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PRECEDENTS IN CONCERT HALL FORM

M. Barron

School of Architecture and Building Engineering, University of Bath, Claverton Down, BATH BA2 7AY

1. INTRODUCTION

While it is obvious to state that prior to this century auditoria were principally designed by precedent, such considerations of precedent still remain of considerable significance today. The design process by precedent involves continual minor experimentation, which is or should still be a relevant approach. For many building types, the historical design process gradually achieved a level of some perfection. In the case of auditoria, historical design led to the development of several refined auditorium schemes, with different ages creating particular forms suited to a particular type of performance. Yet in the development of each design the common problems in all auditoria had to be confronted: of grouping large numbers of people in a compact organisation and providing them with good sightlines to the performing area. Thus although the performance type associated with a particular design may be rare or even irrelevant today, the form of earlier auditoria is of considerable interest. To take the example from the Roman era, the design of Roman baths is for us of mainly archeological interest, while the Roman arena provides lessons for organisation of spectacle, even though Christians are no longer thrown to the lions.

There are four major auditorium designs which pre-date any science of room acoustics (Figure 1):

1. The classical Greek theatre - the fan-shape plan
2. The classical Roman arena
3. The Baroque theatre - the horseshoe plan
4. The rectangular plan concert hall

One notes that the two classical designs are for outside performance while the more recent auditoria are enclosed spaces. One also observes that each auditorium form developed for a particular performance type.

The Greek classical theatre represents an optimisation of performance conditions within some severe limitations. The structural constraints were particularly important. It is

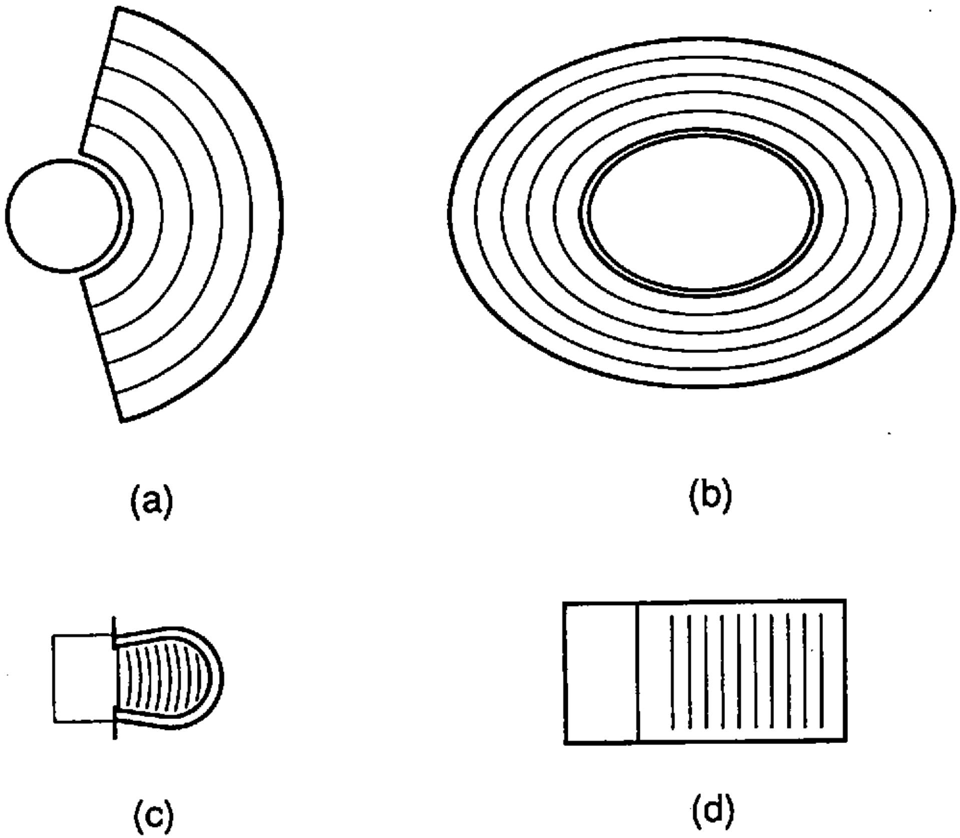

Figure 1. Historical auditorium plan forms: (a) classical Greek theatre (fan-shape plan), (b) classical Roman arena, (c) Baroque theatre (horseshoe plan), (d) 19th century rectangular concert hall.

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somewhat ironic that the capacity of these theatres extended to 14000, almost ten times the capacity of the largest proscenium theatres today. Crucial to the success of the Greek theatres was the steep seating rake, with the acoustic reflection off the stage front probably allowing for a larger capacity than would otherwise have been possible. The Roman arena, as exemplified by the Colosseum in Rome and the Verona arena, cannot be called acoustic spaces but constitute a powerful arrangement for large numbers of spectators. The Romans also developed the system of vomitoria to allow access to the seating from below.

The Baroque theatre form developed both as a response to the nature of theatrical performances but also to the social conventions of the time. It was then as important for members of the audience to be seen as it was to see the stage itself. The form also proved very suitable for opera. Subsequent development of the basic Baroque theatre in the second half of the nineteenth century, particularly in Britain, is a further testament to the possibilities of design by precedent. The public concert hall post-dates the Baroque theatre and developed completely independently. Two fortunate coincidences led to rapid achievement of what is still considered by many to be the only suitable concert hall form. The first coincidence was that the form of large ballrooms proved to be particularly auspicious in musical acoustics terms, while the design conventions for wall and ceiling decoration performed a highly diffusing acoustical function.

While considering the various forms of modern concert halls and their origins, it became apparent that nearly all modern forms can be related to one or other of these historical auditorium forms. If one wishes to group concert hall designs into a family tree, the four historical forms serve well as original ancestors. The following discussion traces this family tree with a series of examples, chosen for their significance in design development. In certain cases the designs have been repeated or further developed, while in others the particular auditorium form has been found unsuitable for concert use.

While most developments in auditorium design can be related to the four historical forms, there is one development in the 1920s which cannot. This is the case not least because attention shifted from the plan to the long-section. Halls from this period which used the ceiling profile to concentrate reflected energy onto the audience can be called "directed sound halls". As a historical movement this design approach was short-lived but it remained influential up to the post-war period.

Necessarily the discussion provides only an overview of the

detailed characteristics of each auditorium. For nearly all the halls mentioned, a more detailed treatment will be found in the author's book [1]. Several halls are also considered by Beranek [2] and Forsyth [3].

2. THE HORSESHOE PLAN

The horseshoe plan dominated design of what is known as the Baroque theatre for over 200 years. It was developed during the first half of the seventeenth century, principally in Italy. During that period there was much experimentation in search of the ideal plan form: the semicircle, the U-shape, the horseshoe, the bell-shape, the straight-sided bell and the truncated oval or ellipse were all tried [4]. From an acoustic point of view there was probably little to choose between these options. If there was a winner it could be said to be the horseshoe plan; it was still used for Garnier's Paris Opéra of 1875. The salient acoustic features of the Baroque theatre are mainly due to their modest size. The typical maximum distance of 20m from the stage to the furthest audience member and a ceiling height normally positioned on visual grounds make these theatres small by the standards of concert halls. The reverberation time is generally in the region of 1 second. Early reflections reach the stalls seating mainly by reflection off diffusing balcony fronts, while the gallery seating is all close to a vertical wall. With a well-raked stalls floor, focusing by the concave walls and balcony fronts may well be of no consequence because focal points are well away from audience.

If the acoustic success of the Baroque theatre is to be assigned to a single characteristic, the compactness of the designs should be highlighted. But if the horseshoe plan is to be used for concert halls, then the scale needs to be enlarged: the width expanded and the ceiling raised in order to increase the cubic volume and thereby the reverberation time. The Usher Hall, Edinburgh, of 1914 provides an instructive example of just such an exercise. The seat capacity is 2217 plus 333 choir with a volume of 16,000m^3 responsible for an occupied reverberation time of 1.7 seconds. What is particularly intriguing about the Usher Hall is that the volume is as large as it is. Though Sabine's reverberation theory significantly pre-dates the hall, it seems unlikely that the designers were aware of his work. Certainly there is no mention of it in the meagre written record.

While the reverberation time is satisfactory in the Usher Hall, in other respects its acoustic performance is less impressive. As well as the horseshoe plan, the hall has a well defined proscenium arch on the line of the front of the orchestral stage.

Choir is seated behind the orchestra in an enclosure which tapers somewhat in plan as one moves beyond the proscenium. The most obvious fault in the Usher Hall is focusing into the stalls by the back concave wall. In some stalls seating areas near the centre line, individual musical instrument groups can be heard more strongly from behind than in front (delays are too short for an echo). Further less extreme examples of non-uniformity are found. The sound in the Grand Circle is disappointing, while that in the Upper Circle is for many the best in the hall. The Upper Circle receives a strong ceiling reflection, whereas the Stalls and Grand Circle are lacking early sound. Paradoxically the deficiency is of early frontal sound, most seats are well endowed with lateral reflections, though at higher seating levels reflections off the side walls are obscured by the balconies which extend round the side walls.

The example of the Usher Hall, Edinburgh, clearly illustrates the problems of taking a building form appropriate to speech and applying it for music.

3. THE FAN-SHAPE PLAN

The acoustic deficiencies of the fan-shape plan have become a platitude to the extent that even the slightest incline of side walls away from parallel creates worried looks. In non-technical publications the fan-shape is wheeled in as a dragon to be slain, when St. George already did his work 15 years ago. The obvious advantages of the fan-shape in terms of sightlines and audience within a specified distance from the stage make blanket rejection of this form too simplistic a view. Clearly the wide angle fan at the large scale has been found wanting, but even in this case the reasons for failure are seldom specified.

The acoustic failings of the fan shape are various. The first problem concerns the rear wall opposite the stage. The fan shape automatically generates a concave curved rear wall which if left untreated creates severe focusing. Either the surface has to be made highly absorbing, with attendant problems of lack of reflections, or it has to be made highly diffusing. Additional concerns include the extreme width at the rear of the hall, which leaves seats in the centre rear of the stalls with few early reflections. Reflections from the side walls also arrive at listeners from directions close to that of the direct sound, producing only a small perceived degree of envelopment. Finally these halls seem to have poorly diffused sound which may contribute to a reduced sense of reverberation. The severity of these shortcomings is a function of the apex angle, a hall with walls slightly off parallel may not exhibit any of them.

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In a discussion of fan-shape halls, two real examples deserve mention. The first of these has a large apex angle: it is semicircular. The Central Hall at York University has a small capacity of 1064 and the furthest seat is only 12m from the stage [5]. Its great virtue is a steep seating rake, which contributes to a high degree of identification and involvement in the performance. It is easy to criticise aspects of the acoustic character of this hall but the intimacy of concerts there can be considered to offset other shortcomings. There is a distinct size limit beyond which this trade-off is no longer valid.

In a design for a large seat capacity with a proscenium stage the fan-shape plan envelope is very hard to avoid. A remarkable resolution of what otherwise might seem an incompatible set of demands was developed for Segerstrom Hall of 1986 in the Orange County Performing Arts Centre, California [6]. While the gross plan is fan shaped, the audience is arranged asymmetrically on four levels in a way which guarantees sufficient early reflections to all seating areas, in spite of a seat capacity of 2906.

4. THE DIRECTED SOUND HALL

The arrival of the Modern Movement in architecture in the 1920s coincided with the development of ideas by Gustave Lyon on acoustics of auditoria. Others had already realised the significance of early reflections but Lyon on the basis of some

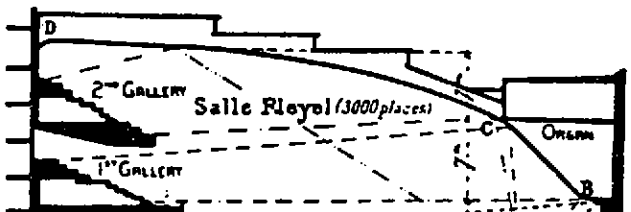

Figure 2. Long section of the Salle Pleyel, Paris in 1927.

flamboyant experiments had convinced himself, somewhat over-enthusiastically, of their paramount importance. The realisation of his ideas came in 1927 in his design for the Salle Pleyel, Paris. He had correctly identified the ceiling as potentially the most influential reflecting surface so that the novel aspect of this hall is its long-section rather than its plan. The ceiling was profiled approximately as a parabola with the source at its focus to direct an intense reflection down onto all areas of audience, Figure 2. This feature achieved the impressive feat of providing intelligible speech for an audience of 3000.

The design was not however without its problems. The rear wall had to be covered by absorbent to suppress an echo path back to the performer, involving reflection off the ceiling in each direction. Even with the echo removed, the performer still had to contend with audience noise focussed onto his position.

For the listener to music, the character of the Salle Pleyel is particular. With so much first reflection energy directed at absorbent audience, the sound behaviour is strongly non-diffuse. The listener hears a loud clear sound but it is highly frontal, virtually devoid of any envelopment or sense of room sound. These are also characteristics of the fan-shape plan but are much more marked in this case. The Salle Pleyel design provides another example of an auditorium suitable for speech but deficient for music.

5. THE RECTANGULAR PLAN

Just as the vices of the fan-shape have become a platitude, so the acoustic virtues of the rectangular plan form are likewise trumpeted as though the simple rule of parallel sides guaranteed success. In this author's opinion there are many examples of rectangular halls with their fair share of acoustic problems. Only a limited range of proportions and dimensions appear to provide the characteristic and uniform sound quality we associate with the famous classical rectangular halls. Detailed treatment of room surfaces as well as details of balcony design can also be very significant. The following traces some milestones in the historical development, rather than investigating suitable and unsuitable designs.

The preferred proportions for large scale classical halls are roughly those of a double cube, that is 1:1:2. If the ceiling height has been chosen to give an appropriate reverberation time and the room surfaces are acoustically diffusing, such a rectangular hall produces a highly diffuse acoustic experience with a strong sense of envelopment due to significant early

lateral reflections. What is intriguing is that this design form arose as much out of the use of ballrooms for orchestral concerts as it did from gradual increases in the size of purpose-built concert spaces.

There is though a definite limit to the seating capacity of these halls. The Grosser Musikvereinssaal, Vienna, of 1870 only holds an audience of 1680, for instance. A major fault of older halls is poor sightlines from side balconies. Simply scaling-up the dimensions is not acceptable. In particular the length of most of these halls is already close to the maximum acceptable. A particularly interesting response to these limitations is to be found in the Royal Festival Hall, London, of 1951 which has a basically rectangular plan [7].

To accommodate an audience of 2645 and 256 choir, the width was extended to 32m in the Festival Hall. There are no side balconies extending along the sides of the hall; the single balcony has a straight front at right-angles to the main axis. In long-section, the ceiling is profiled however in a manner reminiscent of pre-war cinema designs. In this way, the Festival Hall constitutes a synthesis of traditional and more recent design approaches. The logic behind the design is compelling but its most notorious failing is due to inadequate volume. Because of inaccurate absorption figures for audience, the reverberation time of the hall was only 1.45 seconds at mid-frequencies. However if the ceiling were raised to provide a more appropriate reverberation time, some seating areas might find themselves starved of early reflections due to excessive distances to reflecting surfaces.

Four other halls were built in England following the Festival Hall prescription. The most successful of these acoustically is the last but also the smallest of them: the Wessex Hall, Poole, of 1978, with 1593 seats including choir.

The rectangular plan hall is currently experiencing something of a revival. Notable recent examples are the Dr. Anton Philips Hall, The Hague, of 1987 with 1900 seats, the Eugene McDermott Concert Hall, Dallas of 1989 with 2062 seats and the Birmingham Symphony Hall (2200 seats). These last two, by Artec Consultants, have extended the height relative to classical halls, in order to maximise the seat capacity.

6. THE ARENA PLAN FORM

As a performing space, the elliptical arena stimulates a strong sense of shared experience. This characteristic was not lost on

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the British Union of Fascists during the 1930s, who held many rallies in the Royal Albert Hall in London. In the basic Roman arena with continuous seating surrounding a performing area, there is no chance of acoustic reflections from surfaces other than the ceiling. To achieve acoustically acceptable conditions, a more elaborate design is necessary.

The Royal Albert Hall, London, of 1871 was the butt of criticism from its inception. 'The Engineer' magazine considered it "wrong for anything except gladiatorial combat". At the opening ceremony, "the address was slowly and distinctly read by his Royal Highness (the Prince of Wales), but the reading was somewhat marred by an echo which seemed to be suddenly awoke from the organ or picture gallery, and repeated words with a mocking emphasis which at another time would have been amusing". The domed roof of the hall created an intense echo with a delay of about 1/4 second.

Strenuous efforts have been made to suppress the echo, including treating the dome with absorbent, and culminating with the introduction of 134 'flying saucer' diffusers during 1968-70. The second major fault with the hall is the quietness of sound within it. Not only is the audience capacity of 5090 very large, but the internal volume is also excessive so that extra absorbent is included to control the reverberation time. The early reflection situation produced by the elliptical plan is also far from ideal and heavy reliance is placed on an orchestral reflector. Given the inauspicious start, the current acoustics are surprisingly uniform and sufficient to support the extremely popular Proms concert season each summer.

The arena form was revived with staggering élan in 1963 in the Berlin Philharmonie with 2230 seats. Its success was due to the interaction of two masters of their crafts: the architect Hans Scharoun and acoustician Lothar Cremer. Cremer realised the need for early reflections to the audience. Whereas in the Royal Festival Hall additional reflections were provided around the stage, principally by the overstage reflector, in the Philharmonie reflections are supplied by surfaces close to the individual members of audience. Subdivision of the audience into 'vineyard terraces' creates surfaces which can be suitably inclined to produce reflections to neighbouring seating areas. A successor to the Philharmonie design is St. David's Hall, Cardiff, of 1982 with 1960 seats including choir.

The next major use of the arena form was in the elliptical plan Christchurch Town Hall in New Zealand of 1972. This is also a particularly intriguing piece of acoustical design, principally by Harold Marshall. The approach is very different from that in

the Philharmonie. To avoid the focussing problems associated with the ellipse, little of the vertical wall surfaces are exposed and able to provide reflections. Above the gallery seating are a series of large plane reflecting surfaces which direct reflections to neighbouring seating, such that it arrives laterally for audience members. The hall accommodates 2338 audience plus 324 choir with no-one more than 28m from the stage front. Two further concert halls have been built following the Christchurch model: in Wellington, New Zealand, (the Michael Fowler Centre of 1983) and in the Hong Kong Cultural Centre in 1989.

7. CONCLUSIONS

Of the four auditorium forms developed on the basis of precedent before 1900, only two remain dominant for concert hall design today: the rectangular and arena plans. The rectangular plan is the more reliable from an acoustic point of view but is restrictive architecturally. The arena form is more demanding and indeed two entirely different acoustic solutions have been used successfully. It will be interesting to see how these various approaches are handled in the future.

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