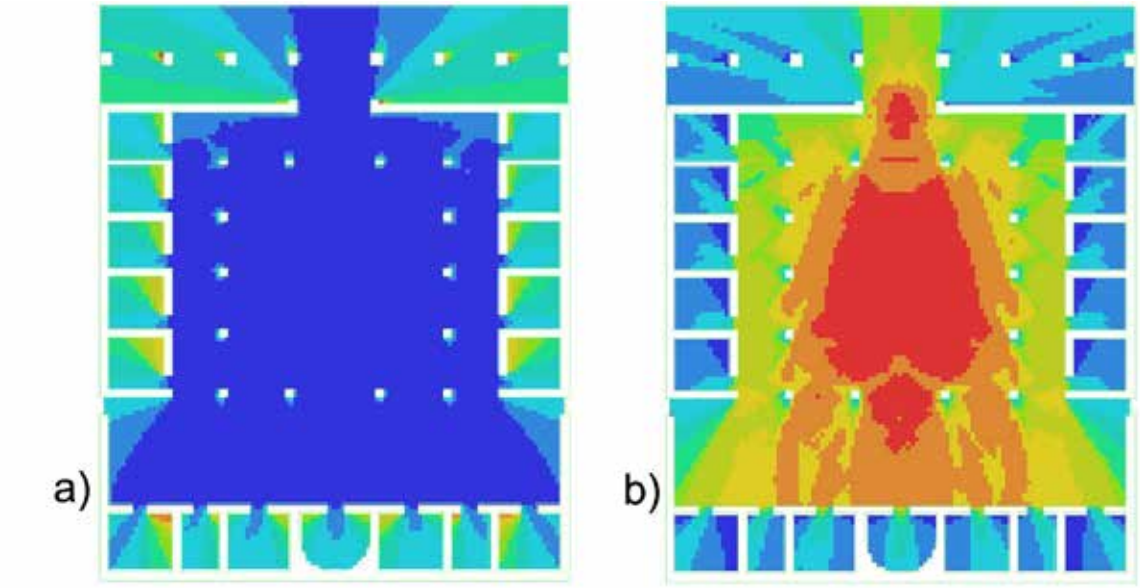

Fig. 9 The visual and physical communication graphs in the conducted state of Principia:
a) Mean Shortest graph; Visual Integration graph.

The graphs for Isovist areas (Fig. 8b) and Connectivity (Fig. 8a) in the first scene (Scene 1) show similarities, although their values differ significantly. By observing the graph for these quantities), the degree of isolation of each of the smaller rooms within the building of the principia is observed. The values that are present for these quantities in the space of the hall (basilica) are almost indistinguishable from those that are present in the space of the inner courtyard of the principia. Within the basilica, outside these values, only the spaces near the side doors of the principia stand out. The expressed minimum values for Isovist areas and Connectivity are characterized by the armamaentaria rooms, while the expressed maximum values of these quantities are characterized by the north-south communication axis. Graphs of both sizes indicate the extent to which the appearance of columns in the inner courtyard affects the visibility of the space inside the porticoes and the inner courtyard. In this regard, certain values of the magnitudes on the route of the columns vary precisely, depending on how close they are to these structural elements. Although these are very slim supports in relation to the building plan, direct communication (Connectivity) is difficult between users inside and outside the courtyard (Fig. 8a) because of the views (Isovist) from individual points that are interrupted (Fig. 8b). When it comes to the size of Mean Shortest Path – Angle, values indicate qualitative characteristics that are practically inversely proportional to the previous ones (Fig. 9a). In the graph for the Visual integration category, most of the maximum values are concentrated towards the central part of the inner courtyard in the width of the central pillars on the north-south route (Fig. 9.b.). At some points on the same route, a sporadic occurrence of maximum values occurs. The rest of the inner courtyard is characterized by slightly lower values, and the maximum values also appear inside the hall space in the width of the courtyard. The mean values of this size are more present in the area of the porticoes around the courtyard, as well as in the rest of the space of the hall, excluding the space along the side exits from the principia.

A different solution in the second scene (Scene 2) can be considered, in which there is an equal number of columns in both directions (Fig. 10, 11). The numbers that are defined in both cases by the considered categories are represented in Table 1. For each point, the number of Isovist views

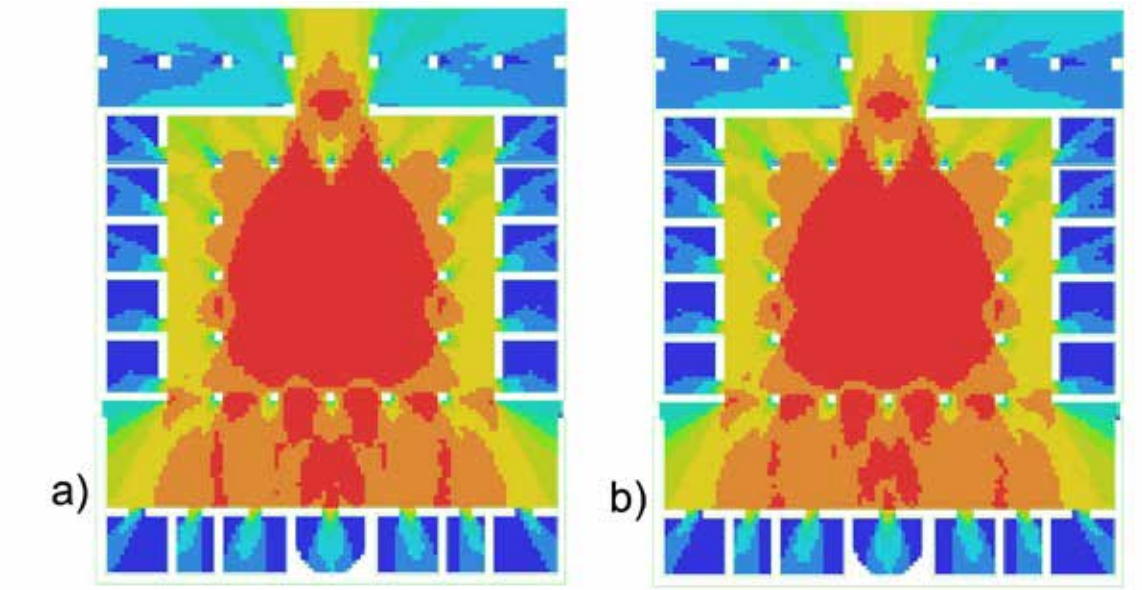

Fig. 10 The visual and physical communication graphs in an alternative solution of Principia plan: a) Connectivity graph; b) Isovist area graph.

it can cover is calculated. Within the category of Connectivity, the number of physically direct connections that individual points have with the surrounding points in the considered space is calculated. The number of visual connection between each point where there is no direct physical connection is calculated by the size of Visual integration. Within the category of Mean Shortest Path, the required number of moving steps is calculated to achieve visual accessibility of the location with other spaces. It is noticeable to what extent the space of the basilica loses its connection with the inner courtyard. It is also clear that there is a break in the clear north-south communication towards the sanctuary of the principia (Fig. 10a.), while at the same time there are some losses in terms of visibility of the entrance to the southern rooms (Isovist areas) (Fig. 10b).

Since the Mean Shortest Path directly observes the movement of users in space, the appearance of columns in the courtyard and hall space is not a significant factor for different values to appear within these two spaces, which was not the case with previous categories (Behbahani, Gu, Ostwald 2017: Fig. 1). The same minimum values for this quantity are read on the entire north-south communication route (excluding the sanctuary) (Fig. 11a). A larger change is noticeable in the part of the visual integration of the basilica space with the central courtyard in the case of changing the number of columns. Comparing with the previous existing solution (Fig. 9b), in an alternative solution, most shades of warm colors take cooler tunes and show smaller values (Fig. 11b, Table 1).

INFLUENCE OF BUILDING GEOMETRY ON THE USER

Concerning the specific arrangement of physical and visual barriers, the function of the rooms, and the geometric relations that prevail in the plan of the Pontes Principia, the mentioned analysis indicates the characteristics of the whole building as well as its components in terms of possible user behavior.

Within principia, in smaller rooms, visibility and communication are obscure, which is especially noticeable within the side rooms of the armamentaria, where the entrances are leaning against the transverse walls. Therefore, these rooms could not serve any greater communica-

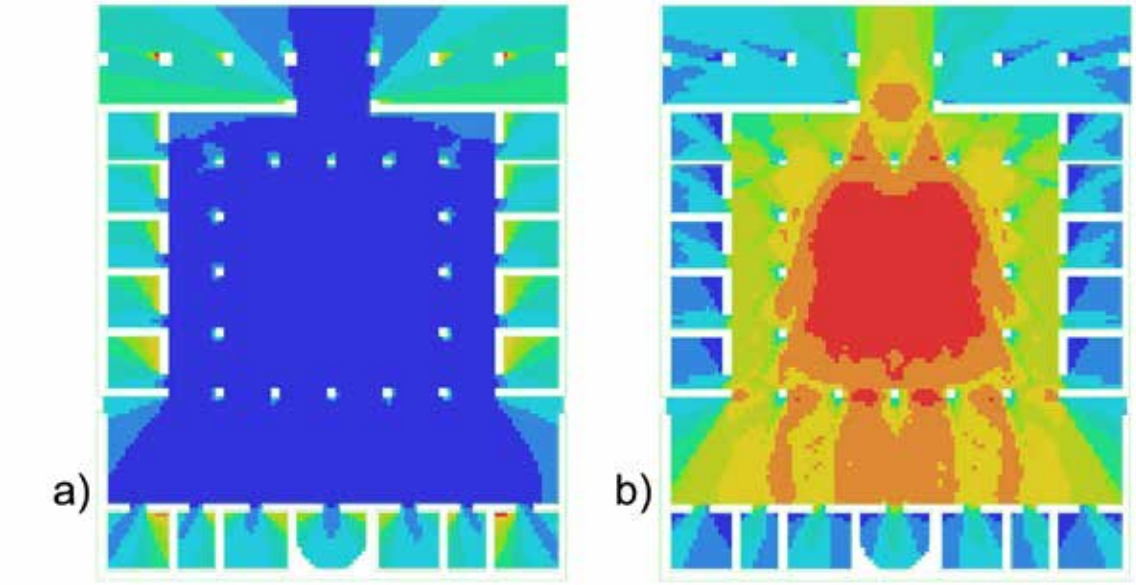

Fig. 11 The visual and physical communication graphs in an alternative solution of Principia plan: a) Mean Shortest graph; b) Visual Integration graph.

tion, so they did not suit a larger number of users within them, and the possibility of efficient distribution within them was relativized if they were weapons depots. Therefore, in the author's opinion, the possibility remains that these rooms could also have served as administrative ones.

According to the expressed values of the considered sizes in DepthMapX, when speaking about Scene 1, in contrast to the isolation of previous rooms, there is a pronounced visual and physical connection between the space of the basilica and the inner courtyard. The values for the Connectivity and Visual Integration (HH) categories that define physical and visual communication at individual points within these spaces are not equal to each other. The communication on the north-south route is clearly emphasized in that area.

In addition to the existing solution, an alternative was considered, where a statically more favorable solution would be applied on the north and south sides with a larger number of supporting columns of the basilica (Scene 2). That number would be equal to the number of columns on the sides of the courtyard. In the alternative solution, the values of these quantities were analyzed in the case when there are five pillars along all sides of the inner courtyard. It is noticeable that the greater distance of a smaller number of columns in the existing solution on the north and south sides contributes to better visual and physical communication. The specific distance of the columns of the hall on the north side conditions the radial expansion of the view from the access part of the principia to the south wall of the basilica, which achieves direct visual communication to the entrances to the south rooms. The derived solution emphasizes the north-south communication and improves the visibility between the entrance part of the building with the sanctuary and other rooms in the south. The variant with a larger number of columns would significantly jeopardize the communication of the basilica with the central courtyard. The space of the hall was characterized by undisturbed communication and visual inspection. Its architectural structure enabled it to serve as a meeting place for the entire commander-in-chief. Its connection with the inner courtyard is especially pronounced. With the applied solution of the plan on Pontes, there was direct physical and visual communication with Aedes. The spiritual center of the principia, but also for the entire Pontes castrum, was certainly in the sanctuary room, which

Scenario		Node Count	*Isovist areas*	*Connectivity*	*Visual integration*	*Visual Mean Shortes Path*
Scene1	Min	12794	10.9343	120	5.8394	0.134763
	Aver.		408.238	45720.03	17.7024	0.404552
	Max		684.376	7638	27.2449	1.85267
Scene2	Min	12788	10.9463	120	5.83558	0.138346
	Aver.		392.878	4397.76	17.1032	0.407653
	Max		663.207	7402	26.1624	1.84938

Table 1 Overview of DepthMapX values of the impact of space on social action for an existing (scene1) and alternative solution (scene2) of principia space.

was placed on the dominant axis of communication in the north-south direction.

Analyses of visibility graphs and visual communication are very important for better determination of functions and communications in the corner parts of the principia on the south side. They indicate specific relations on the above issues in the case of the side (east and west) doors, the tribunal area, and the corner rooms in the south with the southern corridors. On all analyzed graphs, there is a noticeable deviation of the value of visual and physical communication in the area around the side door of the principia (on the west and east side) to the rest of the hall (basilica) space. The western side door was very close to the tribunal, sufficiently hidden concerning the main entrance and to the visual connection with the other spaces. The position of these doors and corridors concerning the corner rooms of the southern tract, the tribunal, and the basilica is reminiscent of the solutions of evacuation exits because through them the user could get out of the principia in the fastest way. During a war, these exits were more suitable for an evacuation since they led to the side alley. These side exits were not on the main roads within forts, so they provided visual protection from an invasion on the main roads within the castrum. These kinds of exit also could help the commander to avoid the crowded basilica and courtyard during meetings in the time of peace and to act faster after leaving the building. This is especially true for those persons who were most familiar with the use of the Tribunal and the corner rooms in the south. It would certainly be the commander-in-chief of the garrison. The definition of the room on the corner within the southern row of administrative rooms indirectly indicates to that solution. All indicators according to the above analysis indicate that the corner room in the southwest served as the working room of the commander-in-chief.[5]

CONCLUSION

The reconstruction of the plan according to which the project of principia in Pontes was created can indicate the basics of the builders' approach to design development. In addition to the usual functional distribution of space in one Roman principia, the builder applied very specific dimensional relations in both directions, according to which the building received a proportional relationship between the individual elements of the structural whole. Modern analyses of the space of the principia have made it possible to get acquainted with the qualitative advantages of such a project idea.

5 Whether a similar case was on the opposite, eastern side should be determined only by future archaeological research.

In the plan of the Pontes castrum, there are certain geometric relations to which the plan of the principia is subordinated, such as the central building of the castrum, and whose position and architectural appearance had to be dominant to other buildings. With its plan, the Pontes castrum satisfied the basic forms of a Roman castrum from the Middle Imperial time, and such was the scheme of its principia. This paper offered reasons for the initial assumptions that plans of castrum and principia were geometrically planned, which corresponds to one of the basic rules of Roman architecture.

The degree of elaboration of the graphic plan of the principia is readable primarily in the basis of the plan on the decomposition of squares, which determines the position and size of individual spaces and rooms. The application of proportional relations does not jeopardize the definition of the north-south direction as the main axis of communication, which is otherwise characteristic of Roman principiae.

Spatial syntax functionality analysis software, such as DepthMapX, allows us to view the qualitative properties of a Pontes principia space through certain quantitative indicators. The application of this software provides direct insight into the functionality of the space, primarily in terms of physical and visual communication.

The analysis of the influence of the geometry of the building was conducted to perceive the behaviour of users, and above all their movement within the geometrically designed plan of the principia. This plan, in addition to geometric regularity, is conditioned by the classical arrangement of rooms for certain functions in one Roman principia, which means that the significance of the analysis of this case can be applied to other *principiae* throughout Roman Limes.

By applying the analysis of the geometry of the plan of the principia and physical and visual communication, the relations and functions of individual spaces and rooms that have not been clarified so far can be presumed. This primarily refers to the specific position of the side doors of the principia, the corner rooms and corridors at the southern end, as well as the spaces of the tribunal between the mentioned elements of the principia. At the same time, the analysis highlighted the role of the central courtyard and the hall as the assembly spaces of the principia.

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REZIME
PRINCIPIJA KASTRUMA PONTES –GEOMETRIJSKI ODNOSI U OSNOVI OBJEKTA I NJIHOV UTICAJ NA PONAŠANJE KORISNIKA

KLJUČNE REČI: PRINCIPIJA, RIMSKI KASTRUM, ANTIČKA ARHITEKTURA, PROSTORNI I GEOMETRIJSKI ODNOSI, PONTES.

Pravilna podela unutrašnjeg prostora pod izgrađenim strukturama unutar kastela Pontes je odredila mesto i površinu Principije. Kvadratni oblik centralnog dvorišta i ritmičan niz pojedinih bočnih prostorija, simetrično rešenje u planu, pojava pravih uglova i paralelnih zidova su nagovestili mogućnost postojanja određenih geometrijskih odnosa u planu građevine. Sprovedena analiza geometrije plana Principije ukazuje da su stranice kvadrata prema kojem je određena osnova centralnog dvorišta u jednom smeru podeljene na četiri dela, a u drugom na tri dela. Takvi geometrijski odnosi su definisali raspone prostorija unutar Principije. Četvrtina dužine stranice ovog kvadrata odgovara rasponu bočnih prostorija i bazilike, dok trećina dužine stranice odgovara širini glavne komunikacije pravca jug-sever, širini i dubini aedesa i pojedinih prostorija u nizu na južnoj strani Principije. Spomenuta podela kvadrata u slučaju Principije odgovara broju delova na koji su podeljene dužine bedema na svakoj strani što ukazuje na istovetan pristup u proporcionalnoj podeli dužina bedema fortifikacija i u podeli prostora Principije.

Geometrijski odnosi su inicirali analizu uticaja plana Principije na ponašanje korisnika po pitanju fizičke i vizuelne komunikacije. Ova vrsta analiza nam je razjasnila prednosti specifične podele kolonade centralnog dvorišta na određeni broj interkolumnija. Ona je takođe postavila osnove za moguća tumačenja funkcija pojedinih prostora, komunikacija i prostorija na jugu, kao što su bočni izlazi, koridori između oficina, prostorije na krajnjim uglovima Principije i platforme za tribunale.

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