BSB
Broad Sustainable Building
Stainless Steel Structure
5 times Less Energy
100 times Cleaner Air
100% Factory-made

WORLD ECONOMIC FORUM

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BROAD Sustainable Building

Bringing manufacturing principles to the construction of high-rise buildings

The challenge

The engineering and construction sector is glaringly lagging behind other industries in process optimization, knowledge transfer and lean principles.

Construction projects today are conducted in a very similar way to those of several decades ago: the bulk of work is still done on-site, with little automation and process optimization. The sector has not fully entered the third industrial revolution, let alone the fourth.

One of the problems is inherent: the construction site. Although it does allow lean principles to be applied to some degree, it is not really conducive to them. The full potential of lean principles in the construction process, transport and logistics is difficult to realize outside a factory setting.

A quite different problem is the industry's inattention to knowledge transfer. True enough, each construction project tends to be an individual, unique, one-off project, but that is no reason for companies to approach it as an individual challenge. It will obviously share many characteristics with earlier projects and would benefit greatly from any lessons yielded by those projects. Yet few companies have a systematic knowledge-transfer policy. As a result, the construction industry – unlike almost all other industries – has barely raised its productivity level in generations and has a poor track record for and on-budget budget delivery.

This downbeat assessment is even bleaker in the developing and emerging countries where construction projects remain heavily reliant on low-skilled labour and use less machinery and equipment. The construction process is, therefore, generally less efficient and the built assets are of lower quality.

One final shortcoming of the industry: inadequate environmental and resource protection, especially in developing countries. Construction remains the largest consumer of raw materials, and buildings are responsible for about 30% of greenhouse gas emissions.

> **The E&C industry is not even in the Third Industrial Revolution, let alone in the Fourth; a step change is required.**

Future of Construction Session in Davos 2016

The idea

Prefabricate buildings off-site to increase the speed and quality of construction.

The origins and emphasis of Chinese BROAD Group were in manufacturing – producing (non-electric) air-conditioning systems for commercial buildings, such as Dubai Mall or Qualcomm HQ, or for civil infrastructure facilities, such as Madrid Airport. And things might have stayed that way if it hadn't been for a parallel preoccupation on the part of the group's chief executive and chairman, Zhang Yue. He had grown increasingly frustrated with the building industry – not only with its often suboptimal quality standards but also with the prevalent disregard for environmental protection.

Backed by his abundant manufacturing experience, Zhang Yue resolved to revolutionize the construction of buildings by applying manufacturing industry processes and principles: factory-made components, quality-management strategies, and energy-efficiency techniques. In 2009, he duly founded BROAD Sustainable Building Co. Ltd (BSB) – a BROAD Group subsidiary specializing in the prefabrication and assembly of high-rise buildings.

Central to its technology are two massive components that are prefabricated in large production lines. The first is the standardized floor plate, a steel frame structure measuring and measuring about 16 x 4 metres (about 64 square metres). Each giant plate is pre-fitted with pipes and wires, and with flooring (such as tiles or laminate). The second centrepiece is the structural steel column, to bear the load. The plates and columns are loaded on to trucks, together with the appropriate tools and equipment (such as bolts), and transported to the construction site for assembly.

During assembly, the prefabricated columns are erected and the floor plates are simply fitted into position, making the construction process “as easy as playing with Lego”. The role of the on-site workers is mainly just to connect the steel columns, bolts and wall panels, and to link up the pre-installed wiring and piping between the plates.

Prefabrication is used for other components too – exterior walls, for instance, complete with four-pane windows and integrated solar shading. Once delivered to the building site, these walls are lifted into position by cranes. In total, 90% of the building is prefabricated in the factory, which maintains efficient production and enables rigorous quality control.

While most buildings are delivered as turnkey products, clients can place orders to their own specifications. They might require only the building shell, for instance, or only the structural components for use in their projects.

BSB has invested more than USD 650 million into R&D and production capacities. Its Xiangyin factory spans 230,000 square metres, and can now produce 5 million square meters of BSB components per year.

In keeping with his vision of environmental responsibility, Zhang Yue favours the trend in which people both live and work in the same building, thereby reducing land use and commute. Accordingly, BSB concentrates on high-rise construction. However, its technology can be applied to other building types, too. It is particularly well-suited to the hospital sector, for instance, since hospitals have such high operating and maintenance costs and could greatly benefit from the energy efficiency that BSB buildings allow.

The impact

BSB's technology proves how steel-frame prefabrication reduces the speed and cost of construction and at the same time increases quality and energy efficiency.

BSB's prefabrication strategy has many advantages over traditional construction techniques, in respect of time, cost, environmental impact, and overall quality.

Time: BSB's speed of construction is especially impressive. Famously, a 57-storey building was completed in just 19 days, having risen each day by three storeys typically. Contrast the 3-10-day cycle (for pouring concrete and allowing it to cure) involved in each individual storey in traditional high-rise construction. Note, too, that BSB's avoidance of concrete, except in the foundations, reduces the building's weight to a mere third or even a fifth of its traditional counterpart.

Cost: Shifting the bulk of work to the factory enables a huge boost in efficiency, thanks to scale effects and lean principles. On-site work is transformed; assembling the building involves little more than a series of short, straightforward, standardized tasks. Factory production also reduces transport and logistics costs, as building materials can be stored and handled in large quantities off-site.

In combination, the efficient manufacturing, assembly and logistics will reduce the costs of a new building by 20%-40% relative to traditional in-situ construction methods. That amounts to a reduction of at least $1,000 per square metre from the average conventional cost (in Europe, North America and Australia) of about $3,000 per square metre.

Environmental impact: BSB buildings typically have thermally insulated walls 15cm-30cm thick, triple- or quadruple-glazed windows, fresh-air heat-recovery machines, external solar shading, and (unsurprisingly, given the company's background) up-to-the-minute air-conditioning and ventilation. The result is impressive: five times the energy efficiency of conventional Chinese buildings and 1% the level of air impurities – a particularly attractive combination for hospitals, of course.

BSB buildings have further environmental benefits. Construction waste is less than 1% (as opposed to 5%-10% for conventional buildings), and the buildings can be dismantled easily, offering the prospect of reuse and recycling of steel. As for emissions during the construction process, they are now virtually eliminated as negligible air and noise pollution is produced when the cranes lift the prefabricated modules to their final position.

Quality: BSB buildings excel in many dimensions of quality. Their light-weight and ductile yet stiff steel structure enhances earthquake resistance, for example. That resistance is rigorously tested and BSB buildings are certified to withstand magnitude 9.0 earthquakes. In the devastating 2008 earthquake in Sichuan, thousands of deaths might have been avoided if the housing had been of higher quality. Protecting people against earthquakes was one of Zhang Yue's initial motivations in establishing BSB in 2009.

In emerging and developing countries, part of the reason for low-quality construction, as mentioned earlier, is its heavy reliance on unskilled labour. By replacing that traditional approach with a standardized, quality-controlled manufacturing process, BSB boosts the quality and safety of new buildings and greatly reduces the need for costly rework.

Since its foundation, BSB has completed more than 30 pilot and commercial projects, almost all of them in China. The most celebrated of these pioneering projects is Mini Sky City (J57), the 57-storey building erected in only 19 days, as described above. Its construction was captured in a time-lapse video that made international headlines and received millions of clicks on YouTube. BSB also constructed the 30-storey T30 building in 15 days and the 15-storey Newark Hotel in a mere six days.

BSB won the Council on Tall Buildings and Urban Habitat (CTUBH) Innovation Award in 2013 – the first Chinese construction company to do so. The presenters paid tribute to the company's technology and its "innovative way of fundamentally rethinking tall building construction". BSB has also received much attention from the media and academia around the world (including Reuters, the BBC and the Harvard Business Review) and was praised by UN General-Secretary Ban Ki-moon for its exemplary sustainable buildings. In 2011, the United Nations Environment Programme honoured Chairman Zhang as its Champion of the Earth for his entrepreneurial and environmental vision.

The barriers to innovation – and the solutions

Scepticism from architects, engineering and construction firms and end-users is far from insuperable. BSB collaborates with design institutes, builds showcase projects and sets industry standards for quality to introduce its innovations into the engineering and construction ecosystem.

Given its clear advantages, why is BSB-style prefabrication technology not more widespread? The main impediment seems to be that of scepticism from architects and designers, whose education would have concentrated on classical construction methods and who tend to associate prefabrication with low quality. To overcome this scepticism, BSB has partnered with several design institutes for the design work and has successfully obtained approval from the national experts committee on construction and the government for the planned 838-metre world's highest building, "Sky City". BSB has launched a joint venture with a design institute in Wuhan not only for planning and designing BSB buildings but also for educating designers. One aim is to show that the floor-plate structure, although standardized, is still amenable to innovative and creative design.

Mistrust of prefabrication is not limited to architects and designers but extends to potential clients as well. BSB's strategy in this regard is to publicize its processes conspicuously. The now-famous internet videos have not only educated the market but also have promoted the BSB brand. And the company has validated its image by rigorously implementing its production-quality principles, in much the same way that Toyota did in the automotive industry. And then there is the sensational prospect of the 220-storey edifice, the Sky City building. Even if the plan is never realized, the vision itself has captured the interest of industry stakeholders around the world. Regulators and property developers alike are becoming more receptive to and impressed by BSB's technological capabilities, and that should facilitate the company's forthcoming endeavour to expand its sphere of operation and to co-invest in flagship construction projects in core markets such as New York or Guangzhou.

Another obstacle that BSB encounters is the lack of environmental awareness on the part of potential clients. In China and other developing countries, many project owners and developers still do not care about the advantages of energy-efficient buildings. That said, the construction ecosystem in China is showing signs of change, with a growing concern for the sustainability and lifecycle performance of buildings. Part of the impetus is no doubt due to government commitments on greenhouse gas emissions. And BSB's showcasing of prefabricated and high-rise buildings conveys a reassuring message to developers: that an environmentally responsible approach generates considerable savings – on the land needed, on materials, and on operations and maintenance.

One other broad obstacle is worth mentioning: the system of third-party supervision that dominates the Chinese construction sector (and is a source of corruption within it). BSB has always been challenging this system – implicitly, by setting quality standards and pressing for more certification; and explicitly, by working with government institutes to promote their *guidelines* on prefabrication into *regulations*. Happily, things are changing. Although prefabrication accounts for less than 1% of construction today, the Chinese government aims to increase that share to 30% by 2026, with a special emphasis on steel structures. Hunan province, with BSB in support, is taking a leading role in this regard. In a similar vein, BSB is seeking to secure its international expansion by getting its technology properly appreciated and accepted in other countries, and is working with international partners to acquire formal certification and building permission.

BSB moved quickly to make its presence felt in the market and demonstrate the power of its innovative technology. As soon as it was equipped to create a minimum viable product, it did so but was hardly going to rest content with that. The company is constantly refining the manufacturing process and striving to optimize the characteristics of the materials. One weak point of steel structures generally is their susceptibility to loss of integrity due to fire and the potential corrosion that will affect them during the lengthy lifetime of the buildings. In response to this challenge, BSB developed the *stainless-steel honeycomb structure*, which improves stability as well as extends the building's life and avoids rework due to corrosion. This form of steel imitates the natural structure of honeycombs and combines strength, thinness, high-temperature resistance, anti-corrosion and sound isolation – and all at an even lower weight and thus higher specific strength than standard steel components. What's more, the honeycomb structure completely avoids concrete – nothing short of a revolution in the construction industry.

Previously, such honeycomb steel, being very costly to produce, was limited mainly to aerospace design, but BSB succeeded in bringing down the cost dramatically by inventing automatic copper-brazing streamline production. The company also uses the innovative steel for columns, crossbeams, floor slabs, walls and roofs.

The stainless-steel honeycomb component will be produced in panels of standard size – 12x2 metres and 15cm thick. That will facilitate BSB's expansion into overseas markets, as the panels will fit into a 40ft container for remote low-cost transport. To rapidly promote BSB technology globally, BSB plans to establish local joint-venture factories and hire local workers for mass production. Through a network of local factories with local supply chains, BSB can not only avoid tariff payments, technical and labour barriers but also contribute to an equitable development of the global economy.

One final possible barrier – again, mainly in developing countries, with their labour-intensive construction processes – is resistance by local stakeholders of traditional buildings, in particular from workers as well as architects and designers who fear losing their jobs. BSB's planned franchise system should address that challenge to some extent – by sharing the benefits locally, BSB would increase buy-in. Two key elements of this strategy are a strict selection process for partners, and in-house training courses provided by BSB to guarantee quality. Candidate partners would need to have experience in manufacturing, government support and sufficient funding to pay the technology licensing fee (about $50 million). They would then have a production line that produces 2 million square metres of BSB components per year and can receive any subsequent technology updates for free.

BSB's mid-term objective is – within five years – to reach a market share of 10% of all new buildings.

Lessons learned

– **Apply winning principles from other leading industries in construction**
With its background in manufacturing, BSB brought a fresh perspective to the design and construction of high-rise buildings, using the techniques, quality standards and lean principles of the manufacturing industry to enhance both efficiency and quality.

– **Combine a standardized platform with easy customization**
BSB presents its standardized technology platform (a platform based on floor plates) as an opportunity rather than a limitation. Clients are able to customize the building according to their needs via a simple menu – an approach familiar to the automotive industry but a novelty in the engineering and construction sector.

– **Provide training and information to designers and architects to overcome their resistance and to create multipliers**
To raise awareness and increase acceptance of its disruptive technology, BSB will partner with several design institutes to engage and train designers and architects – key agents in promoting the technology. As for resistance from construction workers, that should ease once the local joint venture system is rolled out and brings benefits to the local economy.

– **Develop a minimally viable product to showcase an innovative approach and, from that basis, continue making incremental improvements**
BSB quickly developed a basic viable product to demonstrate the power of its technology. By systematically refining its production processes and optimizing the materials used, the company has constantly expanded its horizons, releasing new generations of buildings and developing the innovative honeycomb structure component. This rapid prototyping has featured prominently in BSB's guerilla-marketing strategy (YouTube time-lapse videos) to create global awareness of its technology.

Case Study prepared by the Boston Consulting Group as part of the Future of Construction Project at the World Economic Forum

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