TOWARDS A ROBOTIC REFURBISHMENT PROCESS OF INDUSTRIAL BUILDINGS

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ABSTRACT

The topic of this article is the automation and robotization in refurbishment processes of industrial buildings. The need to mold these production spaces is quite universal. Particularly in the regions with a high industrial development and with a lack of buildable land, there is a need to convert this kind of spaces into an improved production system. The latest developments can be a useful tool for achieving a more efficient way of reforming this type of construction. On the one hand we have the digital or computerized 3D Laser Scanning (Computer Aided Measurement) that allows an accurate 3D modeling of the entire building. On the other hand, the project management using BIM (Building Information Modeling) could provide an easy design of each of the elements of the refurbishment. Finally, through the production of construction elements using robotics as jig or for CNC (Computer Numerical Control) we achieve a neat production of each element. How can be all those technologies applied in the refurbishment or expansion of industrial buildings? The research takes a first approach and analyzes industrial buildings that can be called generic or not specialized. To narrow the field of refurbishment, three major factors are defined. The first is to minimize the bill of the energy consumption of the buildings. This could be done either insulating the envelope, reducing the waste-volume to be conditioned climatically or creating facilities for energy production. The second is that the refurbishment or expansion of industrial buildings should try not to interfere on the production process that takes place in the building. In other words, the assembly of the elements in the construction site should be quick and easy, causing the least of disturbance at the workplace. Finally, the research makes an approach towards a robot integrated industrial or productive building .

KEYWORDS

Refurbishment, efficiency, energy, industrial buildings, robotic environment

INTRODUCTION and MOTIVATION

The efficiency on the management of industrial buildings is an important aspect for the productive companies. A robotic refurbishment or renewal of buildings would facilitate the companies' trajectory towards an improvement of the productive resources. It can be stated that automated refurbishment of buildings is more efficient than ordinary manual procedures (Iturralde, 2012).

The situation for big companies differ from that ones that are considered minor. Many small and medium size companies' buildings are not really fit or customized for their purposes. The building and the productive processes lack coordination between them. There are some reasons for that situation. First, the companies often buy buildings with certain or fixed characteristics, so changes are required in order to get a proper productivity system. Second, the company has to change their final product in order to adjust to the market's situation, so the building needs a transformation whenever the production is changed.

The robots operating on the building renewal will probably need a constructive base, such as guides and rails. Investing a huge quantity just for the building maintenance is not operative. But those rails could be multipurpose and they could become permanent devices. The robot that has been used for maintenance or refurbishment, could work permanently for the production system. The research proposes an integrated robot within the industrial building, a universal customizable solution for the actual or existing buildings, in other words, the research is directed towards a universal robotization of the generic

medium size industrial building. Both the building and the robot will have to be adjusted in order to get that kind of environment. The problem has emerged in the case of some European places. The article focuses on the Basque region.

Need for renewal or refurbishment of the industrial building.

-Lack of land. Last two decades, many industrial buildings have been built. Those buildings consume great amount of land. In some towns and cities, 70% of the urban land is dedicated to industrial or productivity activities (COAVN, 2008). Some studies say that 200 m2 are needed per employee. Re-densification of these industrial areas is needed, with industrial uses or non-industrial uses. Historically, in order to satisfy the needs for more production, companies had to find new places in less populated and flatter areas. While the traditional cities have been settled in the lower part of the valley, the new industrial areas are located in the upper part, and they have a better isolation. Because of this, there is already no flat spare land in the Basque northern region.

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Typical industrial environment on the basque region, struggled in the orography.
Figure 1-Historical solution to the lack of land, the multi story factory: BH bike workshop in Eibar.
Figure 2- Public industrial area development from the 90's. The case of Zumarraga.

-Automated-robotic refurbishment. The refurbishment or expansion of industrial buildings should try not to interfere on the production process that takes place in the building. In other words, the assembly of the elements in the construction site should be quick and easy, causing the least of disturbance at the workplace. In this crisis period, it is essential to keep the activity without any disturbance. The refurbishment works to make improvements should not interfere neither in the facilities neither in the production line at the company. Accuracy and speed of the refurbishment process is needed.

-Customization of existing buildings. Those buildings are regulated by urban plan that fixes the total height of the building, the buildable surface, and the boundaries of the building within the plot. This could be a problem when the producer wants to install the production in that place, because the company has to adjust to the building's urban requirements. There is a need for customizing those industrial buildings (COAVN, 2008).

Ultra dependency of external energy sources

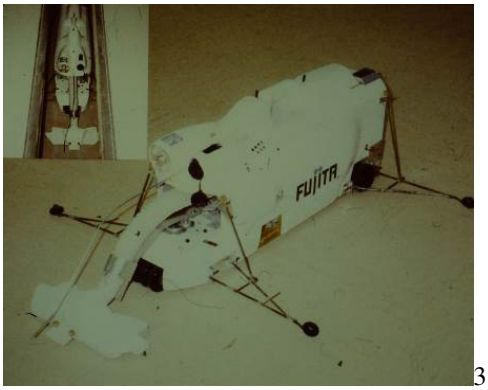
Those industrial buildings and their activity consume large quantity of energy. Almost 50% of the total electrical consumption in the Basque Country comes from industrial productive activity (EVE, 2010). Besides, industrial buildings have been let out of isolation criteria in the last regulations. This has led to a

disaster. But the basque region produces just the 5% of the energy it consumes. Some policies try to minimize the energy consumption of the buildings and its production costs. This could be done either insulating the envelope, reducing the waste-volume to be conditioned climatically, installing more efficient machinery, or creating facilities for energy production.

There are registered 14,000 ha of industrial land. An estimation made indicates that there are 35,000,000 m2 of industrial roof. Those roofs could be used for many purposes. The Photovoltaic panel technology is improving. If the existing trend follows, solar cell efficiency will ameliorate considerably. A big quantity of energy could be produced if we covered all the industrial pavilions in the region with photovoltaic panels. An approximated calculation defines that 4.666 gigawatt per year could be produced covering the roofs with Photovoltaic panels. That is the 25% of total electricity consumption in the basque region. But there is some work to do in the automation of the PV panel installing. Nowadays, it takes about thirty minutes to place the panel on the roof, using galvanized or aluminium structures and anchoring them to the existing roof. If 1.000 people worked for the installation, it could take about twelve years installing the whole industrial roofs in the region. Maybe, it is a too long period.

Nowadays technology

Many tasks in the refurbishing process are already automated. Both interior and exterior robots are already working on site. Those robots operate different tasks, such as dismantling the actual building elements and installing new one (Bock, 2007). Using robots, one can easily add floors, move distribution elements and install new services. Besides, new measuring and data collecting techniques of the industrial buildings (Bosche eta all, 2008) allow a better implementation of prefab construction elements.



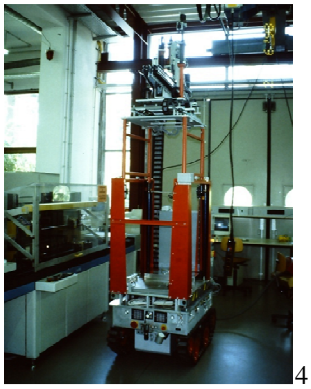
3 
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Figure 3:- Interior Inspection Robot Shinyo Corporation Robot or Fujita Robot Copyright, Thomas Bock
Figure 4:- Interior Refurbishing Robot TB. Copyright, Thomas Bock.
Figure 5:- Interior Refurbishing Robot Komatsu. Copyright, Thomas Bock.

Besides, the use of overhead jib cranes is quite common. The technology get from the automated warehouse cranes can be interesting for the transportation of the robot from one place to another, in the sense that the crane could be the base for different tools or robots. Of course, those single task robots are placed each time they're required during the renovation period.

RESEARCH QUESTIONS

The renewal process of medium size industrial buildings should be improved. Those are the main Research Questions that have been made.

- Could the process of renewing and customizing the industrial buildings be robotized? A big investment just for the renewal should be made in order to operate with robots. But once the renovation is finished, the installed devices could be used for production process of the company. When a building maintenance is needed, those installed elements should facilitate the task too. For instance, the night shift could be used for maintenance, or in other words, robots will be able to operate when the production process is slowed down. In order to not interfere in the production process, the robot should hang from the ceiling. A jib overhead crane could operate better than the common bridge crane.

- Is the installation system of the photovoltaic panels sufficiently automated to place them in roofs in a massive way? We should be prepared for the imminent future when the PV panels are going to be a competitive energy source.

PURPOSE

The article focuses on small and medium-sized production companies' buildings, which are suffering many ups and downs of the market. Those typical medium size companies are related to the second transformation of material which functions as auxiliary to bigger industry. Those industrial pavilion areas are normally from 1,000 sq/m to 10,000 sq/m. Those kinds of little industrial companies normally don't produce big final products, but small-medium size components. This means that the size or span of the structure could be intermediate. They normally work with medium-tech industrial robots or CNC, that is, they're used to industrial robotic technologies.

The purpose of this research is to approximate towards a three dimensional robotic crane, meaning that the crane could move from one structural frame to another. This overhead jib crane could operate both inside and outside. The inner robotic crane could be usable for the renewal and the future maintenance of the building. The crane will need some guides and rails in order to move from one side to another.

In other words, the goal is to create a multitask robotized environment, for getting a flexible production systems that could easily adapt to each context. The crane should use different robots for each purpose. We are talking about a crane that could operate with different robotic tools. This research is an approximation for a robotization of an industrial space, in which both buildings maintenance, renewal and the production are interconnected.

Automated maintenance or robotized maintenance is an issue to achieve. That would facilitate the flexibility of the production itself. If there is a change in production, it could be easy to adjust the machinery and inner distribution using the very same robots that are use for industrial production. Let's put an example: depending on the market's demand, some of the times the building is in disuse. The rapid movement of enclosure or distribution elements could enhance, for instance, the rental of some areas.

Getting a robotic industrial environment is a big investment. The rails and guides used for the crane may have different purposes. The structure could be reinforced in the sense that possible enlargement of the building could be facilitated. In other words, if we focus just in robotics, we may forget some issue related to the industrial building, and if we focus just on the building, we may forget issues related to the productivity. Both aspects have to be interrelated and the design or robotic solution should be coordinated.

Besides, these companies depend too much on electricity. One of the easiest way for covering part of the energy consumption could be installing Photovoltaic panels on the roof and the south facing facades. But they probably will need some public (or private) investment, due to last few years financial crisis. Though, there can be a solution to this. Lately, many energy consumers cooperatives have been created, and they are looking for areas for installing solar panels. If you want to set up millions sq/m of photovoltaic panels, the installation has to be fast; otherwise you will spend a lot of years installing it.

Installing standardized solutions may not be totally efficient in those cases. The buildings' roofs may not have a proper geometry and they need an adjustment in their isolation. A better geometrical

adjustment of the panel in the roof could improve the covered surface ratio. This means that the installation and its elements have to be customized. The panel should be taylor made in order to adjust to the roof's isolation and geometry. The Building Integrated Photovoltaics (BIPV) with customized solutions could be a choice. This way, the company could become a more efficient energy producer instead of being just a consumer. The PV panels could be equipped with insulation material, in order to achieve a better thermal performance in the interior of the building.

CASE STUDY

We will analyze the case of a 2000 sq/m industrial building. It is a typical industry that produces different kind of products. They suffer constant changes in the type of production. The pavilion has an excessive height and volume for the nowadays production. The height of the main production area is around 11 meters. Usually these types of buildings are not often well isolated. The building needs a significant investment in heating, which it has not been done yet. They use a CNC machine, but not a crane. The elements they fabricate are normally light and manually movable. The automation level of their production is medium. Let's say that it is a typical situation of little industrial building in the basque region. In this case, the whole industrial urban area, with up to 20 companies, was developed by the public administration. It can be affirmed that we are facing a universal solution for a common typology's problem.

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Figure 6– Case study, the pavilion in red. Image by Okile.
Figure 7-The interior of the industrial building, showing the non optimized and excessive roof height. Image by Kepa Iturralde.

Over loading the pre-existing structure could create a big issue to solve. The structure should be stabilized. If foundations suffer some movement, the influence would be in the entire building. For instance, the production tools within the building will also be damaged; the leveled machinery should be calibrated again. A more rigid and interconnected structure could be more stable and the settlements could be more homogeneous. In the case of a bigger load in the roof, trusses could be created out of the existing structure, in order to create a rigid light structure.

Exterior boundaries have to be taken into account, that is, the facade alignment and the roof height are limits that the building cannot trespass. Those are geometrical limit that have to be respected due to existing regulations.

Regarding to the inner distribution, it has to be said that each space has its own parameters. Office areas search for warmth and finishes should be more accurate. Instead, machinery areas don't need to be so comfortable and the finishes do not have to be so fine; it is looking for practicality. If we search for a

flexible robotic environment, were the building and the robots work together or coordinated. In other words, the robots should be as integrated as the rest of the services within the building.

If we don't want to interrupt the production process, hanging the robot from the ceiling or using the facades interior layer for hosting the robot can be a good idea. The grid will be part of the building; it will be integrated in its building system. In other words, it could be used as a part of the structure reinforcement or as a part of the inner distribution. A grid will be convenient if the robot has to operate all over the building's area.

Proposal

The proposal could be described with the next points:

-The proposal is based on a overhead robotic crane. These overhead cranes are totally common in those kind of industrial companies, meaning that it will not be considered as an alien.

-The structure has been reinforced before the installation. Specially to avoid horizontal thrust generated by the crane itself. If the robotic crane has to operate accurately, the support structure has to be rigid enough. The weight of the robotic crane should be as light as possible. Trusses may be used in the configuration of the robotic crane, with the purpose of lighten the excessive loads.

-The geometry and kinematic of the robotic crane is important if we want to operate in a flexible way. The overhead crane by itself doesn`t disturb the production process. The robotic appliance should be foldable.

-In order to get a multifunctional robot, we have to deal with modular elements. The system will be proper to install different dismountable tools. The overhead robotic crane will do different tasks during the renewal process. Let's say it could be either used for interior distribution and either for the exterior finishing. In each case, just the manipulation tool should be changed.

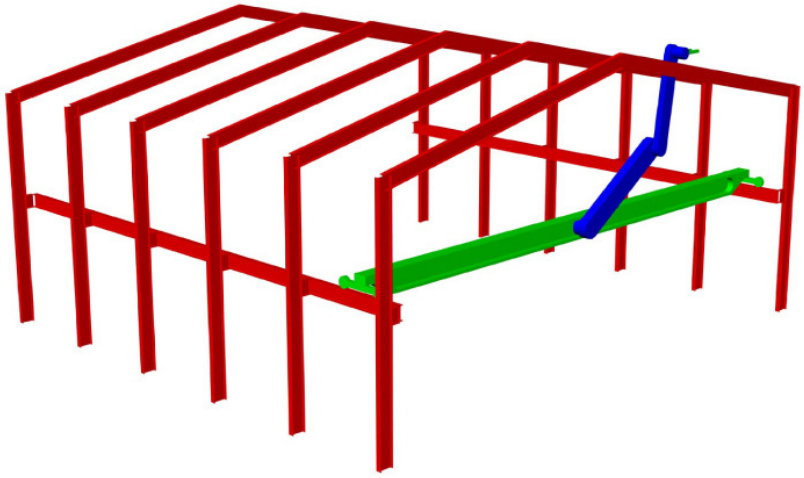

Figure 8– One of the proposed robotization of the industrial environment. Image by Kepa Iturralde.

-The construction solutions. The exterior elements are insulated for the cold days in winter. But cold is not the only temperature problem to solve; It has to be taken into account that the translucent panels on the roof should be protected against over isolation for the sunny days in summer. The PV panels can be arranged in a way that they could give some shadow to those translucent panels. The panel should be

joined automatically, as well as facilities inside the panel. The elements should be prefab enough in order to assembly them easily. Installation of exterior guides and similar should be avoided.

-Once the robotic overhead crane is installed, the renovation processes of the building could be performed during the night production stops of the company

CONCLUSIONS

The proposed robotic crane could be used for the company's production system too, but the robotic tool will differ from the kind of product they fabricate. Different robotic tools could be rented for each purpose, instead of investing a big amount of money.

There could be regulatory problems that could affect all this renewal processes. For instance, fire and urban planning regulation would be a tether against the desired flexibility. Maybe the local authorities could ask you for a project each time you want to move your inner distribution; hence architects and engineers should be involved in this process. Personalized projects for each case will be needed.

If the company will move towards complete automation in its production, isolation probably would not make any sense. No worker will work in those buildings. But it will take long till all that automation becomes reality. Anyway, the company will always require for energy. And finding new energy sources using the existing buildings can be a good solution. Maybe this way, industrial productive companies could become energetically self-sufficient in the future.

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