building radar

Are OR techniques really useful for the construction industry?

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Management Science (syn. for Operational Research) in the Construction Industry

The construction industry is one of the largest industries in the world. In fact, one of Europe's largest employers are construction companies. In 2013 alone, the application of operational research (OR) techniques within the construction industry led to cost savings of about 4% on average for a construction project. It is not only from a cost savings perspective that the construction industry has been a great success. Thanks to management scientists, the quality of construction buildings has increased steadily over the past decade, owing to factors such as decreasing overlay times, better utilization of resources, and improved construction procedures.

Despite these success stories, the cost of construction buildings has increased by approximately two times the growth rate of the GDP in recent years. This has been attributed to new technologies and demographic changes. At the same time, expenditure on for management scientists in the construction industry was reduced in 2013. This is because it is difficult for a construction site to justify why funds should be allocated to optimizing construction processes over measures for direct building ex-and interior. Indeed OR objectives tend to be "ill-defined, overlooked, poorly addressed, or functionally dispersed".

This article aims to address the benefits and challenges associated with employing management scientists in the construction industry. First, research activities of management scientists will be analyzed. Second, shortcomings of linear programming methodologies will be discussed. Finally, the benefits of operational research within the construction industry will be shown based on case study examples.

I. Management Science Publications about the construction industry

The threat of an ever-aging population has seen more management scientists pursuing scientific research from 2000 onwards. In 2005, Masters and PhD candidates were encouraged to participate in conferences and publish papers, to boost participation by younger people in OR research. This has had sustained success. Today, around 30 papers, news articles or blog posts are published in the area of OR construction daily. We, at Building Radar, do our best to further encourage this: besides sponsoring student projects (Master thesis and IDP) of the Technical University Munich, we also encourage our in-house research team to contribute to OR research on construction procedures.

Even though the number of publications on management science issues in the construction industry has increased, the implementation of OR models in practice has been very small. One main challenge of OR publications is the balance of mathematical detail and strategic perspective. To publish a paper in a journal, theoretical understanding of the issue is a prerequisite. This often means papers contain overly complex new methods that defy understanding for non-OR specialists. A researcher often takes years to develop new OR models, while end users simply require easily implementable measures. As a result, most scientific research by scholars cannot be directly employed by practitioners. Thus, a major future challenge for OR scholars will be to shift the focus of management science research from an academic to a more practical perspective. A core focus area should be the management science discipline “linear programming methodologies within construction procedures”.

II. Linear Programming Methodologies within Construction Projects

Within the construction industry, linear programming (LP) methodologies are applied to allocate resources and to develop plans on how to use these resources. In years past, linear programming gained increasing popularity as competition among construction materials suppliers intensified and customers were no longer willing to accept poor service. Management scientists have shifted their goals from minimizing costs or maximizing tenants/building owner satisfaction to a hybrid, which encompasses both. Yet, these objective variables ‘costs’ and ‘construction outcome’ are difficult to measure within the construction industry, and so the source of much scholarly debate.

The focus of the OR analysis has a major influence on the project's findings

As public buildings are generally money-losing operations, governments try to minimize spending. Consequently, OR specialists are constantly looking for cost saving opportunities within buildings. The minimization of costs is mainly dependent on two factors: who is the decision maker and over what time frame do we need to optimize. Possible decision makers include the architect, general contractor, building owner, future tenant, developer, engineer, or consultant. The timeframe varies between optimization per building by minimizing the length of the construction time, and optimization per fiscal year e.g. due to higher initial expenses for prevention to decrease risks of later construction failures. Developed management science models vary significantly with different decision maker perspectives and timeframes. As a result, each area has its own management science methodologies. However, publications tackling architect or general contractors' perspectives are more common than those tackling the perspectives of building owners or future tenants. Interestingly, prior to 1995, no paper was published about this topic from the building owner or future tenant perspective. Indeed, research, especially concerning building owner perspectives, is in its infancy and needs to be intensified. The shift of construction companies in recent years from acting on a purely supply-oriented basis, to a building-owner-centered focus, opens new opportunities for management scientists.

Do not simply minimize initial cost, but set long-term objectives!

In the construction industry, simply minimizing costs with a corresponding drop in quality of the building comes with higher later maintenance costs and lower satisfaction of the tenant with the building's quality. A major issue concerns measuring the relation between cost spending and construction outcomes, as it varies with each construction type, vendor etc.. This is especially complex, given that once the building is developed, it becomes harder and costlier to measure tenants' levels. Current OR practice to quantify the relationship between construction costs and tenants' outcomes uses historic values. However, the experts have argued that this approach can be too inaccurate for decision-making models

of management scientists, as rapid technological progress leads to constantly changing cost structures.

All players have conflicting interest about the research outcome

A further complication for linear programming approaches in the construction industry lies in the hierarchical organization within the construction industry. There are multiple stakeholders involved in the decision-making processes, from architects, to vendors, and general contractors. By contrast to the private sector, the power of a construction sides' management team in the public sector is more limited as planning and control is fragmented. General contractors look after their construction site and are involved in the direct operations of the construction. The management team however is in control of the construction site's resources and generally lacks knowledge of architectural operations. Regarding "productivity, quality of materials and quality of labor", all players have conflicting interest and their own areas of autonomy. While the management team decides on the most efficient allocation of resource budgets to departments, general contractors decide for what these resources will be used. Due to the asymmetric information distribution between both parties, conflicts arise. OR specialists need to consider these opposing interests in their programming models. However, so far, OR models often ignore the different hierarchical levels. Future OR research should reflect the hierarchy level "to ensure completeness and coherence of responsibilities for every managerial area".

OR findings are constantly disrupted by rapid innovation

While linear programming is primarily used for budget allocation problems, integer programming (IP) is mainly used for staff-scheduling problems. A currently widely discussed IP staff-scheduling problem among management scientists is the staffing of construction workers. Management scientists continuously revise their models for

improvement. Most stochastic models in use for managing emergency services are based on Müller and Schneider's model (2014). However rapid innovations in construction technologies, transportation and infrastructure force management scientists to revise and further improve their models frequently.

III. Management Science Application Areas

For each of the stages of management science techniques identified by Müller et al. (2011), a recent case study will be presented to show the benefits of said techniques within the construction industry:

- Requirements for services and developing a service: Mesina et al. (2007) investigated the possibility of offering construction consulting via video–telephone for general construction side issues. Based on a decision tree model that was developed from a survey with 71 participants, construction company types were identified for whom video–telephone consulting worked effectively. As a result, video–telephone consulting was discovered as an alternative to existing onsite services.

- Forecasting service demand and Securing resources: Fizo et al. (2008) researched the demand for building maintenance services over the next five years. To do so, a system dynamic simulation model was developed. With the help of this model, two different interventions were tested in order to be optimally prepared for upcoming budget cuts and unexpected building damage.

- Allocating resources for delivering services and developing programs and plans that will use these resources in delivering services: Ösdi and Schneider (2009) developed a linear programming model for construction worker resource planning. Based on a 4-year planning frame, the model allows us to derive conclusions on the optimal number of construction workers to train, promote, and recruit.

- Developing criteria for delivery performance and managing the performance of delivery: Peter and Ludwig (2012) investigated different stochastic integer

programming models to develop building phase schedules in regards to the availability of the work force. Based on these models, heuristics for human resource scheduling were derived that allow us to minimize the expected shortage of missing construction workers.

- Evaluating the results of construction delivery: To find out the minimal cost of a standardized construction side, operational researchers investigated the optimal materials and resource allocation based on a decision model.

IV. Conclusion: for the construction industry management science is still in the early phase and needs to grow up quickly

Management Science is crucial for the construction industry. While we demonstrated that the application of operational research theory allows cost savings and service improvements for the construction sector, we also discovered future challenges for management scientists. Our researchers at Building Radar discovered the following fields:

Management science theory needs to become more practical and less academic. This would allow more practitioners to apply the concepts.

Over the past years, management scientists have shifted their focus from minimizing costs or maximizing tenants/building owner satisfaction to a combination of the two. This opens new opportunities for management scientists.

Management science research from the perspective of the architect or general contractors is quite advanced, while management science research from the perspectives of building owner or future tenant is in its infancy. There is much catching up to do, as the latter perspective becomes increasingly relevant!

The impact of costs on construction outcomes is hard to measure, but crucial for management scientists for developing accurate models. More accurate solutions need to be found, especially on tracking the construction project of a tenant after the construction of the building is completed.

An ongoing challenge for OR specialists is to reflect the opposing interests of different stakeholders within construction sides that result from their hierarchical organization.

Integer programming is for example used to managing human resource allocation. Rapid innovations in construction technologies, transportation and infrastructure force management scientists to revise their IP models frequently.