

Construction R&D investments in Denmark

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Abstract

During the 1990s and early 2000s, a range of policy reports argued that the Danish construction R&D investments were lagging behind the OECD level. In 2001-2002, a task force on construction/housing research was established to analyse construction R&D investments and develop a roadmap for new research priorities, increased public/private R&D collaboration, improved dissemination of research-based knowledge, and reorganisation of the technical support infrastructure. This paper 1) describes the organisational setup of Danish construction and housing research, 2) quantifies the Danish construction R&D investments, and 3) provides an update on recent developments in the Danish R&D environment. This study applies an adapted Triple Helix perspective on the interaction between government, academia and business. It is based on a comprehensive quantitative survey and analysis of R&D investments, professional competences and profiles of individual research institutes etc. The survey adopted a resource area perspective, which includes the primary industry, manufacturing industry, supporting industry and service industry. In conclusion, this study points at the following lessons to be learned: 1) it is quite complicated to draw firm conclusions on the level of construction-related R&D investments; 2) public construction R&D expenditures are disproportionate compared with other research fields; 3) private R&D investments primarily take place in the manufacturing industry; and 4) the R&D roadmap has not had a significant impact on construction R&D investments.

Keywords: R&D, innovation, triple helix, resource area, roadmap

1. Background: The national context

During the 1990s and early 2000s, a range of policy reports addressed the challenges of the Danish construction/housing resource area. One of the more prominent reports was the policy report "The future of construction – from tradition to innovation" by the Building Policy Task Force established by the Ministry of Housing and Urban Affairs and the Ministry of Business Affairs (By- og Boligministeriet & Erhvervsministeriet, 2000). The Building Policy Task Force identified a range of problems for the resource area and proposed a number of initiatives to be taken within four areas: 1) the role of construction clients, 2) competitiveness, 3) cooperation, and 4) innovation.

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The Building Policy Task Force noted that the development of R&D investments and patents was decidedly negative within the resource-area of construction/housing. The number of patents had dropped, and the investment level was lower than in OECD countries generally. Corporate R&D investment had fallen over the past 10 years, and in terms of trade and industry investments in R&D, the Danish construction industry invested around 20 % below the OECD level. Thus, the Building Policy Task Force proposed the following benchmark for research, development and patents in construction: "The government's goal is to increase the industry's R&D investments and the number of patents to the OECD average by 2005" (By- og Boligministeriet & Erhvervsministeriet, 2000: 16, author's translation). In addition, the Building Policy Task Force suggested i.a. that the government took the initiative to scrutinise the existing construction knowledge system and to develop a national action plan for construction/housing research.

Based on this recommendation, the government set up a task force to draw up proposals for an action plan for Danish public construction/housing research. Taking the work of the task force as its starting point, this paper 1) describes the organisational setup of Danish construction/housing research, 2) quantifies the Danish public and private construction R&D investments, and 3) provides an update of recent developments in the Danish construction R&D environment.

2. Previous studies

A number of surveys and studies of construction-related R&D efforts have previously been carried out. The following highlights the main results of the most notable of these studies in terms of primarily government funded R&D.

On behalf of the Association of Consulting Engineers (FRI), Christoffersen & Bertelsen (1990) described the situation at the end of the 1980s. Based on a questionnaire survey, the study mapped the scale of both public and private construction-related research in Denmark. A few years later, the Ministry of Housing (1993) carried out a survey of construction-related research based on a questionnaire survey. In that study construction-related research was used primarily in the sense of technical research, while e.g. architectural research and social-science research on construction/housing-related issues were not included.

The construction sector's use of technological services was the theme of a report prepared for the Building Policy Forum formed by the Ministry of Housing and Urban Affairs (Bang, 1997). With a focus on communication and technological services, construction-related R&D was only sporadically touched upon. The report primarily focused on how knowledge from knowledge producers could be disseminated to and adopted by the users of this knowledge, i.e. construction companies. In 1997, the Danish Building Development Council (BUR) made a study of knowledge production, knowledge use and knowledge dissemination in the construction sector (Dræbye, 1997). The survey was based on a review and categorisation of articles and other publications of more than 10 pages from mostly public knowledge producers. Knowledge production by private companies was included to the extent that the companies had received support from the public.

In 1997, the Ministry of Housing and Urban Affairs established the Public Research Task Force on Cities and Construction to advise the ministry on research on cities, housing and construction. The choice of method was not described, but by all accounts the conclusions were based on existing knowledge, reports and data (Det Offentlige Forskningsudvalg for Byer og Byggeri, 2000).

In summary, the surveys and analyses reveal that construction R&D has been on the agenda on a regular basis. The previous studies, surveys and policy analyses can be characterised by:

- Common questions: mappings and analyses revolve around two common questions: First, how many resources should be spent on different research themes? Second, how can knowledge dissemination improve from research institutes to companies? Other pressing questions are however left in the dark, like “do we at all have sufficient construction research”, “how can we improve the capabilities of companies to adopt new research results” etc.
- Inward looking perspective: it is striking how little the mappings and analyses seek to compare with other sectors and countries, link to broader R&D policy issues, or utilise theoretical contributions on what fosters R&D investments and how the R&D community operates in general.
- Vague definitions: in general, the very definitions of what to include in the studies are vague with respect to the subject area (housing, construction, planning etc.), research areas (e.g. technical science vs. social science), type of effort (research, development, dissemination etc.), and indicators (funding, outcomes like articles and tools etc.).
- Weak evidence for conclusions: the available resources in the individual surveys and analyses have apparently been relatively modest. It is characteristic of several of the mappings and analyses that the database for firm observations and conclusions are flimsy and inadequate.

3. Research design

3.1 Theoretical framework: Triple Helix

This study applies an adapted Triple Helix perspective on the interaction between government, academia and business. In contrast to other models like the national innovation system approach, the Triple Helix model focuses on the partly overlapping networks of communication and expectations that shape the institutional arrangements between universities, industries and public authorities (Etzkowitz & Leydesdorff, 2000: 109).

In the Triple Helix model, universities, governments and industry are conceptualised as intertwined spirals with different relationships to each other. The spirals are rarely equal:

typically one of them acts as a driving force or “innovation organiser” around which the other spirals orbit (Etzkowitz, 2003).

Thus, the sources of innovation in a Triple Helix configuration is not tuned in advance – they arise and develop at multiple sites in the network of relationships that generates a diversity of strategies and projects that create added value through constant reorganisation of the underlying structure. These are the dynamics of the Triple Helix cooperation, which creates innovation (Etzkowitz, 2003).

3.2 Methods

The survey adopted a resource area perspective – rather than a narrow construction industry perspective, which typically focuses foremost on contractors (for a definition of resource areas, see Erhvervsfremme Styrelsen, 1993 and Danmarks Statistik, 2001). Thus, contrary to most other studies this study includes the four industries: primary industry (e.g. raw material extraction), manufacturing industry (e.g. production of building components), supporting industry (e.g. production and leasing of construction machinery) and service industry (e.g. contractors and consultants).

This study was based on a comprehensive quantitative survey of R&D investments coupled with a qualitative analysis of professional competences and profiles of individual research institutes etc. The institutional profiles were based on an initial screening of all relevant research institutes followed by a more detailed mapping of the most prominent research institutes.

The survey was conducted on the basis of existing sources that were publicly available especially public research statistics, annual reports and websites of research institutions and funding agencies. In addition, special runs in the research statistics of the Research Centre for Studies in Research were conducted.

4. R&D investments

4.1 Organisational structure

It has often been argued that the organisational setup of Danish public construction/housing research is confusing and fragmented. Although construction/housing research is spread over many different actors, most of construction/housing research is concentrated on five key research and educational institutions with construction/housing research as their primary activity. In 2002, the five core institutions were Aalborg University (AAU, primarily the Institute for Building Technology), Technical University of Denmark (mainly BYG • DTU), School of Architecture in Copenhagen (KARCH), Aarhus School of Architecture (AAA) and the Danish Building Research Institute (SBI). By 2007, significant changes in the organisational setup of universities and governmental research institutes had taken place due to a national university reform. Twelve universities and fifteen governmental research institutes merged into eight universities and a few research institutes. During this process, the national building research institute merged with Aalborg University, but has remained an

independent faculty of the university. At the Technical University of Denmark, the technical and management part of the building technology department was separated. The construction management group became part of a newly established department of engineering management.

In addition, a private independent institution, the Danish Technological Institute (notably the Construction Division) was doing construction-related R&D, which occupied a special role as a bridge between public research institutes and private companies. In statistical terms and in line with OECD definitions, the Danish Technological Institute is considered a private institution and not a public institution despite the public support granted by the government (some 10 % of the turnover).

In addition to the core institutions, a variety of other research and development institutions has regularly carried out construction/housing-related research and development, but not construction/housing research as their primary activity.

There has also been a number of supporting institutions in the form of knowledge brokers that did not conduct research themselves, but provided support for research and development, initiated and coordinated research and development, disseminated knowledge or otherwise acted as catalysts in or for change.

Finally, governmental, county, municipal, self-governing, and private non-profit institutions are considered public funding sources according to OECD guidelines. The main sources of public funding for the construction/housing area's R&D were (not in order of priority) a range of ministries, research councils, private foundations, Nordic Council of Ministers through the Nordic Industrial Fund and Nordtest, and the European Union.

4.2 Public R&D funding

In 1999, the level of R&D by the five core public institutions was approx. 175 million DKK (23 million EUR) plus 55 million DKK (7 million EUR) for the Danish Technological Institute (cf. Table 1).

Table 1: R&D funding sources for core public institutions

	AAU Building Technology	DTU BYG•DTU	KARCH	AAA	SBi	DTI Building Technology
Basic public funding	16.1 (66 %)	29 (66 %)	24 (89 %)	12.2 (70 %)	32.2 (54 %)	6.6 (12 %)
Private foundations	1.2 (5 %)	1 (2 %)	0.1 (0.3 %)	0.7 (4 %)	0.3 (0.5 %)	6.6 (12 %)
Public programmes	3.4 (14 %)	2 (4.5 %)	0.1 (0.3 %)	3.4 (19 %)	3.8 (6 %)	
Public sources	3.4 (14 %)	7 (16 %)	2.8 (10 %)	1.3 (7 %)	20.2 (34 %)	
Private firms	0 (0 %)	2 (4.5 %)	0 (0 %)	0 (0 %)	2 (3 %)	39 (71 %)
International sources	0.2 (1 %)	3 (7 %)	0.1 (0.3 %)	0 (0 %)	0.9 (1.5 %)	2.8 (5 %)
R&D expenditure total	24.3 (100 %)	44 (100 %)	27 (100 %)	17.5 (100 %)	59.4 (100 %)	55 (100 %)

Sources: Analyseinstitut for Forskning (special runs from database on research statistics), annual reports from institutions. Figures in million DKK and per cent.

In the general research statistics (Analyseinstitut for Forskning, 2001a & 2001b), the R&D efforts by other public research institutions for the research purpose "Housing and Planning" was estimated at approx. 90 million DKK (12 million EUR) and some 100 full-time equivalent (FTE) personnel. The reliability of this statement is questionable. For example, the Department of Comparative Literature at the University of Copenhagen estimated 10 % of its overall research to be within the research area of housing and planning. Conversely, the Centre for Indoor Environment at the Technical University of Denmark (where the world-leading professor P. O. Fanger was employed) provided 0 % R&D within housing and planning, although indoor climate in buildings can be considered as belonging to the construction/ housing area. Instead, research was classified under such themes as "Disease control and prevention". It is therefore reasonable to assume that some research relevant to construction/housing has been categorised under other research purposes and vice versa.

All in all, the amount of public R&D by other public research institutions was estimated at around 100-150 million DKK (13-20 million EUR) after a careful examination of their research profiles, project portfolio and research publications. To this should be added R&D expenditures at the core public institutions in the amount of approx. 175 million DKK (23 million EUR). Thus, the total annual public R&D expenditure within the construction/housing resource area was estimated at some 275-325 million DKK (some 40 million EUR).

4.3 Private R&D funding

Table 2 shows the funding of R&D within the resource area of construction/housing distributed on different sources of financing.

Table 2: R&D funding sources for private companies

Source of financing	R&D expenditure (million DKK)	Distribution (%)
Public funding	128	7 %
Own funding	1,446	80 %
Other private companies	113	6 %
Other Danish funding	10	1 %
Foreign funding	101	6 %
Total	1,799	100 %

Sources: Analyseinstitut for Forskning (2000 & 2001c).

The statistical summaries of the private companies' R&D should not be considered too reliable. Part of the explanation must be sought in the R&D statistics being based on the companies' primary business sector. The company's entire R&D is attributed to this main industry, although companies such as consulting engineers operate in several different markets with different products and services. Another explanation could be that the sample is not representative of the construction/housing resource area. Finally, the weighting applied to scale the data from the sample to the entire study population may lead to a systematic bias (see e.g. Analyseinstitut for Forskning (2001c) for a detailed description of the methodology behind the research statistics).

The estimate above was supplemented with a second lower estimate at 350 million DKK (47 million EUR) based alone on a narrow definition of the research field "building and civil engineering technology". The total private R&D within the construction/housing area was estimated at approx. 1.2 billion DKK (160 million EUR) corresponding to the R&D efforts in primary and manufacturing industries, and half of the calculated R & D efforts in support and service industries. It should be strongly emphasised that this is an estimate subject to significant uncertainty.

5. Roadmap for construction R&D

5.1 The Task Force for Building Research

In June 2001, the government established the Task Force for Building Research. The task force was composed of six members from the newly established private foundation Realdania (chairman), an architect firm C. F. Møllers Tegnesteue, the National Association for Public Housing Associations, and researchers from the Copenhagen Business School, SBI and Aalborg University.

Besides the full members, the task force also comprised four public servants from the Danish Agency of Enterprise and Housing, Ministry of Science, Technology and Development, and the Danish Energy Agency. The task force was assisted by a secretariat

of five people at the Danish Agency of Enterprise and Housing, which in turn was assisted by two external experts (including the author of this paper).

The mandate of the Task Force on Construction Research in Denmark consisted of three main tasks to be undertaken (Haugbølle & Clausen, 2002):

1. Mapping of a) content and scope of existing public Danish construction research, including interactions with private construction research; b) the institutional, organisational and financial issues regarding public construction research in Denmark; and c) the organisational structure of the knowledge system of construction based on existing reports, analyses etc., and an updating of these.
2. Evaluating a) research needs in relation to the vision for construction in the future; b) Danish construction research in an international context; c) interaction between producers, providers and users of building knowledge; and d) how the public construction research can better serve as a catalyst for private R&D investments.
3. Proposing a) prioritisation of public construction research, b) increased interaction between public and private investment in construction research, including initiatives to strengthen the incentives for firms to develop new construction knowledge; c) initiatives to improve the dialogue between research and users of construction knowledge; and d) reorganisation of construction knowledge infrastructure.

In September 2002, the task force published its report (Udvalget vedrørende byggeforskning i Danmark, 2002). It stated that the Danish construction industry faced three significant strategic challenges: 1) the productivity of the industry was too low, 2) the quality of work was too poor, and 3) the profitability of construction businesses was too low. Thus, a transformation of the industry was required. The task force pointed out that if construction were to make it through the transition it would demand strict requirements to the scope and quality of construction research. Research, it was argued, could bring the construction industry into the knowledge society. The task force concluded, however, that the starting point was somewhat different and identified three challenges (Udvalget vedrørende byggeforskning i Danmark, 2002: 7):

- Danish construction/housing research lags behind. The amount of construction research is at a low level compared with other OECD countries, and the level seems to be decreasing.
- Construction/housing research does not match the current challenges facing construction companies. In recent years, publicly funded research has been directed in other directions.
- Interactions between construction/housing research and its users are not particularly good. The dissemination system is perceived as confusing and characterised by too many independent actors.

The task force believed that these challenges could predominantly be attributed to construction research being driven by public support, and that orientation towards the real users had therefore been inadequate. The task force (Udvalget vedrørende byggeforskning i Danmark, 2002: 7) proposed a strategy based on stronger demand orientation, where construction research could contribute to the development of the construction industry by:

- Supporting construction innovation and change effectively.
- Contributing dynamically to the companies' ability to seek knowledge.
- Providing businesses and authorities with relevant knowledge of high quality.
- Creating the conditions for more active involvement of international knowledge.

The task force recommended a long-term strategic framework resting on four main elements (Udvalget vedrørende byggeforskning i Danmark, 2002: 8, author's translation, original emphasis):

- **Increase funding** by an extra 120 million DKK annually for building research to reach the OECD level. The majority of the funding was to be provided by the industry itself, in particular by new construction projects, through agreement with the construction clients, and it was to be directed to construction research through the Building Innovation Fund, to be established to coordinate the implementation of the strategy.
- **A ten-year national action plan** for construction research running from 2003-2012. The action plan is suggested to be established through an agreement between the government, major public and private clients and relevant client groups along with the firms and organisations of the construction industry. The task force stressed the importance of giving the action plan a time horizon, which would ensure an effective implementation of the results of construction research in construction firms. The action plan was to be realised through the establishment of a number of **innovation consortiums** within the most significant development areas.
- A **re-orientation** of construction research towards research areas of importance for the transformation of the construction industry, not least organisation, management, learning and collaboration along with development of large-scale components and systems.
- A systematic effort towards **improved learning** in construction along with coordination of knowledge dissemination. Learning and dissemination should be part of all research projects and innovation consortiums.

5.2 Recent developments

Ten years after the publication of the roadmap, it is worth asking what became of the recommendations of the roadmap in relation to construction-related R&D. Below each of the four elements in the roadmap are addressed.

First, the suggested increase of funding by 120 million DKK annually has far from materialised. The innovation fund as prime funding mechanism based on a percentage of the budget of new construction projects never came into existence due to a lack of support from i.a. the public construction clients and disagreement with the private foundation Realdania on how to organise, manage and finance the innovation fund. However, some increase in funding has been achieved due to significant and sustained contributions from the newly established private foundation Realdania. Over the past 10 years, the foundation has pursued its own proactive R&D strategy, which included spending some 277 million DKK in the period 2003-10 on research activities alone (DAMVAD A/S, 2011). Realdania has initiated a range of stand-alone projects, spearhead projects and research centres. Half of the R&D expenditure (145 million DKK) was spent on the establishment of six research centres within urban spaces, strategic urban research, housing and welfare, construction management, facility management and indoor environment.

The main source of public funding for public R&D is related to the general funding schemes for research-based educational programmes for which funding for basic research is provided along with funding for educational programmes. In recent years, the establishment of new educational programmes on design and architecture, construction management and informatics etc. has created the foundation for some additional funding for public construction-related R&D through the increased enrolment of graduate students.

Second, the ambition to draft a ten-year national action plan was never met, although endeavours were made to create a common platform for the industry some five years later through the newly established Coordination and Innovation Group for Knowledge in Construction (KIG), which embraces all major actors in the industry. A series of meetings were held where KIG sought to develop an action plan based on inspiration from among others the Swedish construction innovation fund and the Danish food industry where a year-long collaborative effort had led to the establishment of an innovation fund. In 2009, a report was put together by the head of the building technology department at the Technical University of Denmark on behalf of KIG. The report described four focus areas: sustainability and energy; economy and innovation; safety and health; and functionality and experience (Koordinations- og Initiativgruppen for viden i byggeriet, 2009: 3).

A core element in the proposed action plan of the Task force on Building Research was the establishment of innovation consortiums within strategic areas. Although at least three innovation consortiums have been established over the years, they were hardly the direct result of the roadmap. The first initiative was Digital Construction, a development programme initiated in 2000 and officially concluded ten years later, although a follow-up programme has been established for 2011-2014. Digital Construction has been financed in several rounds from various sources. The second initiative is an on-going innovation consortia on sustainable industrialised construction (InnoByg) established in 2010 for a four-year period. The third initiative is the knowledge centre on energy savings established in 2008 for a four-year period. This was established as a knowledge centre, and not as an innovation consortium. None of these three initiatives was directly anticipated in the roadmap as the roadmap only addressed innovation consortiums in rather vague terms.

The third element was to reorient building research through the transition of basic funding by increased competition and new types of performance contracts. The conversion of basic funds did materialise in the case of basic funding of the national building research institute, but not for any other research institute. Despite strong warnings from the national building research institute, including a minority statement in the roadmap, the annual budget of the national building research institute was reduced by 5 million DKK (0.66 million EUR) in 2003 and again in 2011 by an additional 5.5 million DKK (0.7 million EUR). Some of the funds have been redistributed in calls for research proposals on ad hoc themes, which have changed from year to year leading to a strong short-termism and a reduced gearing of the funding available.

Fourth, the ambition to improve learning was based on a range of initiatives related to the establishment of a central knowledge centre (one-stop-shopping), improved dissemination to educational institutions, mandatory dissemination plans for research projects, improved knowledge dissemination from the two national building defects funds, and the strengthening of networks. Especially the creation of one-stop-shopping was considered important, which subsequently led to the initiation of two competing consortiums that tried to develop two different strategies for the establishment of a central knowledge centre. As time would eventually tell, only little changed in the ways dissemination takes place in construction partly due to the financial independence and organisational affiliation of each knowledge broker.

6. Conclusion

In conclusion, this study points at the following lessons to be learned: 1) it is more complicated than that to draw firm conclusions on the level of construction-related R&D investments; 2) public construction-related R&D expenditures are disproportionate compared with other research fields; 3) private R&D investments primarily take place in the manufacturing industry; and 4) the R&D roadmap has had little impact on construction R&D.

First, this study suggests that it is more complicated than that to draw firm conclusions on the level of construction-related R&D expenditures. Careful consideration is warranted when it comes to for example the scope of the study, the definition of what counts as construction or what not, and the difficulties of how to classify and register research activities adequately under different research purposes.

Second, in 2001 the level of R&D expenditures at the core public institutions was estimated at around 175 million DKK. To this should be added R&D by other public research institutions, which are estimated to be approx. 100-150 million DKK. The total public R&D within the construction/housing resource area may amount to approx. 275-325 million DKK. Out of a total public R&D budget of 8.93 billion DKK, the construction-related R&D budget amounts to some 3 % of the total public R&D expenditures, whereas the turnover in private companies of the resource area amounts to some 20 % of GDP. Thus, there is a disproportionate share of public R&D funding for construction-related R&D compared with the economic importance of the construction industry.

Third, the R&D expenditures in private companies within the construction/housing resource area were estimated at 1.2 billion DKK (160 million EUR) corresponding to the R&D efforts in primary and manufacturing industries, and half of the calculated R&D efforts in support and service industries. This estimate is marked by significant uncertainty due to the methodology applied in collating these statistics. Although the exact figures may be questioned, it can be rather firmly concluded that private R&D investments primarily take place in the manufacturing industry.

Fourth, the Task Force on Building Research published a research roadmap for construction-related R&D in 2002. The roadmap suggested a range of actions within four key focus areas: 1) increase R&D funding with 120 million DKK annually; 2) issue a ten-year national action plan; 3) re-orient research priorities; and 4) improve learning. Although some actions have been realised, a range of the initiatives proposed in the R&D roadmap has not been implemented or would most likely have been implemented anyway, for example the increased R&D funding from the private foundation Realdania. Consequently, the R&D roadmap is seen to have had little impact on construction R&D.

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