ORIGINS AND EVOLUTION OF THE URBAN FORM
A Case Study on the Street Pattern of the City Center of Vienna, Austria

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Abstract: This article is a report within the series of study on the Origins and Evolution of the Urban Form. The city center of Vienna has a long history of more than 20 centuries. It provides a good base for study and therefore it was chosen as a case. The study is founded on the hypothesis in which several initial factors related with the natural background (topography and rivers), crossroad situation (destinations), growth of the city and man-made concepts had a decisive influence over the street pattern from the origin to the present. According to methodology the street pattern is decomposed on elements and classified in clusters. The analysis goes through several historical periods. The results of the analyses serve as input for the construction of evolutionary network, which becomes an analytical abstraction of the pattern from the maps and clarifies the origin and evolution of the pattern. It explains that the complexity of the pattern is caused by the appearance of new factors, development of different elements and their coherence with the succeeded one. The study also confirmed the hypothesis and proved the utilization of methodology.

Keywords: Urban Form, Evolution, Origin, Street Pattern, Vienna

1. Introduction:
1.1. Background and Purpose of the Study:
The morphology of the urban form has been studied in several works by Christopher Alexander [1,2,3], where he concerns the generation and growth of patterns using the methods of decomposition and synthesis of the form by structural elements. He also regards the form as a hierarchical structure, subdivided on sets (clusters) of variables (elements) which are assembled (interrelated) under the force of some concept.

On the other hand a large volume of studies [4-12] regard different aspects of the natural background, origins and history of the urban form. The above mentioned studies provide a good departure point and database for further study. They display the importance of several themes concerning the urban form. However, these studies are accomplished independently from each other. The structural analyses are about the form in general and lack detailed examples of concrete cities. And by the same way the historical studies lack structural analysis. Moreover there are no structural analyses reflecting the form changes from the origins and through time.
The present study introduces the original idea to bridge these realms. It is focused on street pattern analysis and covers three domains of study about the form: morphology (structure), genealogy (origin) and evolution (development). It also states a hypothesis, develops and applies a methodology for analysis that promotes the construction of the form generation and evolution diagrams.

Consequently, the first purpose of the study is to investigate the structure and synthesis not only of a single state but the form evolution through time. For that reason also it should construct the diagrams as an evolutionary network of mutually linked components. Thus the study will be efficient to explore and explain the complexity of the street pattern. The study expresses a hypothesis which essence is that the form is evolved from some relatively simple elements and the influences for that formation appear from few factors. Hence comes the second goal to prove the hypothesis. The present approach is useful to understand and construct a systematic structure of generation and evolution of the urban form. If numerous examples are considered and compared it could lead to extraction of rules and one more general theory.

1.2. Hypothesis of the Study and Definitions of the Terms:
The urban pattern is a phenomenon that takes its shape on account of a variety of reasons; it could be planned or spontaneously grown, geometrical or organic. When the pattern of numerous cities with a long history is reviewed, it is observed that even if we can read some simple predefined geometry into the pattern, usually there is a natural explanation for the appearance and metamorphosis of separate streets and places. The form of many ancient streets, for instance, follows the shape of the topography or riverbeds; some axes are oriented to significant points as mountains, world's directions or destinations.

Considering these facts the following hypothesis was expressed as a base of the study:
A. The complex pattern of the cities is a result of the combined action of several initial factors that had formative influence over the form of the streets.
B. The initial factors set the original guidelines and during the evolution their effects have been combined and multiplied continuously. They are related with the quality of the place as natural background (1) and the crossroad situation (2), growth (3) of the city or some uncomplicated man-made concept (4) to establish a spatial order.

1.3.1. Data Sources:
The study follows the formation process of the pattern through time using the following sources [10-23]:
1. Original maps and analytical schemes.
2. Historical studies.

1.3.2. Classification Criterion of the Pattern:
In order to accomplish the analysis of the street pattern on clusters of elements and construct the diagrams, criterions for decomposition and articulation were established. The elements were classified regarding their similarities by the following features:
(1) Physical form: the elements as parts of geometrical entities: crosses, radii, tangents, circles or other enclosure segments.
(2) Function: the movement performed related to the core and the city center – out/ in going, passing-by, enclosing, etc. The elements from one cluster should function together or by a similar way.
(3) Origin: the sources of formative influence (the initial factors) for one cluster should be the same. The time of origin is also used as an auxiliary criterion.

1.3.3. Structure of the Study:
1. Analysis of the Present State: The pattern is disassembled on structural elements, which are arranged on clusters according to the classification criterions (1.3.2.). On this stage the elements that should be explored through the historical analysis are clarified.
2. Analysis of the Historical Stages: It follows the timeline and deals with the plans of six consequential stages and sub stages that reflect major changes of the pattern. The plan from each period (black) is superimposed over the present (gray) for comparison.
3. The results of both analyses serve as input for the construction of the conclusive diagram called evolutionary network. It becomes an analytical abstraction of the pattern from the maps.

1.3.4. Evolutionary Network – Definition and Structure:
The study deals with structural analysis and as we will see later, the diagrams also reflect the internal relation between the components. Therefore the term evolutionary network is considered appropriate.
Components: The network is constructed from initial factors, clusters of elements and links between them. A circle stands for each element and factor, and a linear connection stands for each formative influence from factor to cluster. There are three more types of links connecting element with element and element with cluster.

Constructive Principle and Links:
If we make a picture of all the elements E, which are influenced by factor F, we see that the factor F is a departure point for a whole cluster of elements. For instance element E from cluster C needs factor F in order to be complete. Therefore the constructive principle is summarized in the consequence of factor – cluster – element connected by links.

The links represent the logic of the whole network. The above mentioned types of links are defined by the same three criterion (1.3.2.) applied in for classification of the clusters. Respectively if all criterions (form, function and origin) are fulfilled we have a link of both – structural (cluster) belonging and formative influence. If only the criterion for form and function are fulfilled the link is structural and if the only similarity is in the origin (common initial factor) we have a link of formative influence.

Positioning: Again in the process of analysis the place of each component is clarified in relation with the others. Each factor sits at the origin of connections, which connect it to certain clusters that are completed by it. Each element is positioned and linked in the network with one or two clusters according to the initial factor or according to the direct structural association to some cluster.

1.3.5. Object of the Study:
The pattern of the present city center of Vienna is famous mostly with the plan for Modern reconstruction and Ringstrasse zone. However the streets pattern as a whole is quite complicated (Fig.1.) – indeed it combines the patterns of the star rays, circular segments, bypassing tangents and others. This mixed pattern has been a source of planning problems related with the systems of movement into the city center and also as an influential factor over the rest of the city. It is a result of historical accumulation of elements and their consequential continuity when new streets appeared and the old were transformed. Moreover, it is bounded with some specific features of the place. Considering the above mentioned, the city of Vienna was chosen as one appropriate case for study.
One of the most ancient Celtic settlements lies under the present city core. Next a Roman town rose on the same site, to be followed by the townships of the Germans, Hungarians and the Holy Roman Empire. Later, it was a capital of the Austro-Hungarian Empire and finally, the Modern City of Vienna. The present central city core of Vienna is associated with the place and dimensions of the ancient Roman Town. The entire city center is the area enclosed by the circular (ring) street and the attached zone with a diameter of about two kilometers (Fig.2.). The city of Vienna has been widely investigated. Though the data sources have studied the pattern by a different point of view. The current study was completed by analysis of more than 20 maps and historical materials from three main periods: Antiquity, Medieval and Modern.

3. Analysis of the Historical Stages:

3.1. Roman Pattern / Present Pattern and Topography (Fig.10.)
Vienna is situated at the eastern end of the Alps, where the mountains are lower and the passage is easier. It belongs at the same time to the Alps and the plains. The Vienna basin was a nodal point of ancient trade and military routes. It linked north and south along the "amber route" that ran southward from the Baltic and also linked east and west along the river of Danube. It is a bridge town and as such also a river town.

Within Vienna basin have been located the sites of several old settlements. When the Romans arrived, they found a Celtic place of Vindobona. The Romans succeeded the location and built a military town-campus of Vindobona as allied to the town of Carnuntum. It covered an area, which remained the same until about 1c.AD. Vindobona was located next to an island in the Danube where the riverbanks narrow made the crossing easy. Terraces were adjoined to the slopes of the Wiener Wald, a spur of the eastern Alps, which offered a protection site for a settlement. The Roman camp stood on a terrace, now the center of the city, and was protected by the natural configurations of the terrain.

The ancient pattern of Vienna follows the canon of Hippodamus system (rectangular grid). Its pattern is a result of both – functional utility and the Roman cosmic idea about the city as continuity of the natural elements. The spines of the street system were via principalis VP and cardo maximus CM perpendicular to each other. In the case of Vienna they are rotated on 45 degrees from the world's directions. The Romans considered the mountain as a place where the axis mundi (world's axis) goes. Accordingly CM is oriented toward the near hill and the further southern slopes of the Alps. Along with these first streets the town succeeded a long distance route, the tangent TR that incline to the core and merges with VP.

The topography (T) and rivers (R) are the first initiation factors. They had formative influence over the location of the core, orientation of CM and the entire cross (+). The cross shape is result of a concept (+). The destination factor (D) defined the layout of the TR route from the cluster of tangents (T). A structural link is drawn between TR and VP. (Fig.10a.)

3.2. 13th Century Pattern / Present Pattern (Fig.11.)
During the Great Migrations Vienna had been destroyed and its history is unknown for several centuries. Later the town has grown unplanned around the Roman nucleus. Like for the previous stage there is no authentic maps regarding when and how exactly the planned Roman Town has grown into an organic one and previous researches based and reconstruction from archeological findings are used. The first growth spreads along with VP, on the next southeastern terrace, which offers the best location as topography and natural borders by the rivers. The segments Ss, Sw, Sn, Sei and Si fix the new form where the first three continue the traces of the core. During this expansion these three segments and one north-south going tangent TS,
Fig. 2 and 3.

Fig. 4, The Cross

Fig. 5, The Tangents

Fig. 6, The Radii

Fig. 7, The Segments of Growth

Fig. 8, The Circular Segments

Fig. 9, The Circular Segments of Growth
which coincides with an eastern segment, surround the core. The segment S serves as enclosure of a complex grown between VP, TR and the wall. The second expansion is locked southward between the traces of the first, TR and SSI. The third one, on the end of this period, spreads in all directions except the north where the river remains a natural border and a route. The shape of the town is fixed finally by wall open by six gates on the main roads.

The Medieval Town succeeds and modifies the Roman traces – VP splits on two parallel roads along a large market place and CM remains in its former shape. TS is fused with TR by the same way like VP and TR.

At this stage the evolutionary network enlarges with one secondary initial factor – growth (G). The initial factors of destinations (D), topography (T) and rivers (R) altogether have formative influence over the growth forms. The new cluster of growth segments and circular enclosures (S/C) is consistent of seven elements. A link of formative influence pass from S/C cluster to TS. One more structural relation is drawn between TS and TR. (Fig.11a.)

3.3. 18th Century Pattern / Present Pattern (Fig.12.)

In the 18th and 16th centuries the fortifications of Vienna were renovated. They consisted of twelve powerful bastions and outworks as additional protection. The fortress was surrounded by a wide moat. A wide empty zone as defense against close arm fire encircled the whole structure. Six passages were made through the fortifications connecting the internal web with the external one. Old suburbs and new residential districts began like satellites to surround the city. Radial and more or less concentric roads forming a spider’s web around the inner city connected these suburban centers. The form of the radii R4, R5, R6, R7 and R8 reflects the topography following the convenient paths by the hill. The radii Ra, Re, R9, R10, Rtn, Rvp and R11 have rather free of obstructions way through the lowland. Though there are several radii, which do not follow the natural shapes as the first bridge across the Danube, Rn or R0 that works as an extension of CM and goes uphill against the horizontals. The radii R1, R2, R3, Re, Rw, Rts and Rcm are still in a process of formation without relation with the central web. The circular enclosure consistent from Ce, Cse, Cs, Csw, Cw and Cnw is already traced around the fortress roughly following its shape. The form of the circular segments Ca and C3 coincides with the border of the zone. C1 and C2 are circular segments that still do not reflect the form of the growth.

TCR is a path along the Danube that carries the features of a tangent, radius and a circular enclosure together. Rc1 is another compound element that follows the riverbed of Wien-Fluss and serves as a both – circular segment in the zone and radius toward the suburbs. Cr1 and Rc2 are appearing compound element. The web of the inner city also evolved. The passes of VP and CM on the northwest and southwest are interrupted. VP is disconnected from TR, which is linked unclear with a group of radii where Rtn is the former trace of TR. The segments from S1 to S8 are the imprints of the last growth. The other segments remain in their former shape. The radii Ri and Rx are merely internal short cuts.

At this stage the evolutionary network grows with the new cluster of radii (R). The majority of them are influenced by the initial factors of destinations (D), topography (T) and rivers (R) retaining a link of formative influence and structural (cluster) belonging with R cluster. Rn, R0, Ri and Rx have only link of structural belonging with the R cluster. R0 has an additional link of formative influence from CM and Rc1 a structural link with C cluster. TCR is a compound element linked with T, C and R clusters. The structural link between VP with TR is deleted. There is a link of formative influence and structural belonging from TR to Rtn. The C segments have a link of formative influence and structural belonging with S/C cluster, except Cl and C2, which only structurally belong to it. R1, R2, R3, Re, Rw, Rc2, Rts, Rcm and Cr1 are still isolated from their clusters. (Fig.12a.)

3.4. 19th Century Pattern / Present Pattern (Fig.13.)

The present period is a sub stage of the former one since the street pattern was not radically changed. On the other hand it contains already the original traces for further evolution. The southern part of the city wall was demolished and extended. The surrounding bastions and outworks were leveled down and the mob was filled in. The buffer zone was transformed in a city park and the pattern of the paths was modified. New openings through the wall were made and the gates increased to eleven, which facilitated the unification of the internal and the external webs.

During this time Rtn is fused into TR, Rw is connected with a new gate, CM is extended and R0 is united with it. Re is stretched across Wien-Fluss to the gate and connected with the web. Rc2 continues along the river by the same manner like Rc1. The radius Rcm beyond the river is extended as a new bridge leading straight to the gate and approaching the core. Cr1 is generated also from existent path beyond the river and continues as a circular segment in the zone without influence from the growth. R1, R2, R3, Rtn and Rts remain disconnected from the central web.

At this stage the changes are few. Rtn and R0 disappear. Rtn and the link with TR are deleted. Rw is also linked with R cluster. Re is connected to the network with a structural link. Rc2 is linked with R and C clusters like Rc1. Cr1 is structurally related with R and C clusters. (Fig.13a.)

3.5. Modern Center (19c.) / Present Pattern (Fig.14.)

The reconstruction from 1857 is regarded as a turning point not only in the design of Vienna but in the city history. The city’s defense system was demolished and a circular boulevard, the Ringstrasse, was built. The course of Danube River was altered and regulated. The whole defense zone was built up. However the elements of the new pattern have its predecessors. Now most of the radii are connected with the central web. They were regulated in a grid pattern that rotates around the center perpendicularly to the circular elements. R2 and R3 are fused into Rs, which cross the Wien-Fluss and adjoin with the segments.
Fig. 10. Roman Pattern
Present Pattern and Topography

Fig. 11. 13c. Pattern
Present Pattern

Fig. 12. 18c. Pattern
Present Pattern

Fig. 13. 19c. Pattern
Present Pattern

Fig. 14. Modern Pattern (19c.)
Present Pattern

Fig. 15. Present Pattern (20c.)
RC stretches from the circle to the web across the river. Rvp is extended to the inner web, VP to the outer one and both are connected. Similarly Rcm and CM are extended and attached. TR is traced in parallel, separately from TE. The trace of Re with the inner city is moved southward and continues as an element of the inner web. Unlike it RW is disconnected from the central web into the new pattern. Rts, R1 and Rt still have no relation with the central web. Ra is disconnected from the central web. It is fused with Ca in CR and both act a single compound element. Unlike Cr1, Cr2 is another composite element that cross the river to the north bank. Both are without former trace and regulated in the grid.

In the new pattern C1 follows the border of the former zone and Wien-Fluss. C2 is regulated with the grid, parallel to the Cw and Csw also following the edges of growth. Ci is a grid generated element without former trace. The segments S6 and S8 are eliminated and Sw is extended.

*At this stage the grid factor (#) is introduced. Most of the R and C elements are connected by link of formative influence with it. R2 and R3 are structurally linked with the new element Rs. Rt is deleted and TS is structurally linked with R cluster. Rw is also eliminated. Rvp and Rcm are structurally linked with VP and CM. The tangents TR and TS are disconnected. Ra and Ca are substituted by CR, which is linked with C and R clusters. Cr2 develops like Cr1. The links of C1 and C2 with C cluster are changed to links of formative influence and structural belonging. Ci is a new element structurally related with C, but entirely influenced by the grid. RC structurally belongs to R and formatively to C cluster. (Fig.14a.)*

3.5. Present Pattern (20c.) (Fig.15.)

This period is the final stage of the Modern center. R1 is extended through the former zone to S1. A new building disconnects S4. Rt and Rts cross the rivers and fused respectively with TS and TR.

*At this sub stage R1 is connected with the R cluster. Rt and Rts are deleted and instead of it TS and TR are structurally connected with the R cluster. S4 is also canceled from its cluster. (Fig.15a.)*

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**Fig.16. Links and Elements of the Evolutionary Network - Graphic Indication:**

- Formative influence: Initial Factor - Cluster of Streets
- Initial Factor - Initial Factor

**Cluster - Element Links:**

1. Formative Influence
2. Structural (Cluster) Belonging
3. Formative Influence and Structural (Cluster) Belonging

- Clusters of Streets: (+) Cross, Tangents, Radii, Segments of Growth and Circular Segments
- Cluster's Element
- Initial Factors: Destinations, Growth, (+)Cross and (+)Grid
- Set of Initial Factors: Topography and Rivers
4. Conclusions

Summarized, the initial factors have the following formative influences:

1. The **topography** and the **rivers** define the location of the central city core and the cross (+) elements. They are influential factors over the form of majority of R elements.
2. The **destinations** are the ultimate influential factor for the formation of the elements from T and R clusters.
3. The **growth** is a subordinate factor influenced by the combined action of destinations, topography and the rivers. It defines the form of the elements from S/C cluster.
4. The **cross** and the **grid** factors are identical concepts, which express purposeful human design. However, they appear in different time and there is no influence of the cross shape over the grid. There is no separate cluster connected with the grid factor but the formation of wide variety of elements from R and C clusters is influenced.

Also from the evolutionary network is observed that:

1. The complexity of the pattern is caused by the fact that during the evolution six factors were acting simultaneously and four different clusters of streets were developed and combined with each other. This integrity is represented by the three types of links in the network (formative influence, structural/cluster belonging or association of both) and relevant elements.
2. The elements from R and S/C clusters are fundamental for the street pattern – they are the most numerous and the highest influenced one by the natural background; the compound CR (RC) elements are linked between R and C clusters; the tangents appeared as another case of mixed elements with links to R and S/C clusters. The both, R and C clusters, are strongly influenced by the grid. It is also substantial that basically the influence to R and C clusters comes from the same factors but the growth changes the effect. Where the radii have to bridge the rivers, for instance, the circular segments follow the riverbeds.

As an abstract of the analysis the **evolutionary network** confirmed that:

The **street pattern** is the result of the combined action of the **initial factors** that had **formative influence** over it; the elements of the **natural background** (topography and rivers), **crossroad situation** (destinations), **growth** and the intentional design **concepts** are the **initial factors** that had decisive formative influence over the pattern.

This study fulfilled the **purposes** of finding the origins, following the evolution of the form, and explaining the structure of the pattern in result. The **hypothesis** was sufficient as both a supposition and departure point. Also the **methodology** proved its effectiveness as a tool to explore the pattern.

Notes and References:

(16) *Atlas der historischen Schutzungen in Österreich. Bd.2*, Wien, Gebundene Ausgabe Büllau, Kön