MODERN METHODS OF CONSTRUCTION: A SOLUTION FOR AN INDUSTRY CHARACTERIZED BY UNCERTAINTY?

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Modern methods of construction (MMC) are suggested to deal more effectively with uncertainties that construction commonly presents to clients and contractors, i.e. uncertainties inherent in traditional construction regarding e.g. time, defects, safety, environmental impact, costs, profits and lifecycle performance. But do MMC really reduce these uncertainties? Furthermore, MMC change stakeholders' frames of references and they also carry their own inherent uncertainties from the previous century, e.g. poor quality and social exclusion. Perhaps MMC introduce more uncertainty than they reduce? These questions are addressed in this review that covers current research from the leading construction management journals as well as institutional reports from Sweden and UK. Uncertainties inherent in traditional construction are put in relation to the attributes offered by MMC, and the attributes are discussed with respect to their ability to reduce uncertainty, for clients and contractors respectively. Conclusions from the review are that the industrialized construction process, when fully implemented, does contribute to uncertainty reduction through its predictability regarding time schedules, costs, and improved working conditions. On the other hand, this implies standardized processes which also lead to a greater need for standardized components, early decision of the final design and a non-transparent production process that is hard to monitor for the client. These attributes of MMC challenge roles, responsibilities and put new demands on different stakeholders of the construction process, which contribute to uncertainty for both client and contractor.

Keywords: modern methods of construction, industrialized construction, uncertainty, contractor, client.

INTRODUCTION

The House Builders Federation in UK defines MMC as "methods which provide an efficient product management process to provide more products of better quality in less time". In Sweden "Industrialized Construction" is used very much in the same sense, "…an efficient, profitable, diverse building (method) where customer requirements are the focus" (Lessing 2006). In this work MMC is defined as methods of construction that use parts manufactured and assembled off-site or components manufactured off-site and brought together on-site for assembly (see e.g. Kempton and Syms 2009). The authors would like to complement this definition in accordance

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with Höök (2008) stating that MMC should comprise "one evident process owner and a clear product goal of repetition in housing design and production". Modern methods of construction (MMC), whether referred to as MMC or as pre-fabrication, off-site or industrialized construction, have around the world been suggested to present opportunities to reduce the inherent uncertainties of traditional construction (Gann and Senker 1993; SOU 2002; Lessing, Stehn and Ekholm 2005; Barker 33 Cross-Industry Group 2006). Through attributes such as standardized processes, a controlled production environment and one owner of the project process, MMC are presumed to minimize uncertainty related aspects such as time, cost, defects, health and safety risks as well as to improve predictability and whole lifecycle performance, see Table 1.

At the same time, stakeholder uncertainty, especially client or market uncertainty, has been suggested as an important barrier to MMC (Gann and Senker 1993; Pan, Gibb and Dainty 2007; Engström, Stehn and Sardén 2009). MMC attributes are supposed to enhance the performance of the construction industry might, just as well, be sources of more uncertainty and problems as they changes well established frames of references in construction are challenged. To further complicate the introduction of MMC the concept is associated with attributes such as poor quality and social exclusion, a heritage from large housing programmes during the previous century.

Hence, MMC are suggested to deal more effectively with the uncertainties that construction commonly presents to contractors and clients. But do MMC really reduce these uncertainties? Furthermore, MMC change stakeholders' frames of references, and also carry their own inherent uncertainties from the previous century. Perhaps MMC introduce more uncertainty than they reduce.

These issues are addressed in this review that covers current research from the leading construction management journals as well as institutional reports from Sweden and the UK. Uncertainties inherent in traditional construction are put in relation to the attributes offered by MMC, and the attributes are discussed with respect to their ability to reduce uncertainty, for the client and the contractor respectively.

WHAT IS IMPLIED BY "TRADITIONAL CONSTRUCTION".

The key characteristic of traditional construction is that almost all of the production occurs at the building site. The difficulties within the sector to change and develop has by some researchers been associated with this building site production, suggesting that changes that occur do so within the isolated setting of the respective building sites (Green 1999; Pheng and Hui 1999; Höök 2008).

Commonly identified characteristics of traditional construction in Sweden include (Engström, Stehn and Sardén 2009): conservative and strong culture, known and well-tested solutions, clear frameworks and roles, multiple deliveries in a fragmented production chain, skilled workforces with extensive practical knowledge, craftsmen jargon ("make it work", fixing things as they occur), handling changes as they occur, meeting new demands from customers even during the production stage, prototype nature/unique product, uncertainties concerning costing and additional costs commonly arising.

UNCERTAINTIES IN TRADITIONAL CONSTRUCTION

The uncertainties inherent in traditional construction have been discussed from multiple levels, depending on the focus of the research. Going through the

Table 1: MMC attributes and their benefits

MMC ATTRIBUTES	ASSUMED BENEFITS FROM MMC ATTRIBUTES
Standardized processes (Gann and Senker 1993; SOU 2000; Gibb 2001; Roy, Low and Waller 2005; Boverket 2008; Höök 2008)	Time (minimization/reduction of) (Gibb 2001; Goodier and Gibb 2005; Wahlström 2005; Pan, Gibb and Dainty 2007) Cost (minimize/reduce) (Gibb 1999; Pan, Gibb and Dainty 2007) Predictability (increase) (Gibb 2001; Venables, Barlow and Gann 2004; Goodier and Gibb 2005)
Controlled production environment (SOU 2000; Venables, Barlow and Gann 2004; Höök 2008)	Cost (minimize/reduce): (Gibb 1999; Pan, Gibb and Dainty 2007) Predictability and long time preformance (increase) (Gibb 2001; Venables, Barlow and Gann 2004) Quality (increase) (Goodier and Gibb 2005; Wahlström 2005)
One owner of the project process (SOU 2000; Höök 2008)	Healt and saftey risks (minimization/reduction of) (Paevere and MacKenzi 2006) Time (minimization/reduction of) (Paevere and MacKenzi 2006) Predictability (increase) (Gibb 2001; Venables, Barlow and Gann 2004) Quality (increase by minimizing defects) (Goodier and Gibb 2005; Wahlström 2005; Paevere and MacKenzi 2006) Cost (increase) (Paevere and MacKenzi 2006)

construction management literature, at least three rather distinct levels of uncertainties are identified; sector uncertainties, corporate uncertainties and project uncertainties.

Sector uncertainties inherent in traditional construction

The construction sector is fighting high costs and a reputation of poor performance (Josephson, Larsson and Li 2002). It is no wonder that these are two of the main contributors to uncertainty. The sector is also fragmented, and the fragmentation is yet another reason for uncertainty (Thompson and Sanders 1998; Conley and Gregory 1999; Miozzo and Ivory 2000; Dawood, Akinsola and Hobbs 2002; Baiden, Price and Dainty 2006). In 2000, Miozzo and Ivory showed that the development of contract conditions and regulation seamed to be crucial in establishing stable employment and training conditions. Today the construction sector is made up of several interdependent sub-groups that have different reasons for their participation in construction activities. This differentiation restrains the process and the supply chain towards cooperating to be able to deliver the right quality at the right price for the customer (Höök 2005). One consequence of more integrated and developed industrialized construction will be a decreased number of actors and amount of work on-site (Andersson, Aspling and Johansson 2003).

Corporate uncertainties inherent in traditional construction

Many of the sector uncertainties have consequences for the corporate level as well. For example conflicts between different parties are in part associated with the industry's adversarial relations due to the contracting system (Miozzo and Ivory 2000). The construction contracting system is based on competitive tendering which includes significant sources of uncertainty in it self. To further complicate the contracting situation it demands cost estimations, and each contract represents a high proportion of each firms' total turnover. This has the consequence that small changes in the tender success rate have great impact on the economy (Winch 1989). Another reason for uncertainty at the corporate level is the project organization that results in temporary organizations (Winch 1989) and leads to focus and demands on the coordination between different organizations (Miozzo and Ivory 2000). This division of work amongst actors in the project, together with the fact that construction is a small batch production, is a barrier for experience transfer from one project to the next as the actors have changed (Winch 1989). Further more, small batch production in itself is a source of uncertainty due to learning curve problems.

Project uncertainties inherent in traditional construction

Due to the lack of knowledge transfer between projects (Miozzo and Ivory 2000) there is seldom any statistics to rely on when judging the size of important project parameters such as time, cost, and quality related to particular activities. Hence, subjective estimates are needed (Winch 1989; Ward and Chapman 2003), e.g. one may not know how much time and effort will be required to complete a special activity, nor might one be able to obtain complete geological information. This is further complicated if the activities are not well defined, new, or complex, or the estimates have been made under time pressure (Ward and Chapman 2003). The estimates made are further used for planning design and logistics in the project. The sector and corporate uncertainties relating to contracts and relations (Winch 1989; Ward and Chapman 2003) are evident at the project level as well. Different actors have different objectives and the inter-dependencies between these need to be enlighten (Ward and Chapman 2003).

The uncertainties discussed above are synthesized and summarized in Table 2.

MMC ATTRIBUTES AND THEIR ABILITY TO REDUCE UNCERTAINTY

Next, the attributes and related benefits of MMC, presented in Table 1 are further discussed with respect to their ability to reduce uncertainty, for the client and the contractor respectively.

MMC reducing uncertainty for the contractor

One consequence of more integrated and developed MMC will be a decrease in the number of actors and the amount of work on-site (Andersson, Aspling and Johansson 2003), hence, a reduction of the impact of conflicting interests seems likely. This allows for more rationally coordinated processes to be executed (Boverket 2008), e.g. optimized and integrated design and construction (Paevere and MacKenzi 2006). The integrated processes make it easier to avoid sub-optimization and delays/re-work due to conflicting sets of regulations, codes and tolerances. Another reason for this is the more extent use of standardized products that is induced by MMC. This also gives the opportunity to make the construction work more repetitive and, hence, the learning curve problems should be reduced. MMC also reduce the contractors' uncertainties as it allows for a better control over production costs through, e.g. shorter building periods, less on-site work and fewer workers, less impact of weather, reductions in transportation of materials, reduced unplanned onsite remedial works and changes to project cash flow (Gibb 1999; Venables, Barlow and Gann 2004).

MMC reducing uncertainty for the client

With one process owner it is easier to gain and maintain control over the construction process c.f. (Postnote 2003; Pan, Gibb and Dainty 2005), for example one set of regulations and codes can be employed. This is enhanced by the fact that the use of standardized processes and components makes the work more repetitive and that the assembly on-site is fast, c.f. (Postnote 2003) and not as exposed to bad whether. MMC also reduce client uncertainty through the shift of responsibility for integrating the different project actors as both the design and construction process can be dealt with by one company. This in-house management reduces the impact of conflicting interests and makes it easier to manage the process effectively.

Table 2: Uncertainties inherent in traditional construction – a synthesized summery

Traditional construction	Uncertainty	
Sector uncertainties	Fragmentation	Parties focus on achieving their objectives and maximizing their profit rather than creating a product for the customer (Thompson and Sanders 1998). The nature of the skills profile, where the delineation between different skills are very unyielding, and by the employment conditions of the Swedish construction workforce (SOU 2000).
	Relations	"The traditional method (design-bid-build) of managing construction projects is largely adversarial in nature (Design 1986)" (In Conley and Gregory 1999: 320). "The adversarial attitudes, the lack of communication, and the legal posturing involved with the traditional method of construction management are the major contributors of inefficiency in the construction industry (Design (1986)." (In Conley and Gregory 1999: 320).
	Regulations	"Safety considerations and a range of regulations, standards and codes" (Miozzo and Ivory 2000: 513).
Corporate uncertainties	Management and Organization	The project organization of the construction industry results in temporary organizations and the experience is not transferred into the next project as the project members/actors have changed (Winch 1989). The construction "contracting system is based on competitive tendering which includes significant sources of uncertainty in it self" (Winch 1989: 338) To further complicate the contracting situation it demands cost estimations. Conflicts between, and demands on, the coordination between different organizations (Miozzo and Ivory 2000).
	Technology	Require enhanced precision. Construction is a small batch production which in it self is a source of uncertainty due to learning curve problems (Miozzo and Ivory 2000).
	Cost/Economy	As "each contract represents a high proportion of the construction firms' total turnover, small changes in the tender success rate will have great impact on the firms' economy" (Winch 1989: 338).
Project uncertaintie	Variability and basis of estimates	Variability in the size of objectives such as time, cost and quality. Estimates produced by project parties may be unclear, "but articulating them makes these estimates available for scrutiny and comparison with other estimates" (Ward and Chapman 2003: 100).
	Design and logistics	The nature of the project, deliverability and the process for producing it (ibid).
	Objectives and priorities	"The different project objectives held by interested parties, and any inter-dependencies between different objectives need to be appreciated" (Ward and Chapman 2003: 101).
	Relations	"…the multiplicity of people, business units, and organizations involved in a project" (Ward and Chapman 2003: 101).
	Site specificity and Quality	The problem of obtaining complete geological information can be a major source of uncertainty (Winch 1989). "Rework has become an endemic feature of the procurement process in construction that invariably leads to time and cost overruns in projects" (Josephson, Larsson and Li 2002: 76).

In the previous section the reasons for MMC reducing uncertainties for the contractor through a better control over production costs were discussed. For the same reasons the clients' uncertainties about the product costs are decreased, e.g. the return of investment is faster due to shorter production time, the predictability of outcome and cost is higher (Gibb 1999; Venables, Barlow and Gann 2004). A standardized production process also support the production process and on time delivery.

A MMC contractor view on MMC reducing uncertainty for the client
MMC make it possible to achieve economies of scale in terms of cost and technical optimization (Boverket 2009); hence, the clients' costs should be lower but, from an uncertainty reduction perspective even more important, the predictability of the total project cost should be more predictable. MMC also create buildings with better quality, improved accuracy in technical performance and good building physics c.f. (Postnote 2003; Johnsson and Meiling 2009). But at the same time MMC are sensitive to changes in regulations/codes as new ones can result in a need to change much of the factory production and thereby become very costly.

A client view on MMC reducing client uncertainty
MMC generally include the introduction of methods for quality control. While this is supposed to lead to improved quality, the effect on the outcome is dependent on how well the contractor can meet the new demands for broarder knowledge and skills that these methods put onto the workforce (Andersson, Aspling and Johansson 2003).

The shift in responsibility for integrating actors and managing both design and construction reduces the impact of conflicting interests. At the same time, there are relatively few companies that actually can manage projects process ownership. Furthermore, integration makes it harder for the client to compare alternatives, both concerning costs and design, especially as many MMC contractors, at least in Sweden, are limited to commission design-build projects. There is also a need for the design to be set much earlier when applying MMC then in a traditional construction process (Pan, Gibb and Dainty 2005). The standardization that allows repetition and quality improvements is at the same time considered as a limitation when it comes to architectural and aesthetical values. To balance different requirements, and at the same time gain full advantage of MMC, calls for special knowledge and skills as well as ICT-support which is not yet fully developed.

Table 3 synthesize and summaries the MMC attributes discussed below and the challenges arising from the same attributes.

Are MMC a solution for an industry characterized by uncertainty?
MMC attributes addresses the uncertainties inherent in traditional construction. By the means of a standardized process, a controlled production environment, and process ownership MMC present possibilities to improve the management of the fabrication of buildings, the outcome of construction, and the impact on the surrounding environment. This in turn leads to better cost control and cost savings due to reduction of labour hours as well as less rework and earlier returns of investments. From this point of view, MMC seem to extensively contribute to the reduction of uncertainty for construction industry stakeholders. But on the other hand, the same attributes also includes uncertainties due to the many unknown factors, especially for the client. MMC offer "new" ways of making business. They make the actual process of production non-transparent. They also demand decisions about final design to be taken much earlier then what clients are accustomed to. This changes roles, responsibilities and put new demands on the different stakeholders of the construction process, which contribute to the uncertainty for both clients and the contractors.

As this review shows, both the benefits of MMC, and the uncertainties rising from them are rather well studied and researched. In real-life practice, stakeholders have to manage the challenges introduced by MMC to benefit from their advantages. In addition, what this review also implies is that these challenges are further complicated by that:

Table 3:MMC attributes reducing uncertainties and different challenges arising from them.

Traditional construction	Uncertainty	MMC Reduces inherent uncertainties by:	New challenges introduced by/as a result of MMC are:
Sector un-certainties	Frag-mentation	Allowing rationally coordinated processes to be executed (Boverket 2008). Decreasing the number of actors and on-site work (Andersson, Aspling and Johansson 2003).	New demands are put onto the workforce. A need for broader knowledge and skills than today.
	Relations	An optimized and integrated design/construction and the potential for process integration (Paevere and MacKenzi 2006)	A difficulty to form necessary strategic alliance because of the law of public procurement. There is also few manufacturers that can manage larger projects.
	Regulations	One process owner that provide one set of regulations and codes and better control over different sets of standards and codes (Höök 2008).	New regulations/codes that result in a need to change the whole production and thereby become very costly.
Corporate un-certainties	Manage-ment and Organization	Better integration between different actors (Boverket 2008). In-house management and skills which reduce the impact of conflicting interests (c.f. Miozzo and Ivory 2000).	That it is harder for the client to compare alternatives both concerning costs and design. A lack of the needed multi-skilled workforce.
	Technology	Standardization of components that reduce the learning curve problems (Boverket 2008).	That standardization has bad reputation and might scare potential clients.
	Cost/ Economy	Savings due to shorter building time, less on-site work, fewer workers, less transportation, reduced unplanned remedial works and changes to project cash flow (Gibb 1999).	It is harder for the client to predict the actual outcome as he has no control over the construction process due to this there might be higher initial costs.
Project un-certainties	Variability and basis of estimates/ Design and logistics	Predictability of outcome/ cost due to speed of construction and return of investment etc.(Venables, Barlow and Gann 2004).	That the design needs to be set much earlier then in the traditional construction process
	Objectives and Priorities	In-house production that reduces the impact of conflicting interests (c.f. Miozzo and Ivory 2000).	New processes and relations and no existing knowledge on how to handle them.
	Relations	Decreasing the multiplicity actors involved in a project through one company taking responsibility for a grater part of the process (c.f. Höök 2008).	That it is harder for the client to compare alternatives both concerning costs and design. New cooperation's but no existing knowledge on handling them.
	Site specificity and Quality	The ability to design for manufacturing and more control over the production process achieved in the factory (Venables, Barlow and Gann 2004).	That it is harder for the client to predict the actual outcome as he has no control over the construction process.

- a reduction of sector uncertainties not necessarily will reduce uncertainties on other levels, but rather present new uncertainties on the corporate and/or project level.
- while MMC reduces uncertainties for one stakeholder, such as the contractor, they simultaneously introduces new ones for other stakeholders, such as for example the clients.

The overriding conclusion is that MMC changes, rather than reduces, uncertainties within the construction sector. The future of MMC depends on its proponents' ability to, not only meet the suspicion and conservatism of construction clients, I.e. stakeholders accustomed to, or even schooled into, the traditional way of construction, but also to translate different stakeholders advantages to explicit values as acknowledged by other stakeholders.

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