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Systems approach as used in this paper refers to the process of a building coming into being. The systems approach attempts to relate the processes of factory production and school construction in that the problems of the spacing and fitting of construction components are considered at the beginning of the design stage of construction. For the systems approach to insure minimum cost, high quality and flexibility it must be based on production volume, reasonable notice time to industry for tailor-made components, and clearly defined functional goals. (HH)

A SYSTEMS APPROACH TO SCHOOL CONSTRUCTION

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"To say that things are fast changing in vocational education is not quite true. The pressure for change is enormous, change is in the air, change is being effected to some degree in some school districts, but this is basically a revolution in the making, it has not as yet arrived. When it does, though, the lightning speed and intensity of change will more than atone for its slow start." This is a quotation from a recent article on vocational education in School Management Magazine, titled "Vocational Education -- A Time to Shift Gears." I think most people would agree with at least part of that statement. There certainly is a pressure for change. But there seems to be a lot less agreement on the direction that that change ought to take. Since I'm not an expert in the vocational technical field, I suppose I am free to offer solutions to some of the problems relative to the task of designing facilities in which to house these new programs.

For some years I have been engaged in trying to interpret what people said their program was in order to get it translated into a form that the architect could understand. It's exceedingly difficult to build and create spaces for programs when we don't know the exact nature of these programs. One of the things that school administrators, planners, and architects like to do when confronted with this problem is to hop into an airplane and look at what everybody else has been doing. And we, of course, are going to do some of that very thing this week ourselves. Educational Facilities Laboratory, with whom I am associated, has spent a lot of time and money sending people around the country to look at what other people are doing to solve their own particular problems. We have a regular road show that comes through our planning laboratory at Stanford University -- hundreds of people every month, all looking to see how someone else has solved the problem of facilities for programs. Primarily they are interested in finding solutions to facility problems. I think this proves to be a very valuable experience. I do think, however, that these tours will be helpful only if the demonstration facilities are related in some meaningful manner to the programs that they are designed to show. The building, no matter how esthetically pleasing or technically perfect, exists for only one purpose, and that is to facilitate some educational program. Unfortunately, very few awards are based on this premise. The national design awards and the magazine awards, and all the other awards usually are graded on some criterion of attractiveness, rather than on how functionally suitable the building is for the program it houses.

If we really believe that the building spaces should reflect the program, it seems to me that one of our more important tasks is to interpret this correctly and concisely so that it can be put directly into the bricks, mortar and stone. All of this, of course, has been said before. The real problem is how do you go about translating this when you don't know what the program is -- when you can't see clearly the direction, the scope, or the magnitude of the program under development. If we had a final answer to the program and that answer would remain unchanged for the life of the building, say for fifty years, then we would certainly be a long way toward solving our facility problems. We would describe the program, devise our spaces to fit that program, cast it in stone, and be confident that we would have a building that would serve us well during its 50 year lifetime. But the situation in which you and I find ourselves is quite the opposite of that. While there may be a few who can detail the program they now have, there are still fewer who can forecast what it is that they intend to do in the future, and fewer yet who can see a clear direction that we ought to be taking in this field. Will we have a building that is really functionally geared to the program requirements for one, five or ten or 15 years? Just how long will this building we are thinking about and planning for now really be useful?

The program requirements given to the architect three years in advance of the time when the building is first to be used may not even have relevance for the proposed program that will be housed in the building on the day it opens. What can and should be done, then, to provide for this expected change in program and, consequently, in the space changes required to house these programs? What is clearly needed are spaces that can quickly and inexpensively be adapted to changes in program and teaching methodologies. The key ideas, of course, are the need for flexibility achieved at reasonable cost.

The first question I always field after describing some of the things that we have been doing in the systems field is, "How much did it cost?" or, "Is it more expensive than conventional construction?" Yet the real question is not, how much did it cost to build, but rather, how much value did you receive for what you spent? Generally speaking, we have found that there is nothing more expensive than a cheap building.

One of the measures of value that should receive more study is the one based on the concept of the useful life of the building. To illustrate, let's look again at our building that we built to house a program which was to continue for the 50 year life of the building. If that building had cost $5 million to construct and it had its planned useful life, that building would only have cost us about $100,000 a year -- very inexpensive. If, on the other hand, that building's life was only 10 years and at the end of those 10 years extensive and expensive remodeling was required to bring it into line with the things we wanted to do then, the difference in per year cost of the building suddenly becomes very apparent.

Some of these kinds of considerations were considered recently at a conference in St. Paul, Minnesota at which the North Star Research Institute commissioned one of the local architectural firms, Zellerby and Company, to take a look at just what this meant in terms of a very simple structure, a small classroom building. The results were startling and, without burdening you with many figures, underscored the point that the long-term return on facility investments is far more critical than are their initial costs.

Are there any answers, then, to the cost/quality flexibility problem? Let's examine for a moment two major problems in this area. First of all, one of the most obvious reasons for the increase in the cost of buildings is the high cost of on-site labor, up 38 percent in the last eight years and showing no sign of leveling off. The second major factor is in the inherent inefficiency of our building technology. We seem still to be in the handicraft stage when it comes to building construction. In an effort to reduce the amount of on-site labor, we have turned to the traditional American way of cutting cost, that is by industrialization. This means we produce in our factories larger and larger building components and have them shipped directly to the site ready for rapid installation. This method takes advantage of the generally lower factory wages and the generally higher measure of quality control that is available in most plants. Such attempts to industrialize the building process are not without their own special problems: social, political and technical. There are, however, some signs of progress even within these complicated areas. One thing is clear, though, the handicraft approach to building schools simply will not be appropriate in the years ahead.

The on-site labor problem is closely related to the second major obstacle to be overcome. That is finding ways to improve our building technology. One of the major efforts in this regard is what is known as the "systems approach" which is sometimes confused with a lot of different things. We have systems for car washes, systems for research, and systems for aiming and directing very complex guided missiles.

In discussing building systems, I think a distinction should be made between the building system itself, and the <u>process</u> by which a building comes into being. In a sense one can regard any building as being built with a system, or a set of sub-systems. However, the way in which a conventional building comes into being is often far from systematic. Much of our interest focuses on the discrepancies between the systems of the building and the way in which they are designed, as well as the way in which they are built.

With the advent of larger and larger components and more and more factory work, the architect is spending greater portions of his time trying to fit together these larger elements as they are delivered to his job site. An example might help to clarify our concept of building systems. There is an analogy between a well-designed and familiar system, the human body, and the building systems as we know them today. It is common in medical training to separate the study of the human body into various functional systems. The body has complete systems which perform entire functions. Take, for example, the muscle system or the skeleton system. These two familiar systems perform functions closely analogous to those found in the building industry. It's significant also that these systems have little meaning as independent human components. They perform no meaningful function unless they are operating together and in harmony with the rest of the organism. If any of these systems becomes displaced or malfunctional, we are at once disturbed because we know there is something wrong with the total system of the living body. Likewise, should a portion of the skeletal system become visible, we know that serious injury has occurred. Another analogous point is that all systems grow concurrently with the overall growth of the body. The parallels between the human body and a healthy building are, indeed, numerous.

One additional element should be mentioned. So far we've only talked about the functional aspects of body and building. It might be well now to think for a minute about some esthetic considerations. While the skeletal system may be a thing of beauty to a student of anatomy, to most of us it has different connotations. Esthetics, while typically independent of function, should not be despised either in human bodies or school buildings.

Recently, we visited the Lockheed Aircraft Factory in Marietta, Georgia and watched the way they put some of those giant planes together. And, of course, they get parts and systems that are designed in every quarter of the United States, bring them there and fit them together. If they were to operate on the same kind of principles that we operate with in *constructing buildings, I'm sure that they would have a peculiar looking aircraft by the time they finished, and one, incidentally, which would not be very airworthy. Certainly consideration has to be given to all of the elements that go into the structure: what space each will occupy, and how will it relate to the other pieces so that we finish with a functionally efficient system. While a building admittedly represents a lower form of design than an airplane, there is, nevertheless, a tendency for the modern building to become more and more complex. In place of a simple masonry shell to which a few heating pipes will be added and a few lighting fixtures installed, we see now a complex arrangement of ductwork, lighting conduit, air conditioning systems, piping, television conduit, and a great variety of elaborate electrical systems, all of which have to be closely integrated into the final building. The traditional process of school construction is fast becoming antiquated in the light of the great multiplicity of technological requirements set for modern educational facilities.*

One of the major problems arises because the building is made up partly of components manufactured in distant factories and partly of materials both fabricated and fitted together on the job site. The factory-made components are designed with little relationship to each other, requiring much of the architect's time to arrange for their concerted functioning. If one returns to the analogy of the human body, the building scarcely comes together in a way similar to that of the human body. If one had set out to design the human body, farming its components out to various sub-contractors with one making the hand and another the arm, and still others the remaining parts, one can see that without very close coordination between all of the contractors we would have an exceedingly difficult task in getting anything that would function properly. Yet quite often this is the very way we set about constructing our buildings.

We take all of these separate pieces, which were designed without any particular relationship to one another, and then hope in a short period of time that we can succeed in getting all of them to relate properly to one another. The systems building very deliberately attempts to recognize this basic problem of building design and to relate processes of production and construction to this design approach. If we take a look at the systematic process of building construction, we find it existing in varying degrees, all the way from a very simple expression, perhaps through volume bidding, to a complete system with numerous ranges in between. Of course, most of our buildings are evolving out of one or another of these partial systems.

We are participating in a project in Pittsburgh, Pennsylvania in which the people there are going to build five large high schools, for five thousand students each, within a very short period of time. They plan to consolidate all their high school students within a very large and complex program. They have turned to a systems approach as a means of assuring quality control for this massive undertaking.

In establishing this process we are separating the functional systems of the building into appropriate categories. This is what we did when we worked with the S.C.S.D. Project. The project directors decided on the categories that they thought were the most appropriate for us to tackle at a particular time. Everybody would have liked, for example, to work with the plumbing as it related to the building. But after doing some investigation, we came to the conclusion that unless we wanted to devote all our energy just to plumbing we would not get very far. What we finally did was to decide on a structural system to embrace all support problems of the building, including air conditioning, lighting and interior partitioning as the first of our components. It's possible to get these systems designed by those involved at the factory level in such a way that they will relate to one another efficiently when they come together in the building. Thus, the structure is designed from the very outset to recognize the needs of air conditioning ductwork and space for electrical conduit. As a result, when these systems come together on the building site, most of the problems of spacing and fitting have already been solved at the point of design or production. I'm sure you'll all agree that it's a good deal easier to move a water main around on a drawing board than it is after it is covered with six inches of concrete!

Production for volume, besides enabling better functional efficiency, can also result in some substantial cost rewards. As the cost of labor increases, and as the complexity of buildings increases, we can see the need for more and more rationality in the design and construction process. Systems building is an attempt to introduce this rationality into the building process at an early stage. By now we have gained enough experience with it to show that the gains in economy and in function can be significant.

For systems building to be effective three conditions are necessary. First, there needs to be a large volume of building so that appropriate industries may be involved in components on something approaching a mass production basis. Secondly, there needs to be sufficient preliminary time to enable industry to get to work in an effective way to produce properly tailored components. Usually the large project brings with it the time necessary for industry to do its work. Thirdly, the project should have clearly defined functional goals upon which it is possible to reach a consensus for what is required. Knowing the educational requirements makes it possible for specifications or standards to be written enabling industry to take proper advantage of the large volume of work. Clearly, there is no economic value in a large volume of work if all the components must be different. A good example of how this works out in practice can be seen in the auto industry where there are a large number of unit options, but where all are based upon a small number of parts which are rationally designed to fit quickly together.

Brunell, 120 years ago, designed a wooden hospital in

England, shipped it from there in transportable pieces to the Crimea and assembled it near the battlefield. This hospital was big enough for 200 beds, and that, I would remind you, was fully 125 years ago! Legend has it that this was the beginning of the concept of component design. At the very least it was a prime example of the logical use of building components made to fit together easily and quickly, and to overcome a particular set of circumstances. Another example occurring 125 years later is the School Construction Systems Development project which has been used in portions of the Southern Nevada Vocational Technical Center. We made a movie which we designed to use with contractors and people who were interested in the systems concept. This is not a finished movie, but it is a unique one. It consists, in part, of a time-lapse photography sequence of the construction of the mock-up building used to test all of the pieces that went into this system. We mounted a camera on a telephone pole behind the job site that took a frame every 75 seconds all through the exterior construction phase and then put all these together to show how the building unfolded, much like you do in showing children through time-lapse photographs how a flower blossoms. The movie gives a graphic explanation of the systems approach and shows better than we can relate the organized flow of work which is its initial aim.

In summary, it might be wise to add that the use of the systems approach to design and construction of vocational technical facilities is not going to solve all the problems of providing a dynamic program geared to the needs of a space age society. What this method can do is to help provide a facility to house such programs effectively and efficiently, and over a longer period of time than any other approach that I know of at this time. It happens that a great many of the needs for flexibility, better value for the building dollar, and efficiency in construction are objectives that are equally applicable to most types of building. Certainly there is a need to study the construction process further. We need especially to look at our requirements in terms of our own programs to see whether or not what we are doing is appropriate for our own type of program.

In the last analysis, it is important that we get good value for the money we spend, stretching that dollar value over a long and useful period of time. A systems approach to construction is much like purchasing blue chip stocks: it not only gives you immediate return on your investment, but over the years assures you of sizable annual dividends.