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MULTICRITERIA EVALUATION OF PIPE ORGAN CONSTRUCTION PROJECTS

Abstract

The construction of a pipe organ is a heterogeneous problem. Each interior, for which the instrument is planned, has its individual architectural and acoustic characteristics. The design of the instrument must be matched to the interior and therefore it will be individual and usually unique. Each investor commissioning a pipe organ also has his/her individual taste, preferences, and budget. These most important factors make the construction of a pipe organ a sum of the various relationships and a result of the willingness to compromise between objective factors and preferences of people. This paper presents the issue as a multiobjective task, in which we consider various criteria, such as size, volume, palette of timbres, etc., and show how the various options are presented to the investor. Will the best designers' solution be accepted by the investor and his/her budget? We should handle the various criteria so as to satisfy the investor without compromising the quality of the instrument.

Keywords: pipe organ construction, pipe organ sound project, multicriteria decision problem.

1. Introduction

The organ is an instrument belonging to the group of keyboard aerophones, in which the sound is created by the vibrations of the air column in the pipe. Due to the presence of reed pipes in many instruments whose sound source is a metal reed made to vibrate by the compressed air, the organ is also classified as an idiophone.

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Organs were built already in antiquity. In Christian Europe they appear in the high Middle Ages. Their modern evolution, both technological and timbral, has been taking place since the tenth century. In each stylistic epoch (Middle Ages, Renaissance, Baroque, Classicism, Romanticism, revival styles, new styles in the 20th century, modern times) organs were characterized by different features, drawing on the styles then used, but they always had individual characteristics, given by the designer and bearing the mark of the creator's individuality.

Organ are built by organ builders having at their disposal an appropriate workshop equipped to process materials necessary for the construction of the instrument: various kinds of wood, metals, leather, textiles, etc.

The timbral variety of the organ is visible above all in its disposition. An organ stop is a set of pipes of homogeneous construction, characterized by a uniform timbre. An organ can have several stops, from a few to several tens or even hundreds, depending on the size of the entire instrument. Stops are grouped into timbral sections controlled by various keyboards (e.g., section I or II of the consecutive manual, or the pedal section).

The organ is a musical instrument which for several centuries of its history has been characterized, more than any other instrument, by a great richness of form and size, both as regards its appearance and its sound. This is related to the constantly changing taste of the society, that is, to the stylistic eras in which the organ builders lived and worked, as well as to the technological progress in the manufacturing of the individual components of the organ. Above all, however, the variety in organ building from antiquity through modern times stems from the fact that there is no ready-made model of the instrument’s appearance or sound. The design of an instrument is always adjusted to the given interior and to the expectations of the people who are directly interested in the construction of the given instrument.

For the given investor, several designs of an organ can be prepared, which differ significantly but are all based on the invariable parameters determined by the characteristics of the interior in which they should be realized. They may be regarded as decision variants which are worth evaluating with respect to various criteria. The purpose of the present paper is to attempt to define and order such criteria.

The paper is organized as follows. In section 2 we present selected issues related to the designing of an organ. In section 3 we describe the elements of an instrument and the possibilities of their shaping. In section 4 we present factors influencing an organ design in progress, while section 5 deals with the issue of the evaluation of an organ design as a multicriteria decision problem. The last section is a summary.

2. From the history of organ design

Theoreticians of organ building of earlier centuries focused on technological and material issues occurring during the process of perfecting this instrument, which has lasted incessantly since the Middle Ages[1]. From among many outstanding personages, let us recall a few names, representative for the consecutive centuries: Arnolt Schlick (1511), Constanzo Antegnati (1608), Dom Bédos de Celles (1766-1778), and Johann Gottlob Töpfer (1855).

The visual aspect of the modern organ, originating in the Gothic model of the organ casing, developed autonomously in various regions of Europe, in accordance with the stylistic tendencies changing over the centuries. An analogous dependence is visible, to simplify matters greatly, as regards the variety of organ timbre until the end of the Baroque era. The Classical era brought a stagnation in this field, although in southern Germany, Austria, and Silesia, organ building was still booming.

Due to the transformations occurring in music at the turn on the 19th century, the organ ceased to satisfy the requirements of composers and performers, and as a result they fell out of fashion. Creative organ builders of the nascent Romantic style in music struggled to maintain the position which their instruments had held up to that time, starting new trends in the technology and technique of organ construction. Above all, they reformed the principles of timbral aesthetic of this instrument, creating, as a result, the so-called symphonic organ. The credit for this goes mainly to two organ builders: Eberhard Friedrich Walcker (1794-1872) (Moosmann, Schäfer, 1994) in Germany and Aristide Cavaillé-Coll (1811-1899) (Eschbach, 2005) in France.

The new Romantic style in organ building assumed a specific manner of designing their disposition[2]. As time went by, this manner became so obvious that the idea of the organ timbre in the entire Europe was shaped by almost uniform patterns. Interesting directives in this respect can be found in the *Guide for the organists* by Antoni Sapalski (1880), probably the first work of this type written in Polish, published at the author's expenses in Cracow in the second half of the 19th century:

"The relationship of the size to the number of stops can be presented approximately in the following way, for instance:

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[1] In this paper we don't deal with the undisputed achievements of antiquity in the field of organ building, nor with the treatises from those times.

[2] This statement is a simplification and does not take into account the differences of approach to registration of symphonic organ in various European countries. One should mention at least two previously listed, very different schools: French and German. But the timbral ideals and the conception of gradual dynamic changes remain consistent for the entire Romantic Europe.

1. To every two 8-ft[3] stops one should add one 4-ft stop.
2. To every three 8-ft stops one should add one 4-ft stop and one 2-ft stop.
3. To every four 8-ft stops one should add one 6-ft stop (5-1/3 fifth), two 4-ft stops, one 2-ft stop, and a triple 2-ft mixture.
4. To each 16-ft stop one should add four 8-ft stops, one 6-ft stop, two 4-ft stops, one 2-ft stop, and a triple mixture or cornet.

It is difficult to state a rule based on this small example, which, however, serves as a kind of basis for the relationship of stop sizes which should be taken into account in the disposition of a planned organ".

Nobody had to ask Sapalski what stops exactly he had in mind, because everybody interested in the matter had a very similar idea as regards the organ style: the underlying Romantic aesthetics was taken for granted by all.

That era, like all others, had its end: in literature, in painting, in music, as well as in organ building. The slogan of revival reached its apogee several times, for instance in neoclassical architecture, or, later, in Romanesque revival or Gothic revival architecture. As regards the organ timbre, the return to Baroque models occurred, in the most advanced centers, at the turn of the 20th century, with the creation of the movement called *Orgelbewegung*, inspired by Albert Schweitzer. The creators of the new style turned against the Romantic tendencies, common in the organ building of that time, and postulated a return to the Baroque tradition, in particular to the ideals of the organ builders from the times of Johann Sebastian Bach. The principles of the 17th-century art of organ building had not been yet thoroughly investigated at that time, and therefore organs inspired by the assumptions of the *Orgelbewegung* have stylistic features characteristic both for the late Romanticism (intonation) and for the Baroque era (disposition features).

Theoreticians of organ building in the first half of the 20th century (Ellerhorst, 1936; Supper, 1855) gave the following exact guidelines for the relationship of the interior size to the instrument size:

1. In small interiors: for every increase by 50 cubic meters, there should be one stop added in the disposition.
2. In medium-size interiors: for every increase by 75 cubic meters, there should be one stop added in the disposition.
3. In large interiors: for every increase by 100 cubic meters, there should be one stop added in the disposition.
4. In interiors with capacity of:

[3] Here "8-feet" refers to the length of the first, longest pipe, which decides about the pitch of the given stop. The longest the pipe, the lowest the pitch. Pipes are measured in feet, which is the historical unit of length.

a) up to 100 persons − 4-6 stops,
b) up to 200 persons − 8-12 stops,
c) up to 400 persons − 17-22 stops,
d) up to 600 persons − 30-40 stops,
e) up to 1500 persons − 70-80 stops.

Both Winfred Ellerhorst and Walter Supper referred here to the previously mentioned neo-Baroque style.

Over time it turned out that the the tendencies in organ building in the 20th century and the first decade of the 21st century reflect the polystylism of art in other disciplines. Those tendencies include stylization and avant-garde. When designing an organ, we reach to exact historical models (copies) or are inspired by the individual styles (stylistically oriented modern instruments); we strive to achieve a universality of the organ by mixing styles. As a result, although one can play music from any era on such an instrument, none will sound truly authentic (universalism). Moreover, using modern techniques, we build gigantic organs equipped in several improvements, often of startling performance possibilities.

The preference in organ building for specific styles[4] and the bold expression of aesthetic opinions by the persons commissioning and designing the flagship masterpieces of the organ-building art in the last half a century prove, on the one hand, a high level of their awareness and organological knowledge and, on the other hand, show the multitude and the variety of solutions which can be applied in the process of designing an instrument for the specific interior.

To sum up, we can say that we live in times when the idea about the timbre and appearance of the organ is not homogeneous, as it was the case in the past. Nowadays we have at our disposal knowledge about styles, organ building experience, access to choice materials and techniques, thanks to which we can realize bold and varied designs. To take advantage of these possibilities we have to make decisions in various aspects, search for compromises or argue the legitimacy of "hard" conceptions and original solutions.

3. Elements of the instruments and possibilities of their shaping

An organ consists of:
1. Casing.
2. Console or keydesk (with the keyboards and couplers).
3. Prospect or façade pipes (visible) and pipes inside the case (invisible).
4. Wind chests (cases with valves, where the air is distributed to the individual pipes).

[4] By a style we understand references to a specific era and region.

5. Tracker-action (a mechanism linking valves with keyboards).
6. Wind system (bellows, calcant, blowers).

In organ building, the following are evaluated:

1. Visual aspects:
   - the shape of the casing,
   - architecture,
   - the definable style (or its lack),
   - exposition of the instrument,
   - the console.
2. Timbral issues:
   - the disposition of the organ (the number or stops and their types),
   - a definable timbral style (or its lack),
   - loudness and the ability to carry the sound,
   - the timbral palette and the possibilities of the dynamic shaping of the sound.
3. Technical issues:
   - type of windchest used,
   - type of tracker-action used,
   - selection of air pressure and of the type of wind system,
   - equipment supporting the use of the instrument.

4. Factors influencing the design of an organ

Based on these fundamental and necessarily simplified issues, we shall attempt to name and define the factors that influence the design of an organ. We distinguish here objective and subjective (human) factors; next, we will describe the main features of the organ, influenced by these factors.

Objective factors:

1. Characteristic of the interior:
   a) acoustics,
   b) architecture and style.
2. The amount of space destined for the organ and its parameters:
   a) bearing capacity,
   b) surface area and height of the room,
   c) shape of the room as well as architectural and structural obstacles.

Subjective (human) factors:

1. Individual aspirations and tastes/preferences of the investor.
2. Financial resources of the investor for the construction of the organ[5].

[5] One should remember that the organ is the most expensive instrument, intended to be used by several generations.

3. The conception of the designer.
4. Professional knowledge and experience of the organ builder.
5. The equipment of the organ-builder's workshop.
6. Musical and technical preferences of future users.

Each of the factors mentioned previously can influence the shaping of the individual parameters, gathered previously into three groups of issues. To simplify, we can describe this influence as follows:

1. Interior characteristics:
   a) Acoustics − depending on the acoustic predispositions of the room, the designer estimates the required size of the instrument and the best localization of the instrument, and assesses which bandwidths are carried best in the interior and which need reinforcing, e.g. by multiplying them in the planned disposition. Moreover, knowing the acoustic parameters of the room, the designer can refer in his or her sound design to an historical sound style (such as the north-German Baroque style or else the diametrically different French Romanticism style), whose features will harmonize with the acoustic properties of the interior.
   b) Architecture and style − depending on the results of acoustic research and the most appropriate suggested location of the instrument, the designer, in agreement with the investor, decides as to the localization of the instrument and for adapting to – or else contrasting with – the architectural style and interior decor. Knowing the size of the disposition planned, the organ builder determines the necessary volume of the organ casing to which the architect has to adapt the external appearance of the instrument.
2. The amount of space planned for the organ, and its parameters:
   a) Bearing capacity − the mechanism, case, and the pipes of a medium-to-large instrument usually weigh from a few tons to more than ten tons. The planned location of the instrument has to be adequately prepared. In some justified cases it is necessary to perform additional alteration work, simultaneously with the work on the construction of the organ, to reinforce the place. This, too, has an impact on the costs of the enterprise.
   b) Surface and height of the room − it may be impossible to build an instrument of the size appropriate for the acoustics of the room, because of inadequate space or height of the room to house the organ. It is then necessary to make a compromise. For instance, two registers may have to be reduced to a single register, whose sound characteristics will be capable of "replacing" them.
   c) Shape of the room and obstacles − when the church choir or the alcove or balcony in the concert hall has a regular shape, there are no difficulties with the organ construction. Very often, however, difficulties arise, caused

by load-bearing beams protruding from the floor or ceiling, centrally situated windows, steep vault arches or cornices or architectural details which can't be removed. When designing an organ, it is necessary to adjust the design to the room shape and to carefully omit the obstacles. Also, windows, external walls, and the heating system often cause later degradation of the instrument, because of the exposure to solar radiation and problems with thermal wall insulation. For that reason, when designing the layout of the instrument, one should preserve appropriate distances from these obstacles or recommend additional construction work.

3. Individual aspirations and tastes/preferences of the investor − depend on the level of his/her knowledge of the organ; they influence substantially the conception of the designer as well as the actions of the performer (organ builder).
4. Financial resources of the investor for the construction of the organ − budget shortages limit not only the investor's aspirations and the designer's conception (who often has to choose less expensive solutions, against his/her opinion), but they also influence the organ builder, who is encouraged to limit the costs, which may result in a lower quality of the final product.
5. The designer's conception − it has to follow the expectations of the investor and the users, it also has to correspond to the characteristics and parameters of the interior. Much depends in this matter on the qualifications and experience of the designer and on his/her ingenuity and imagination. The designer has to take into account the planned way of using the instrument (for instance, concert solo performance, accompaniment to singing during the liturgy, ensemble performance, playing with an orchestra, teaching). The designer has also to indicate the preferred technological solutions and suggest the layout of the individual sections of the instrument in the context of the acoustic properties of the interior and the planned timbral effect.
6. Professional knowledge and experience of the organ-builder − it a necessary condition for the understanding and proper realization of the designer's idea.
7. Equipment of the organ-builder's workshop − lack of specialized, often very expensive tools makes it impossible in many cases to realize ambitious designs.
8. Musical and technological preferences of future users. We take into account professional users, technologically and scientifically prepared to use the instrument, who also have vast knowledge of the stylistic variety in organ-building. Each user has his/her own artistic taste whose influence on the conception and the way of building the instrument is proportional to the authority of the future user with the investor and performer.

The organ console can also be designed in many ways. In this case, what is evaluated are the appearance and ease of use. To facilitate the use of the instrument, modern technologies are applied nowadays, for instance, electronic tech-

nologies, whose application naturally raises the price. The shape of the console and the electronic aids are therefore a criterion which depends strongly not only on the user's preferences, but also on the investor's affluence.

5. Evaluation of organ-building designs as a multicriteria decision problem

The set of criteria discussed here depends for the most part on the place where the organ will be constructed, although to some extent it refers to universal issues. The basis is determined here by objective factors which we cannot (or want not) change (that is, first of all, volume and acoustics of the building). Based on this, we can prepare for the investor several organ designs, which will differ significantly. They can be defined as decision variants, which can be evaluated as regards, for instance, architecture of the casing, timbral style, solutions of instrument construction or ease of use. The definitions given in the previous sections constitute the first attempt to describe this phenomenon in a universal way. The order of the criteria and, in general, the consideration of variants of the individual groups of criteria depend on the interests of the investor and the expert. Once the variants and the assessment criteria for a specific realization are created, one should discuss the issue of measurement scales to be used for the individual criteria so as to best render the intentions of the persons performing the evaluation. In our research, we do not include any examples, since their thorough presentation would require a detailed description of all previously mentioned issues, which would be outside the scope of this paper. In the future, however, conducting such a process (be it hypothetical or supported by actual design and construction) and describing its results, seems well-founded.

6. Summary

The construction of an organ is often a compromise solution taking into account the factors listed above. Objectively definable conditions, such as: room size, results of acoustic research, technical expert opinions, interior style, can be assessed by various experts/designers in various ways. We start the assessment with timbral issues. Assuming solid preparation and knowledge of organ building by the group of experts, we obtain several good, but most likely differing designs, reflecting the tastes and preferences of each expert. Following this, the next group of experts presents their preferences as regards the shape of the organ casing which can house instruments with the expected sound characteristics. These experts are usually specialists in organ mechanics. They too take into account the objective factors researched previously, together with an additional proposal outlining the timbral characteristics of the organ. At the top of this

pyramid stands the investor, who is able, to some extent, to cope with the proposals presented. His financial resources and willingness to finance interesting, but not always necessary, solutions suggested by several experts are confronted with his own individual and artistic taste, both as regards the sound and (usually to a larger extent) the appearance of the instrument. The investor seeks the opinion of trusted persons and of the person who will use the instrument most often – the parish organist, the orchestra musician usually playing the organ part, etc.

Assuming a thorough and solid organ background of the closest advisor or of the investor himself, one could dispense with the "pyramid" of experts described above and, without problems, commission the construction of the instrument conceived by the experts directly from the investor's favorite organ building firm. This, however, happens extremely rarely, and the closest advisor of the investor is often a moderately educated organist led by his own comfort-seeking nature and not by the organ's quality.

Uncrowned king of musical tools, the most expensive of all instruments, living up to 200 and more years, certainly deserves to be the object of a solid and thorough multi-criteria project supported by well-founded knowledge and multidisciplinary research in many disciplines of art and technology.

A few years ago Małgorzata Trzaskalik-Wyrwa had the opportunity to present a similar issue from the field of historical organ conservation. That, however, dealt with an already existing historical substance, to which one had to adapt the most suitable conservation-related decisions. In the case of the construction of a new organ, the weight of the particular criteria changes. The designer and the organ builder create a new reality, a new musical tool. Therefore, more possibilities appear for theoretical discussions BEFORE the start of its realization. AFTER the organ had been constructed and a large amount of money had been spent, it will not be easy to bear the critique when one has neglected to work out the design. Here we see a wide range of opportunities of applying multi-criteria methods, which − although they probably will not automate the decision-making process − will encourage to define the criteria precisely and will influence the awareness of the group of people interested in the realization of the project, as regards the weight and values of the actions undertaken and their influences on the final shape of the newly created organ.

To end this discussion, we quote again Antoni Sapalski's *Guide...* This quotation shows that now as in the past, attaching very high importance to the lowest price criterion is not the right method in organ building, since it impacts its quality: "It seems to follow that the size of the instrument should depend strictly on the size of the church. This should not, however, be always the guiding principle, since this instrument, among all known instruments, requires the largest amount of work, and therefore also higher costs; hence, imposing too much restrictions

in this respect on the organ builder puts him in the situation in which he is either unable to apply himself to the actually necessary size or else it is not possible to require of him to construct the instrument and perform its artistic completion" (Sapalski, 1880).

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