11 Reflections on the Presentations

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Our purpose here is to anticipate how technological change will affect the building industry either from the supply side or from the demand side and to determine whether any of these changes could create problems that Congress ought to be aware of and, potentially do something about.

A. The Six Construction Industries

Here in Washington we often choose to talk about the 'building industry,' and discuss issues like changes in the levels of employment, changes in quality and safety, changes in productivity, changes in opportunities and risks from foreign competition, as if it were a single industry. I don't think this makes much sense.

In many ways the building industry is no more monolithic than the transportation industry. The transportation industry includes the airlines industry, the railroad industry, the trucking industry, and the shipping industry. There is little crossover between the organizations, the institutions, the skilled manpower, the technologies, and the R&D base that are utilized by those sectors of the transportation industry.

Practically no Federal policy can affect each of the separate industries within transportation. But since you don't want too many units that report to the President, you can create a Department of Transportation and lump all of those things that have to do with movement under it. It also is useful to talk about a transportation industry for economists who want to make measures of the national economic sectors. It avoids having that many more pages of statistics if you can somehow or other have a number that represents the contribution of the transportation industry to the gross national product.

The building industry, or the building industries, as I prefer to call them, are combined for much the same reason. It makes sense to look at the several building industries if what one wants to identify is expected changes in the industry.

For our purposes, it seems to me there are six industries which react quite differently to those kinds of issues:

- The first is the *housing industry* — the collection of organizations, technologies, skills and financial mechanisms whose purpose is to convert raw land, usually purchased on a speculative basis, into dwelling units that can be sold or rented to individuals and families. The major distinction for the purpose of analysis is that this process is begun before there is a buyer in mind. The builder of these houses builds a house against a potential market, not against clients who come to them and say, "These are our needs, and we want a house of this kind." Very few houses in the country are done that way, and I put those in the fourth category.
- The second is what I call the *manufactured building industry.* I call this a separate industry because it is a collection of organizations, technology, labor and financial mechanisms whose purpose is not to convert land into buildings, but rather to manufacture off-site units that are anywhere from the whole unit to subassemblies, which can be transported to the site. A few companies like the Ryland Corporation own house manufacturing capabilities, as well as build conventionally, and I'm sure we can find all kinds of exceptions at the margin for each of these.
- The third industry I call the *commercial developers.* I mean by this people who buy raw land and convert it into buildings other than housing — people who develop industrial parks, people who develop shopping centers, or people who develop office buildings. Again, the character of this industry is that there is no client in advance, There's a prospective market out there, and there's land, and there's an investment to be made in building something on this land which will eventually be leased or sold to a set of users which will emerge.
- The fourth industry, is the one that most of us

think about when we talk about *'the building industry,'* It is the conventional collection of organizations, design and engineering firms, banking institutions, general contractors and subcontractors, regulatory bodies, etc. that build buildings for specific clients: an agency of the Government, a private client, or sometimes a wealthy family. The client sets the requirements, decides on where they're going to locate, usually purchase their own land, and then enter into a process in which a design is created for them that's eventually put out to competitive bids. The 'building industry' listed here is the only industry in which competitive bidding occurs. It is practically the only industry of building where there will be a major change if there is a technological breakthrough. It's the one building industry where bidding can reflect market conditions as a result of changes in prices.

None of the industries listed above really have much competitive bidding. Sometimes market competition works in the housing industry, but only over a long period of time. The major impact of the housing industry, as we've mentioned already this morning, is what it cost to buy the land, and what is the mortgage rate that they have to pay? We used to speculate we could practically build a house for nothing, and it wouldn't change the price which people would pay for housing, because the market price for housing was determined by a whole lot of factors other than the technology of building.

- The fifth industry, *the remodeling industry,* is one we sometimes forget. Of the $250 billion that represents our 10 percent of the gross national product, is included almost $50 billion in this remodeling industry. This probably does not include rehabilitation of existing buildings in the sense that an architect and contractor might do it, nor does it include rehabilitation of the kind that homebuilders do. It means the remodeling industry that sells things from aluminum storm sash, to screen doors, to new store fronts for small businesses; that is financed by short-term financing rather than increases in mortgages. It is not regulated by building codes, by and large. For a long time, it could be characterized by the blue suede shoe type of salesman,
- The sixth industry, and the one that OTA chose not to cover in this workshop, is what I call the *heavy construction* industries. These industries build highways, dams and facilities. Their clients are primarily public agencies and utilities.

I can make a couple of statements about these six industries that are useful even though there are exceptions to everything I'm about to say. First, the fourth industry in my list, 'the building industry,' is the only place in which technological change has a dramatic and immediate impact.

Secondly, if one tries to make a definition of an industry which is a collection of people who represent a common interest because they supply a common concern, these definitions hold up pretty well. One of the ways that is very visible if you work in Washington, is by seeing who is it that lobbies. And the people who lobby for each of these groups don't really concern themselves by and large with the other groups, People who are lobbyists for the housing industry are not, by and large, concerned about the commercial developers or the remodeling industry or the heavy construction industry, and vice versa.

Also, another way to look at it is who supports the R&D and where is the R&D done. A few universities do research that crosses over these industries, but if you look at the individual in the university who is doing research, their research is oriented towards one of these industries, as contrasted to the industry across the board. I also think that there are very seldom movements of companies, of skilled labor, or even of financial mechanisms across these industries.

The prospect, therefore, is that when we talk about the impact of technological change, as OTA will be doing, and what that means to the building industries — and we provide advice to policy makers like Congress about what can be done about looking at the impact of technology on the building industries, that if we are being as clear as we can be about it, that we mean there are these six industries and not one industry.

B. Evolution vs. Revolution

We must also be clear about the nature of the changes now underway in the building industry. We're in an industry in which the character of change has been evolutionary and not revolutionary, and that's likely going to continue to be the case. A lot of my fellow executive directors here in the National Academy of Sciences are responsible for areas that have only been around for ten years or fifteen years. Some, like chemistry or physics, have been around for over one hundred years. But we've been building buildings for over five thousand years. Over that five thousand years inventions and innovations have been introduced, primarily by trial and error.

When we have an industry like the electronics industry, the mean time between surprises is zero. One expects a new surprise to come out of that technology practically every day, but it was born in a period of time when the kind of race that it's running is equivalent to the 100-yard dash. The pace of change in the building industry is more appropriate for running in a 26-mile marathon. You don't use the same techniques in the 26-mile marathon that you use in the 100-yard dash. The construction industry has learned what works, what doesn't work, and how to bring about change very slowly.

Well, what is a revolution? And if we were to try to describe to Congress whether there are revolutionary changes possible, conceivable, or likely to happen in this industry, what would we mean by 'revolution' as contrasted to 'evolution?' There's a simple definition of 'revolution' for this purpose. By 'revolution' one would mean the rapid displacement of an existing set of ideas or skills or institutions. That is, somebody would be out of business who's now in business, or some idea would be out of vogue that's now in vogue, and a new idea, a new set of skills or new set of institutions that were considerably different, not just slightly changed, would have come into existence. Technology has created many 'revolutions.' Consider the field of medicine. Practically no child has measles today. Diphtheria has been eliminated in the world, not just in the United States. Literally in the world there are zero cases of diphtheria at this point. Technology is transforming the office. 1 learned to type when I was in the service. But the word processor is so much more convenient than the typewriter that the typewriter is practically useless to me today. I wouldn't want to use a typewriter, as such, even though there are new typewriters still coming out on the market.

Tower cranes are one of the technological changes that were introduced into the building industry that displaced old concepts, and I gather the tower crane may, in turn, be displaced in the near future.

Well, what kinds of things have we talked about in this workshop that have the quality of revolutions? I thought I would concentrate on those since evolution in this business, after five thousand, is relatively easy to deal with. Maybe some of us believe there needs to be some ameliorating consequences on the part of Congress, but by and large, I'm impressed after twenty-five years in Washington that in our society, we do adapt to evolutionary changes. We're less good at, less clear about how to deal with revolutions.

So what kind of revolutions might be coming out of what we've talked about, 'revolutions' meaning the displacement of an idea that's in present currency, the displacement of a set of skills or the displacement of a set of institutions?

The clearest, most easily understood, example is what I would sum up in the word 'telematics' the combination of electronics that combines communications, computers, electronic controls, et cetera.

In Harry's report on the first day, and Alton Bradford's as well, most of us are made aware of the fact that telematics is dramatically going to change the building process. This is conceivably revolutionary in the sense that there will be displacement of skills in professional firms as a result of this telematic change.

We also heard from the team of Reisman, Clevenger and Patri an example of telematics being incorporated in the products which we design and make, namely the ‘intelligent’ building, It’s not quite as clear whether that’s going to be revolutionary, except that there does appear in the case of the ‘smart’ building a good possibility that there will be a displacement of the concept of office buildings that are not ‘smart’ buildings, and that therefore, our inventory of office buildings, particularly the ones that are in the open market, will represent a new opportunity for upgrading performance if they’re going to stay competitive.

It’s interesting that telematics introduced into buildings, is the first revolutionary change in the fabric of our cities in almost one hundred years. One hundred years ago we had a very dramatic set of changes which included:

1) The invention of the steel process (the Bessemer process) and therefore the ability to separate the structural part of buildings from the walls. This made it possible for the first time in history to build buildings that were taller than four or five stories. The steel skeleton began to emerge as a technological possibility a little over one hundred years ago.

2) Associated with that was the necessary invention of the elevator, because while people will walk up five or six stories, the possibility of them walking up more than that is not very likely.

3) Another invention was the invention of a whole set of things that made indoor plumbing possible. You just have to imagine a sixty-story office building in downtown Manhattan that had all outdoor privies to imagine the land problems that that would impose if we didn’t have indoor plumbing.

4) And then a discovery really, the discovery of electricity, and the application of electricity to indoor illumination so that spaces inside of buildings could be used without daylight.

5) Then a set of inventions that made communications possible, primarily the telephone. The ten thousand people who work in the Empire State Building could not continue to function in our society if they had to deliver physical messages between each other on pieces of paper and were not able to talk on the telephone.

6) Then the invention of the internal combustion engine and its incorporation in the automobile. This dramatically changed the urban setting.

7) The invention of the set of devices called furnaces that changed the nature of how we heat space from essentially what was a wood burning or coal burning fireplace, with enormous logistics problems, to the centralization of that heat producing device in something called a basement.

Now, that set of inventions has two interesting characteristics to it. Every one of them were reduced to patentable positions in the United States between 1880 and 1892, and since 1892, there has not been another single invention that dramatically changed the performance characteristics of buildings.

However, we may be, with the ‘smart’ building, and with telematics, in the middle of the first dramatic change in the performance characteristics of buildings since 1892.

Next, in this workshop, we discussed the question of whether or not there are any surprises coming in the manufactured housing business. That is, is the process of making buildings off the site likely to produce some dramatic changes over the next few years? I think what Don Carlson and Eric said clearly indicates that if it’s not going to come out of the United States. But the subject which we have not talked about is that it might come from foreign competition. Japanese or the Swedes or some place else might develop a truly capital-intensive process.

It we examine how much capital equipment is invested in a typical U.S. prefabrication plant per worker, I think it’s still probably not much more than $2,000. The average farmer in Pennsylvania spends $75,000 on his equipment to do his farming on an everyday kind of farm. So we’re very far from being a capital-intensive industry at this point, even with our manufacturing processes.

I’ve not heard, but it would be interesting to hear, what Japan’s equipment investment is.

David Claridge and John Millhone talked to us about energy conservation. The message there for Congress seems to be there's no surprises coming unless, and that's a very hard thing to predict, unless we have another world crisis of some kind, in which we have our sup ply of fossil fuels dramatically curtailed. Then we might have to do something more dramatic than what we did in 1973.

An interesting example from the energy conservation area seems to be a byproduct of technological changes in energy uses. Even such evolutionary changes, sometimes can be very dramatic. The dramatic change that's coming out of energy conservation is the decline in the business of the heavy building industry. The people who build power plants are the ones who are getting revolutionary changes introduced into their activities as the result of energy conservation, because electric utilities don't need the kinds of capacity they thought they were going to need fifteen years ago. Just yesterday, for example, TVA announced the cancellation of another set of nuclear power plants. Those big projects that big civil engineering companies did are disappearing, and the result is very interesting. Most of them are looking to other parts of the world for business, and they tell me that there are really no giant projects that they see in great abundance going to come out in any part of the world. So that means that the Swedes, the Koreans, the Japanese, the French, the Italians, all of the big companies in most parts of the world are looking every place else in the world for business that's going to represent a new opportunity for them. That may be the most revolutionary thing for the construction industry to come out of energy conservation.

Dick Tucker talked this morning about what seemed to me more of an emphasis on problems than opportunities. The interesting notion that he represents is the constant concern than I've heard for at least thirty years now in this industry about we need more support for R&D. I don't think there's any shortage of capital for R&D anywhere, whether it's Federal funds or private funds. What we're short of is good ideas. When somebody like Dick and his colleagues put together a good set of ideas, they can get the money to support their work.

I have never heard of somebody who had a good idea that didn't get funded. I've heard lots of people with half-baked ideas, and I've heard lots of people who have complained that if they only got some money they would have good ideas, but by and large, the money is available if there are good ideas.

Wendel was the biggest surprise for me. He represents true revolution. He represents that breed of cats like those who are out there changing the world in Silicon Valley in California, They didn't ask anybody if it's all right to come out with a new set of ideas. They went ahead and produced a new set of ideas. When I taught architecture 1 had students who had ideas like his but he's actually getting them built. Wendel is not only revolutionary because he has some good ideas, but because he's getting them built.

Al Dietz said that there are no revolutions coming about for materials. However, the use of waste materials, the new applications of materials like composites and laminates may change some of the processes. We can say to Congress apparently we don't see any surprises coming out of the materials field, including out of NASA.

Chuck Thornton talked about the actual cost of the building as being only one-third of the cost to the owner. I have a hunch, that the financial community will soon be entering some revolutionary changes. Banking and financial institutions are not going to go out of business. We need money to make money, but they've gotten so greedy and so big in my lifetime that the central part of every city in the United States, and in most of the world, is dominated by buildings built by financial institutions. When I was a boy we were building churches, schools, hospitals, suburban homes. Banks were little places, in which if you didn't do well in high school you went to work. All of my children's friends who did well in business administration or economics, or almost any other subject in college, go to work for banks in New York City and make astronomical salaries. The credit card companies are tying to charge me 19.8 percent on short-term credit when we're complaining about what, 14.5 percent mortgage rates in housing? Something is wrong somewhere. Somebody is making too much money.

Every time in history when somebody is getting too much of the pie for themselves, some kind of revolutionary change occurs. New institutions come into the business, and those new institutions create a different way of doing things. I think that one-third cost now of buildings that does into money might, in fact, precipitate not only a change in time, but a change in the way money enters into this system.

Then finally the lesson that comes from NASA, that Stan talked about, is that the largest single invention in our lifetime has been the invention of how to invent. For the first time in history we can purposefully go about inventing whatever the mind of man can conceive. That's never been true in history before.

How we go about invention is the key. What we did not do when we decided to go to the moon was to hire an industrial designer, an aeronautical engineer, and interior decorator and a couple of other professionals and say, "Design us a spacecraft that we're going to send out for bids." Why didn't we? Because the big secret of invention of invention was how to use ignorance as a resource. How to find out what it is we don't know. That's what the space program has taught us; how to systematically go about finding out what we don't know. Work on a collection of things that you don't know until you do know something, and you can release a new set of discoveries.

I think we're in the building field with telematics now at a stage where we may produce a revolution of that kind, a new set of characters who will say, let's systematically go about not just new product development, but new concept development by using ignorance as a resource.

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1 will address the needs and opportunities of the building community as I see them. I will briefly address opportunities as they relate to computation and automation, education of professionals, productivity, and building research. Suggested will be a model for change that might be given some consideration.

On the subject of automation and advanced computation, it's amply evident to all of us that this technology is coming on like gang busters. The work that Wendel is doing in the design and manufacturing of space frames is extremely advanced. But we must be impressed with the fact that it's still fragmented. The hardware, the software, and the languages still don't interface. Wendel showed that he had to bring the architect to his office in order to communicate. The day will come when he, through his computers, will be able to communicate directly with any of his clients, and his clients with their clients and consultants. Expert systems have not yet received much attention, but the opportunities for expert systems will put new demands on architects, engineers, and researchers.

We continue in a construction process that regenerates the same information over and over again in spite of the fact that we have this wonderful new capability in front of us. Basic information about the building is generated at the predesign or programming stage. It's regenerated at the design stage, not any by the architect, but by each of the involved consulting engineers.

For example, an architect will develop the necessary information to design a wall system. The mechanical engineer again will develop some of the same information to calculate heat gain and heat loss through the walls. The structural engineer will need some of the same information to determine the loads on the foundations. Then the contractors bid the job. They take off much of the information from the plans and put it into their computers to prepare bids. The building regulator, who has to check the plans for compliance with the building codes, does it again; maybe not to the same depth, but he needs to look at the plans that relate to safety characteristics such as fire resistance. Over and over again, the same information is regenerated, each time increasing the chance for errors and decreasing overall productivity.

The contractor, after receiving the award, has to take the information off the plans and specifications in detail for ordering the materials and scheduling the work. The fabricator extracts the same information to develop shop drawings. Yet, when the project has been completed, the previously developed information is not available to the owner and occupants who need it to operate and maintain the building. Nor is it available to those who want to rehabilitate or demolish the building,

We need to develop the necessary interface standards which will allow the various proprietary hardware and software systems to talk to each other. We should develop these standards, using the voluntary standards organizations now in place. This will permit all affected parties to have an input and a part in the development of the standards.

Research needs to be conducted to obtain knowledge on the application of artificial intelligence to the development of expert systems for construction. In the area of education for professionals, we have been told — it was said over and over again during these past two days — that tomorrow we're going to have to work differently, architects, engineers, and constructors will need to work as a team. Nevertheless, today we still see much fragmentation at the university level. For example, mechanical engineers usually don't learn much about building technology as part of their education. They may be in the same building, but they don't talk to the civil engineers, and the civil engineers don't talk to the architects even though they do most of the structural design. Electrical engineers usually don't show much interest in buildings, and the architects are off in their corner, concerned primarily with drawing and the aesthetic aspects, not the technical issues of buildings. Many builders and contractors are educated in schools where business management is the matter of primary concern.

If we look at the recent past, you will see that architects have enjoyed relatively less of the design fees paid for building design and construction; and their proportion is decreasing. Engineers, on the other hand, because they are applying more technology, have experienced an increase in their part of the pie. The time has come when many firms refer to themselves not as AE firms, but as EA firms, which was almost unheard of ten years ago. This indicates an increased emphasis on technology applied to building design practice. I think it's time that we look at the opportunities to educate this team as a whole. There are big potential payoffs by studying and improving the way we educate young professionals so they can better work together as team members.

The next item I want to touch on is productivity. I was interested in what Dick Tucker said about increasing productivity at the job site, but I want to address the subject from a different angle. We were told yesterday that the environment in the 'smart' office building can increase productivity 24.9 percent. That is a very impressive number. Michael Clevenger made a convincing argument that we can increase productivity by that amount. Let's look at the meaning of increasing the occupants' productivity, not just the typing pool's production of typed pages; but let's see what it really means in dollars.

Several years ago we provided technical support to the General Services Administration for their building systems program during which we looked at the life-cycle costs of a building from a productivity viewpoint. When we looked at the life-cycle costs over an office building life, the numbers came out something like this. The initial cost to build an office building is in the order of two percent of the total cost to build, operate, and product in it over a life time. Approximately 6 percent of the total cost is for operation and maintenance, and 92 percent is to pay the people who work in the building.

So let's extrapolate from these numbers and look at what an increase in worker productivity can mean in the total scheme of things. Even if you add an additional 25 percent to the initial cost of the building, in order to increase the productivity of the people in the building by even 10 percent (e.g., reduce labor costs by 10 percent). You would get a return of 18 times the investment. I know of no other investment as financially attractive today; and if you achieve the suggested 25 percent increase in productivity, you get a return 46 times its cost in present worth dollars. Those kinds of investment opportunities are unheard of. We ought to be looking at the impact that a more productive built environment could have on the construction industry, the opportunities for architects, engineers, building materials and equipment suppliers, developers, and investors. We need to look at this opportunity for all types of buildings, from office buildings to the factory floor. What would increased productivity mean in educational facilities, on one hand, and retailing, on the other hand?

I support a thorough study, including behavioral research, to understand the impact of acoustics, lighting, thermal comfort, air quality, space relationships and aesthetics in buildings as those qualities affect productivity. Such research may be a major opportunity for the construction community. Also a hard look at the influence of the built environment on productivity would be a great opportunity for the country to improve productivity.

A number of papers here argue the need for more research. Research money will usually be available when the financial opportunity justifies the investment, and when the results of that research accrue to the people who make the investment, Yes, then there is money available.

But there is not money readily available to conduct research in which the benefits accrue to society as a whole. There is need for more research support as part of education for building professionals. Other countries are spending a lot more money on building research in proportion to their populations. I don't think they have better ideas than we. Foreign governments are spending money directly on generic research which I mentioned before, and they are providing incentives for proprietary interests to encourage research.

The Japanese private entrepreneur has a lot more incentive to do research than does U.S. Homes. We heard yesterday that US. Homes does no research. Individual Japanese construction companies have building research capabilities comparable to what we have at the

National Bureau of Sandards. Some individual Japanese companies have two hundred professionals doing research. When that knowledge hits our shores we're going to feel it more than we do now. Canada is spending a lot more than the U. S., and they are doing a lot more to transfer research results into practice. Also, research has a tremendous influence on quality education. If we're considering improving the education of our professionals, we need to consider supporting research in the same universities.

Mr. Kelly mentioned three large industries in his introductory remarks. The three largest industries in this country are health care, food production, and construction; each approaching 10 percent of the GNP The health care industry, through the National Institute of Health, has an annual appropriation from Congress over $4 billion; and yesterday we heard about the wonders that are taking place in that area.

Look at agriculture. That is the one industry where nobody in the world approaches the U.S. in productivity and efficiency. The US. population is fed efficiently and effectively with the best quality and widest variety in the world. We export more agricultural products than any other product area. The Department of Agriculture spends about $1 billion a year on research.

The construction industry is about the same size as these other two sectors, and spends in direct appropriation at a national level of $8 to $9 million. In addition, NSF supports some building related research in universities; HUD spends a little money for building research; but there are not sufficient monies spent on generic building research in the United States.

Let's look at these numbers. Health care is supported at a level of over $4 billion at NIH, and food production at approximately $1 billion at the Department of Agriculture. Construction represents only one-half of one percent of what is spent for research at NIH. I am not suggesting building research should be at the same level, but I am suggesting that there are excellent building research opportunities that need support.

There are other needs. There is the need to effectively implement findings to improve building practices. John Millhone talked to that point yesterday when he said we know a lot about energy conservation and its use, but we need to transfer that knowledge to the local level so that it's used in rehabilitation.

It would improve our competitive position worldwide if we would develop more new construction technology and transfer it into practice. Let's examine our country's successful model, agriculture, which I mentioned just a minute ago. The Department of Agriculture has a program of national research. There is support for research at the land grant universities in every state. There are related educational programs, and there are technology transfer specialists, called county agents, around the country that move the results of that research into place.

I think we ought to look at the USDA model to see if it might apply to research and education for construction that would offer enormous benefits to the Nation.

I have a couple of additional points I'd like to made. One is that we haven't heard anything about indoor air quality. IAQ is something that's going to get a great deal of attention during the next few years. We don't know what quality of air is required for good health and productivity. We don't know how to accurately measure the quality of air that we breath. So these are two tremendous problems; the first, being health related, I hope the medical profession will tackle. The second is a measurement problem which we in the construction industry can tackle with sufficient support for research.

The other area I want to mention is diagnostics. Diagnostics is needed for two purposes: one, for acceptance and quality assurance of the products and systems we build, and the second is for analysis of our existing buildings, particularly in preparation for rehabilitation. We will see a great deal of good work in the area of diagnostics during the next few years. There's much interest in the research now underway.

I agree with the observations made by others that rehabilitation has been a major growth area and will continue. In order to effectively and efficiently rehabilitate our existing building stock, it's essential that we understand the performance capabilities of that stock. As Eric Dluhosch suggested, it is inefficient and wasteful to gut a building and rebuild the whole inside, What we need to do is to have nondestructive evaluation, diagnostics, so that we can determine what the performance characteristics of that building are so we can maximize the use of our existing resources as we rehabilitate them. There are many opportunities in the areas of thermography and ultrasonics, for example, as well as other NDE technologies. Quality control for new construction and analysis for rehabilitation will require major growth in the development of diagnostic capability.

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