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Current Status of Automation and Robotics in Construction in Sweden

Pär Åhman

Technical Development Department
The Swedish Construction Federation, Gothenburg
Sweden

ABSTRACT

This paper gives a comprehensive description of the construction industry in Sweden, such as its magnitude, sectors and activety level. It also describes the development in the construction trade during the last decades both in general terms and in an R&D perspective. This background is furnished to put the automation efforts in the Swedish construction industry into proper context. A description follows of some automated systems and robotics in use at working sites today. Finally, two major R&D-projects and some minor ones are presented.

1. INTRODUCTION

For a long time the construction market has been an essential part of the Swedish economy. In 1991, approx. 300,000 persons were directly engaged in construction. Another 300,000 were indirectly involved, for example, in the construction materials industry. The construction industry represents about 15% of the Swedish gross national produkt (GNP).

During the 1960s and in the early 1970s the construction industry experienced a boom. In 1968, when housing construction reached its peak, more than 100,000 housing units were started. 15 years later, the number had fallen to 30,000. A new boom during the late 1980s raised the production to 60-70,000 new housing units annually.

The main reasons for the rapid expansion in the 1960s and early 1970s were the demand created by urban migration, increased demands for improved housing standard, and the preferential treatment given to housing construction on the capital market.

Since then, the construction of hospitals, schools, offices etc., also has fallen off, but not as sharply as the housing sector. In the case of public construction, the gradual decrease in investments within the municipal sector has been a contributory factor.

The investments in civil engineering projects also has declined over the last decade. There will probably be a change during the 1990s as a result of governmental efforts to give precedence to infrastrucural concentrations.

Repairs, conversion and maintenance shows a strong upturn and account for nearly 50% of the total construction output.

The construction industry in Sweden during the latter part of the 1980s saw new prosperity. In 1990, the gross investments in building and civil engineering works, including repairs and maintenance, reached a new peak of approx. MSEK 215,000 (MSEK = million Swedish Crowns; US$ 1.00 is close to SEK 6.00) (Fig. 1).

In mid 1991, though, a most severe recession began in the construction industry. At the moment it is very hard to predict the end of this recession The market probably will not see an upward trend before the mid 1990s. Before the recession, the construction market in Sweden was in a top position in relation to its population. Also, the other Nordic countries have experienced a boom. As an example, The Nordic countries in 1991, with a total population of 23 million had a larger construction market than Great Britain, with a population of 57 million people (source: Euroconstruct, Barcelona 1991) (Table. 1).

2. R&D IN THE CONSTRUCTION INDUSTRY

2.1 Share of total volume

In 1990, a survey was made [1] of technical and administrative R&D performed by Swedish contractors. The survey shows that total R&D in the construction industry in 1989 reached 1,6% of total value added, which means about MSEK 490. In the survey, R&D was defined in accordance with current OECD practice. It was found inappropriate to use a narrow technical focus, since contractors share characteristics of both services and goods production. As a consequence, we may expect that construction firms spend more resources on process innovations than on product innovations.

2.2 Significance of firm size

The survey [1] shows that there is an obvious correlation betweeen firm size and R&D intensity for the firms covered by the survey. Large firms (more than 500 employees) accounts for more than 75% of the performed R&D (Table 2).

2.3 Contractors financing of R&D

The presence of externally funded R&D is also tied to firm size, where large contractors are the large recipients. Nevertheless, internal financing is almost the rule, covering 93% of all R&D expenditure. The remaining 7% are covered by funding agencies, such as the private fund SBUF (The Development Fund of the Swedish Construction Industry), the Council for Building Research and other Government agencies.

3. FUNDING OF R&D AND FIELDS THAT ARE GIVEN PREFERENCE

3.1 Financing by a special levy

In 1954, a special levy, the Building Research Fee, had been imposed by legislation on all building employers to finance government-coordinated building research. During the two first decades, relatively small resources were allocated to projects directed by contractors and with active contractor participation. With the oil embargo in 1973 and the consequent rise in energy prices, the government mechanism for coordinated building research was, to a great extent, turned towards the issues of energy conservation and energy production for buildings.

In 1981, the Swedish Riksdag (Parlament) decided to abolish the Building Research Fee, mainly for reasons of administrative convenience.

3.2 Private and tax financed building research

When the Building Research Fee had been abolished the contractors felt that the time was ripe for an independent plan for R&D cooperation, in addition to what would now be tax financed building research. This plan was intended to create a climate for development in its member firms (at present about 5,000), encourage cooperation between contractors and also cooperation between contractors and firms from other industries, emphasize technology and production issues, not least in relation to the technical universities, and finally, to strengthen the position of private enterprise in the construction sector. As a result the The Development Fund of the Swedish Construction Industry (SBUF) was set up as an independent organ in 1983. Its aim is to promote development work in the construction industry. SBUF currently spends about MSEK 40 annually on support for development projects. Co-financing with Government support, mostly from the Swedish Council for Building Research, occurs frequently. The projects, that have been funded by SBUF, have been assigned to eight major themes:

1) Renovation of buildings
2) Damages to buildings
3) All-weather production
4) Computer-aided design and construction
5) Management of materials
6) Quality assurance in construction
7) Renovation of water and sewerage systems
8) Maintenance of roads

For 1992 and 1993, the contractors have made a new agreement with the government to contribute an annual support to R&D in the construction trade of MSEK 25, in addition to the funding through SBUF. The support is preferably intended for R&D at technical universities. A condition is that the contractors have a strong influence on how the fundings are utilized. The Government aim also is to involve adjacent sectors like proprietors, municipalities, the building material industry, etc. This will result in an annual support of MSEK 70, starting in 1993.

Seven areas of priority for R&D have been identified for this new fund:

1) Material technology
2) Information technology
3) Mechanical services
4) Indoor climate
5) Facility management
6) Infrastructure
7) Economizing of resources

R&D on automation and robotics in the construction industry is part of the area "information technology".

4. AUTOMATION AND ROBOTICS IN CONSTRUCTION

Robotics in the Swedish construction industry is applied to working tasks with bad environmental problems, e.g. demolition, tunneling and handling of materials. Some succesful robotics, such as Conjet, are used in concrete removal by use of high water pressure technique. Another example is robotics for soil reinforcement works in existing buildings. Robotics are also used for tasks like inspection of sewerage systems and other pipes.

In some cases big cranes are equipped with TV-cameras and remote control. Some of them also have sensors for detection of obstacles to prevent collision.

In general, all robotics for construction sites are remotely controlled today.

Automated systems are common for prefabrication of structural elements such as concrete slabs and walls. The building material industry also is highly automatized.

5. R&D ON AUTOMATION AND ROBOTICS IN CONSTRUCTION

At the Swedish Construction Federation in Gothenburg, there has been a tradition of cooperation on R&D among the contractors since the 1960s. Since 1980, 10 contractors within the Federation are cooperating in R&D-projects under the name of FoU-Väst. FoU-Väst annually has about 25 different projects in progress in four main fields:

1) Quality Control and Construction Design
2) Methods and Technical Facilities
3] Technology of Materials
4) Damages or Deterioration to Structures

More than half of the projects are handled in close cooperation with the universities, especially Chalmers University of Technology in Gothenburg.

In 1987, a project started on automation and robotics in construction. All contractors in FoU-Väst, including one of Swedens major machine-rental companies, the Swedish Building Workers' Union, Chalmers University of Technology, and the Construction Industry´s Organisation for Working Environment Safety and Health are involved in the project. In the initial stage, the project has been financed by the SBUF and The Swedish Work Environment Fund.

In this robot project, the working-site has been analysed regarding methods of production, economy and working environment (ergonomy, health and accidentrisks). The analysis is the basis of the project. It describes areas, that people directly involved in the production want to change.

By evaluation of the different criteria a prioritylist for automation or use of robotics was made. Masonry was placed in a top position on that list, followed by roofing and work at great heights, cleaning, concreting, reinforcing, hacking, plate-handling, scaffolding etc.

The project has continued with the development of a prototype (Fig. 2 and 3) of a multipurpose mobile robot for concrete slab finishing, grinding, and cleaning. This prototype has been tested in a laboratory for more than a year and in this phase is not built to be equipped with working tools. At this time a new prototype for field conditions is at underway.

Another major project is carried out by the Belab company in cooperation with the Royal Institute of Technology in Stockholm and the University of Technology in Linköping. In this work a specification for a mobile multfunctional robot for plastering, grinding, and painting of internal walls and ceilings. The development of a prototype has just begun.

This project is financed by The Swedish Council for Building Research, The Swedish Environment Fund, the Development Fund for the Painting Contractors, Ernströmsgruppen and Nordsjö Nobel.

Some other projects, within FoU-Väst, that could be mentioned are:

• a remotely controlled mobile robot (Fig. 4) preferably for demolition work, but also escavating, sawing and making holes in concrete. The arm of the robot is computer-controlled in a world coordinate system.

• an automated station for cleaning of sheet piles under high water pressure

• a mobile, automated station for cleaning of concrete equipment using high water pressure technique.

• a semi-automated method for cutting of concrete piles, where the cutting machine operates automatically.

Apart from the above mentioned examples of projects, a national program for Swedish R&D on automation and robotics in construction has been presented. It establishes the necessity of cooperation between manufacturers, contractors, and technical universities. It also promotes R&D in three major fields:

1) Robotic systems
2) Automatized or robotized construction processes
3) Socio-economical and other consequences

6. CONCLUSIONS

Most robotics in use in Sweden are remotely controlled. More advanced technology is still in a prototype stage, but efforts are being made that will pay off in the near future. The R&D on robotics and automation is concentrated to simple and economical solutions with a clearly defined practical use. The aim is not to achieve a fully automatized working-site but to find solutions that will promote production efficiency, safety and work environment in an optimized economical way.

To succeed, it is necessary to have a joint R&D-cooperation between contractors, manufacturers, universities and others who are concerned. It is most important that the efforts are made in cooperation and not as segregated phenomena.

REFERENCE

[1] J. Bröchner, B. Grandinson, "R&D Cooperation by Swedish Contractors", Journal of Construction Engineering and Management, ASCE, 118 (1), 3-16, 1992

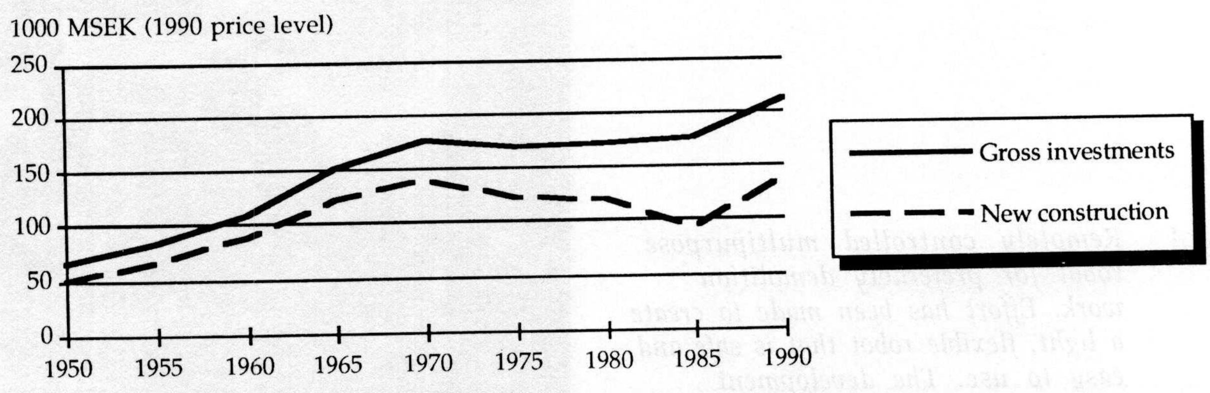

Fig. 1 Gross investments in building and civil engineering works.

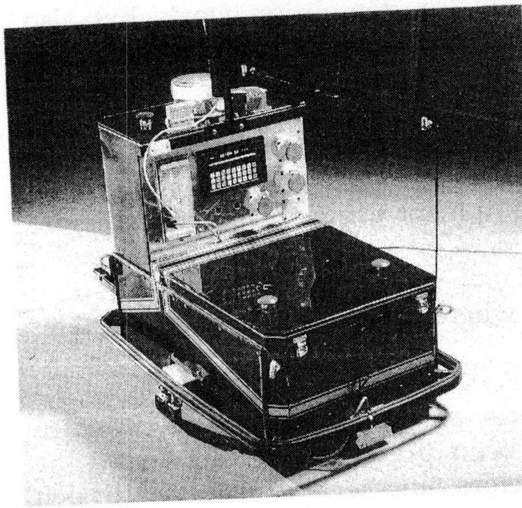

Fig. 2 *The laboratory prototype in the FoU-Väst project has been developed and tested in the Robot Laboratory at Chalmers University of Technology, Gothenburg.*

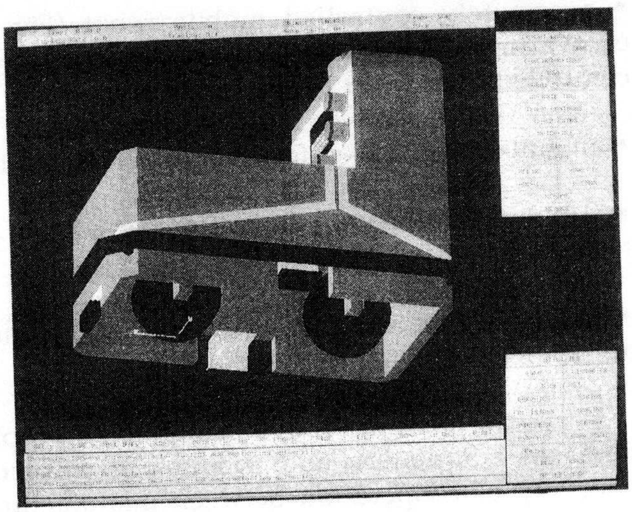

Fig. 3 *Simulation motions have been analysed in the FoU-Väst project. Simulations have been made in both 2D and 3D.*

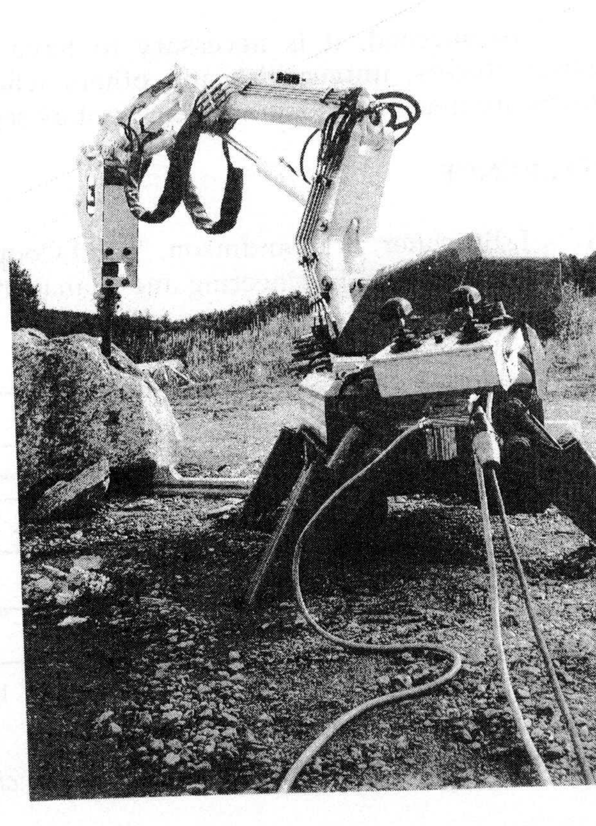

Fig. 4 *Remotely controlled multipurpose robot for preferably demolition work. Effort has been made to create a light, flexible robot that is safe and easy to use. The development work is carried out by Såg- & Betongborrning AB, Gothenburg.*

Gross investment in 1000 MSEK 1987 (1990 price level)		1987	1988	1989	1990	1991	1992 (prognosis)
Denmark	109.3	1.1	-4.3	-4.4	-4.5	-4.5	2.0
Finland	107.7	1.0	10.0	14.0	-1.0	-14.0	-10.0
Norway	111.2	5.7	-0.8	-15.0	-13.7	-3.7	3.3
Sweden	197.0	3.8	2.4	5.4	1.9	-2.0	-7.0
Germany	950.8	0.0	3.0	5.0	5.0	3.5	1.5
France	734.6	4.2	5.2	4.3	2.3	0.1	0.1
Italy	648.6	-0.5	4.3	3.8	1.6	1.2	0.9
Great Britain	455.8	8.0	7.0	4.0	1.0	-10.0	-5.5
Spain	343.3	10.4	10.5	13.0	9.0	4.0	1.0
Switzerland	205.8	5.8	6.4	6.1	0.3	-4.5	-1.0
Holland	158.5	2.0	11.0	3.0	1.0	-1.0	-6.0
Austria	130.7	3.2	5.7	4.1	5.8	5.0	4.0
Belgium	112.1	5.0	14.0	10.0	5.5	-1.0	2.0
Ireland	26.0	-	-3.4	9.6	10.9	-5.0	-1.0
Europe total	**4,291.4**	**3.2**	**5.3**	**4.9**	**2.8**	**-0.5**	**-0.3**
Of which the Nordic countries	**525.2**	**3.1**	**1.9**	**0.8**	**-3.3**	**-5.5**	**-4.4**

Source: Euroconstruct, Barcelona, December 1991 and The Swdish Construction Federation, March 1992

Table 1. *Annual change in gross investments in some European countries calculated as a percentage.*

Item	Number of employees			
	0-49	50-499	500+	Total
R&D performed (MSEK)	30	80	380	490
of which: external funding (MSEK)	0	3	32	35
Total value added (MSEK)	8,500	5,300	16,200	30,000
R&D intensity (R&D devided by value added)	0.4%	1.5%	2.3%	1.6%

Table 2. *Estimated R&D intensities among Swedish contractors.*