

NEW OUTPUT QUALITY INDICATORS IN CONSTRUCTION PRODUCTIVITY MEASUREMENT

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Abstract

Productivity increase in the construction industry is often seen as low. Construction innovation projects could be prioritized partly based on expected contribution to industry productivity. Quality change in construction outputs and inputs is crucial. The purpose is to explore new output quality indicators. The analysis draws upon life cycle analyses for facilities, project benchmarking schemes and environmental assessment systems. Disruption of client core activities due to technology and method choice in construction projects should be taken into account, and also the willingness of clients to pay for risk reduction. The result is a set of output measures. Primary output is identified as 'useful area'. Secondary output measures, with estimates provided by expert panels, would include effects on future energy consumption, effects on other future operations and maintenance resource needs, effects on client/user disruption, reduction of client/user risk during operation and maintenance, user comfort, architectural quality, and external societal effects. However, it would not be feasible or even desirable to collect a wider range of data routinely for the production of official statistics at the industry level.

Keywords: productivity, life cycle analysis, benchmarking, services, innovation

INTRODUCTION

Official statistics in OECD countries usually indicate that the annual rate of productivity increase in the construction industry is low. Earlier research has identified several reasons, including quality measurement errors (Crawford and Vogl, 2006; overview by Huang et al., 2009). As a consequence, international comparisons of construction productivity growth at the industry level, including the partial measure of labour productivity, are difficult to perform and to interpret (Ive et al., 2004). More recently, comparative analyses across industries and countries within the European Union and in relation to the US, relying on the EU KLEMS database, have been made available for the 1980 to 2005 period (Timmer et al., 2010).

Despite the problems associated with productivity measurement for the construction industry, it can be argued that construction innovation projects could be prioritized partly based on their expected contribution to industry productivity. This assumption has been made in the Swedish *Bygginnovationen* (The Construction Innovation, www.bygginnovationen.se) project, operational in its first phase since 2009. How to measure quality change in construction outputs is a crucial question, although there is also a problem with input qualities that change, such as educational heterogeneity in labour inputs. Developing productivity measures for the purpose of selecting innovation projects requires that the quality measurement issues are penetrated. As with the approach chosen by Goodrum et al.

(forthcoming), the ambition has not been to devise new metrics that could be applied throughout the industry for the production of national statistics. However, the exercise might give rise to new ideas for routine collection of productivity data.

The purpose of this paper is to explore the possibility to introduce new output quality indicators in construction productivity measurement. Construction productivity can be analysed at the industry, firm, project and activity/task level (Huang et al. 2009), and there are complicated relations between measures for aggregate and activity levels (Goodrum et al., 2002). For the assessment of innovations, higher levels than the construction project seldom appear to be useful, and there are lower levels such as technologies and components that may be relevant. Both contributions to total (multifactor) and to partial (usually = labour) productivity should be possible to measure, while output and input definitions should be as far as possible consistent with the OECD (2001) recommendations for industry level productivity measurement. This suggests an ambition to measure outputs according to market prices for construction projects, which means a client-oriented view of the value of innovations.

As the construction industry (NACE 41-43) includes both new construction and repairs, and also the whole range from housing to heavy civil engineering, it was decided to attempt the identification of a single set of measures that could be applied to proposed innovation projects of all types and not only for new construction. There will then be a need for estimating different weights for quality measures when applied to different types of construction: assessing a refurbishment innovation project that claims reduced disruption of building user activities is obviously different from assessing a new greenfield construction technology. It should be pointed out that an assessment of contribution to productivity is only one of several tests that an innovation proposal must pass in order to be supported by the *Bygginnovationen* project in its second phase, beginning in 2011; the commercial viability of an innovation project has to be analysed separately.

QUALITY CHANGE IN PRODUCTIVITY MEASUREMENT

Recent developments in service productivity measurement (Djellal and Gallouj, 2008) show that many issues encountered in the service sector are of relevance when analysing productivity growth in the construction industry. One relevant example of new approaches to the measurement of quality change in service outputs include the recognition of how the productivity of professional services is related to the productivity of whatever these services are intended to support as intermediate inputs, although this insight is hard to translate into data collection. Hitherto, the concept of 'client productivity' has only been used in the context of management consulting services (Martin et al., 2001), but it could equally well be applied to construction.

Another possible extension of traditional data sources is when data from customer satisfaction surveys are brought into the analysis (Färe et al., 2002). Just as in many services, there is the added complication of the customer participating in the production process of construction, e.g. when approving technical and schedule changes at construction site meetings. Co-production easily leads to the question of how co-productivity can be measured.

Although there remains a potential for the hedonic approach to qualities associated with built facilities, the estimation of implicit prices for housing attributes (Zabel, 1999; Leishman,

2001) is subject to severe limitations in the number of attributes that can be included, and for other types of facilities, even if omitting refurbishment projects, the unique features of each facility are clear obstacles. However, there are other sources of inspiration for better measures of construction output qualities, and the analysis presented below draws upon elements of life cycle analyses for facilities, project benchmarking schemes and environmental assessment systems. Furthermore, successive changes in government regulations for construction appear to offer clues.

Life cycle analyses

Many clients are thought to take the life cycle consequences of choice of materials, technologies and design more seriously than they used to do. Since the 1970s, client concern with energy cost for the operation of facilities has increased the demand for construction output qualities that raise the need for a range of inputs, and the more recent policy interest in construction sustainability emphasizes the relevance of life cycle assessments (Ortiz et al., 2009). Among public infrastructure clients, there is a growing awareness of future costs of maintenance and operations, as for steel bridges (Lee et al., 2004). If more clients are to be understood as basing their decisions on an investment view of the facility to be built, there is a number of issues to be resolved before we know the effect (as implicit prices for construction output qualities that correspond to facility features that lower future costs). One of these issues is fundamental: estimating the implicit discount rates that various categories of clients in various regions could be said to apply in their investment decisions.

Client concern with the life cycle aspects of facilities would be reflected primarily in design specifications and thus influence contract sums. The rise in long-term qualities is unlikely to be registered in traditional measures of construction outputs.

Project benchmarking

Since the UK Egan report in the mid-1990s, inspired by survey practices in the car industry, schemes for benchmarking performance in construction projects have gained widespread popularity (Costa et al., 2006; Rankin et al., 2008). In what ways do these mostly client-oriented schemes point to new output quality measures?

Construction project benchmarking can be seen as the outcome of a combination of ideas taken from customer satisfaction surveys and the project success literature. As yet, we are unable to impute what the actual client demand levels are for project attributes currently used in project benchmarking schemes. Applying the Just-in-Time principle is a good example of how a supplier might exhibit lower productivity and the customer firm a higher productivity, unless there is a compensating price premium paid by the customer. Traditional measures of construction productivity obviously fail to reflect whether contractual time schedules are met. On the contrary, for the customer who is unable to open a new production line because the built shell is not ready, there will be a measurable loss of productivity. Time precision, probably like cost precision and quality precision, is a service process quality that has not been thought about in the context of construction productivity, although it is likely that there is an implicit price for such qualities.

For the purpose of selecting innovation projects, it seems necessary to take into account the disruption of client core activities due to technology and method choice in construction projects, not least in the context of repairs and refurbishment. In general, the experiences from project benchmarking indicate that the willingness of clients to pay for risk reduction in construction projects might need adequate measurement as one or more output qualities. Now

it can be argued that there will only be weak reflections of service process qualities, as well as attitudes to risk, in construction contract sums, because clients tend to select as contractors those who have submitted the lowest tenders. However, there are signs that even public clients, whose freedom of choice is more restricted by procurement legislation, increasingly rely on non-price criteria for the award of contracts and that soft qualities such as ability to work in partnering relationships can be recognized by procurement officials and affect the ranking of submitted tenders in a way that corresponds to a set of implicit prices.

Environmental assessment schemes

The ongoing diffusion of environmental assessment systems such as LEED, BREEAM and CASBEE gives rise to the question of to what extent environmental ratings are associated with output quality changes. Eichholtz et al. (2010) have provided evidence of the economic value of 'green buildings', which should be possible to interpret as affecting construction productivity. One aspect is that clients might show willingness to pay for the image effect of owning a certified building, but this may be nothing but a transitory phenomenon.

These assessment systems offer numerous ideas for measures of environmental qualities. This is also the case with current European standardization efforts, primarily the EN 15643 series Sustainability of Construction Works - Sustainability Assessment of Buildings, which is intended to cover more than environmental sustainability, for which there is already the draft standard EN 15978 Sustainability of construction works - Assessment of environmental performance of buildings - Calculation method. It remains to be seen whether there will be a similar degree of consensus for measuring social and economic performance.

Construction regulations

In the context of selecting innovation projects, one reason why trends in the development of construction regulations are a potential source of relevant measures for construction output qualities is that in the future, existing technologies and designs may become obsolete due to government decisions. Additionally, an increased reliance on market pricing of public services that are currently offered free or at subsidized prices may in time make construction firms internalize effects that currently are external to the market mechanism. Prescient firms might recognize this and direct their demand for construction qualities accordingly, perhaps also influenced by assessment systems such as those mentioned above.

Returning to the idea of considering effects on client productivity, fire regulations for commercial buildings can be chosen as an example. Here there are three effects of regulations to be considered: (i) on client productivity, (ii) on third party (= neighbour, e.g.) productivity and (iii) on public services (= firefighting, e.g.) productivity. As to client productivity, the first of the three effects, a paternalistic view is that clients are subject to search costs for information, or that they suffer from bounded rationality so that they are unable to act fully in their own best interest.

SUGGESTED OUTPUT MEASURES

The result of this analysis is a set of output measures, where the primary output is identified as 'useful area', subject to a set of correction factors. Secondary output measures would include effects on future energy consumption, effects on other future operations and maintenance resource needs, effects on client/user disruption, reduction of client/user risk during operation and maintenance, user comfort, architectural quality, and external societal

effects. However, for a given proposal for a construction innovation project, most of the secondary output values would have to be estimated by expert panels according to simple scales in relation to defined reference buildings and reference technologies, which would represent a typical current base level in the domestic market for new construction or refurbishment.

The examples of related terms in Table 1 have been collected from Gilchrist and Allouche (2005), Hawk (2003), Lee et al. (2004), Rankin et al. (2008), REHABCON (2004), Rouse and Chiu (2009), and proposed European standards for Sustainability of Construction Works.

Table 1: Suggested output measures.

Output	Explanation	Examples of related terms
Useful length/area/volume	A user-oriented measure of capacity. Can be modified with a 'future capacity for flexibility' coefficient and coefficients for site-specific factors	urban/rural, geological and climatic factors
Energy	Discounted future reduction for the facility in use [kWh]	fuel consumption
Other operations and maintenance	Discounted future reduction of non-energy operations and maintenance resources for the facility in use	routine maintenance/rehabilitation; feasibility of post-repair monitoring, normal service life of repair
Disruption	Reduction of disruption of user activities	quality issues – available for use; user costs; traffic delay cost, noise/dust/vibration; repair time, cost of business disruption
Risk	Reduction of non-deterministic effects for the customer, within the contractual period and during the subsequent life of the facility (discounted, probability weighted)	time, cost, quality deviation; highway vehicle damage, vulnerability costs; fire safety; security
User comfort	Discounted future user comfort in excess of reference comfort levels	user costs; indoor air quality, acoustic performance, accessibility, smooth travel exposure; comfort and convenience, safety of users; traffic accidents
Architectural quality	Discounted future owner and user architectural experience in excess of a reference level	aesthetic contribution
Social effects	Discounted future reduction of negative external (non-market) effects	environmental damage, business effects; sustainability – design; indirect socio-economic losses; effects on third parties, environmental costs; property damage, noise, emissions, vibrations

A note on inputs

To obtain partial measures of productivity, the ratio between selected output measures and input measures can be estimated. The main input categories chosen here are Labour, Materials, Energy, Services and Environmental externalities. These categories can be divided into subcategories; 'waste' can appear both under (bought) Services and under Environmental externalities. Also with inputs, there is a problem with quality changes that are ignored or underestimated traditionally, such as heterogeneity of labour input, where shifts in educational level should be taken into account (Jorgenson et al. 2003). If wages or salaries reflect educational levels and skills, they would be better measures than number of manhours worked, used indiscriminately for the calculation of labour productivity.

CONCLUSIONS

Over the years, an increasing part of the value of construction outputs in typical OECD countries appears to have shifted towards qualities that are difficult to measure directly when applying conventional methods for calculating industry productivity. When selecting innovation projects according to their expected effects on construction productivity, it is important to devise a wide set of output measures that reflect a broader view of qualities, although it would not be feasible or even desirable to collect a wider range of data routinely for the production of official statistics at the industry level. For the purpose of international comparisons of productivity data, it is necessary to retain classifications and methods of measuring outputs and inputs that minimize the need for subjective assessments of intangible qualities. Unfortunately, this also reduces the usefulness of productivity data aggregated the industry level in many countries; analysis of these data can no longer be reliable guides to the development of either government policies or corporate strategies in regions where construction demand has shifted towards a wider set of qualities that are difficult to measure.

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