

# Industrialization of the Construction Industry

By

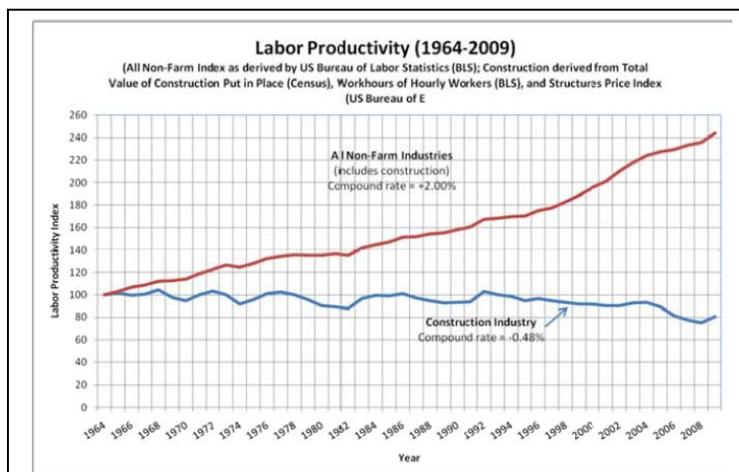
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*The quality of life for every American relies in part on the products of the U.S. construction industry—houses, office buildings, factories, shopping centers, hospitals, airports, universities, refineries, roads, bridges, water and sewer lines, and other infrastructure. In 2007, the construction industry accounted for \$611 billion or 4.4 percent of the Gross Domestic Product (GDP), more than many other industries, including information, arts and entertainment, utilities, agriculture, and mining (BEA, 2008). The industry employed almost 11 million people (about 8 percent of the total U.S. workforce) and put in place buildings and infrastructure valued at \$1.16 trillion (U.S. Census, 2008). (National Research Council. *Advancing the Competitiveness and Efficiency of the U.S. Construction Industry* . Washington, DC: The National Academies Press, 2009.)*

Like many other industries the construction industry is under constant pressure to improve productivity, reduce cost, and minimize waste in the operation. While the productivity in the manufacturing industry has improved by four hundred percent (400%) over the last century, the construction industry’s productivity has, in the best case, stayed flat or turned negative (**Figure 1**).



**Figure 1** (Source: Chapman and Butry, “Measuring and Improving the Productivity of the U.S. Construction Industry: Issues, Challenges, and Opportunities.” Building and Fire Research Laboratory, National Institute of Standards and Technology: Gaithersburg, MD, 2008.

One main reason for the improvement of the manufacturing and other industries' productivity is the "Industrialization" of those industries. Industrialization of any industry will rely on the following five factors:

1. Management of Labor
2. Management of work
3. Lean Operations
4. Modeling and Simulation
5. Feedback from the source

The driver for establishing and applying industrialization in manufacturing was the American Society of Mechanical Engineers (ASME) in the late 1800s and early 1900s. Currently no known association is leading this mission in the construction industry.

A marked result of the advancement in productivity of the manufacturing industry is the relative price of an automobile. Whilst the cost of an automobile has gone from 140% in 1910 of the average national per capita income in the United States down to 33% in 2012, the cost of an average dwelling has gone up from 333% to 619% of per capita income during the same period.

In a monumental and historical study conducted by the National Research Council of the National Academies on behalf of NIST<sup>1</sup> the challenges and obstacles facing the construction industry were categorized and listed as:

### **Fragmentation of the industry**

*"The sheer number of construction firms (760,000 in 2004) and their size—only 2 percent had 100 or more workers, while 80 percent had 10 or fewer workers—make it difficult to effectively deploy new technologies, best practices, or other innovations across a critical mass of owners, contractors, and subcontractors. The industry is also segmented into least four distinct sectors—residential, commercial, industrial, and heavy construction."<sup>2</sup>*

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<sup>1</sup> (National Research Council. *Advancing the Competitiveness and Efficiency of the U.S. Construction Industry*. Washington, DC: The National Academies Press, 2009.)

<sup>2</sup> Some practitioners would suggest that transportation-related projects be treated as a fifth segment of construction based on the characteristics of these types of projects (Hinze, 2001).

## **Interconnectivity and interoperability**

- *Its diverse and fragmented set of stakeholders: owners, users, designers, constructors, suppliers, manufacturers, operators, regulators, manual laborers, and specialty trade contractors including plumbers, electricians, masons, carpenters, and roofers.*
- *Its segmented processes: planning and financing, design, engineering, procurement, construction, operations, and maintenance. Each process involves different groups of stakeholders, and shifting levels of financial risk.*
- *The image of the industry—work that is cyclical, low tech, physically exhausting, and unsafe—which makes it difficult to attract skilled workers.*
- *The one-of-a-kind, built-on-site nature of most construction projects.*
- *Variation in the standards, processes, materials, skills, and technologies required by different types of construction projects.*
- *Variation in building codes, permitting processes, and construction-related regulations by states and localities.*
- *Lack of an industry-wide strategy to improve construction efficiency.*
- *Lack of effective performance measures for construction-related tasks, projects, or the industry as a whole.*
- *Lack of an industry-wide research agenda and inadequate levels of funding for research.*

Furthermore the same study identified solutions for breakthrough improvement of productivity in five areas:

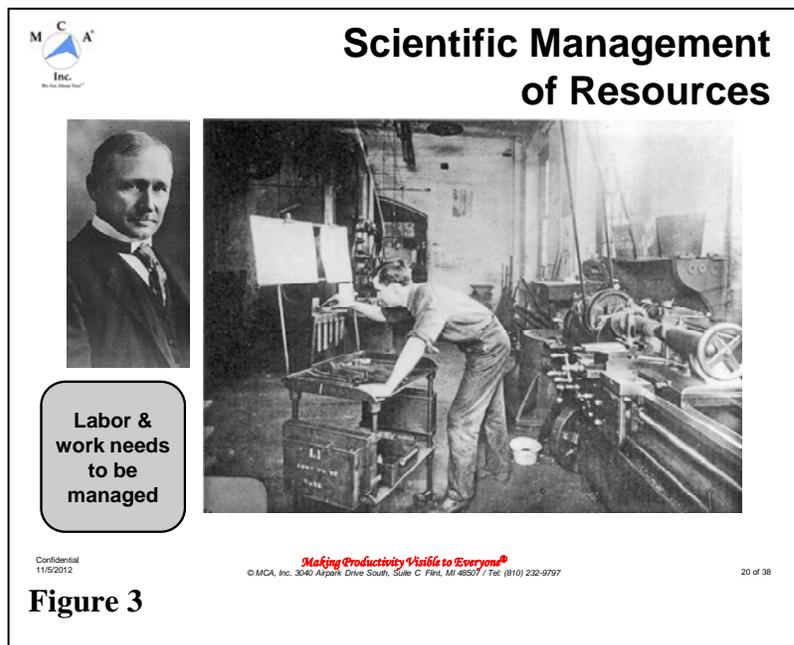
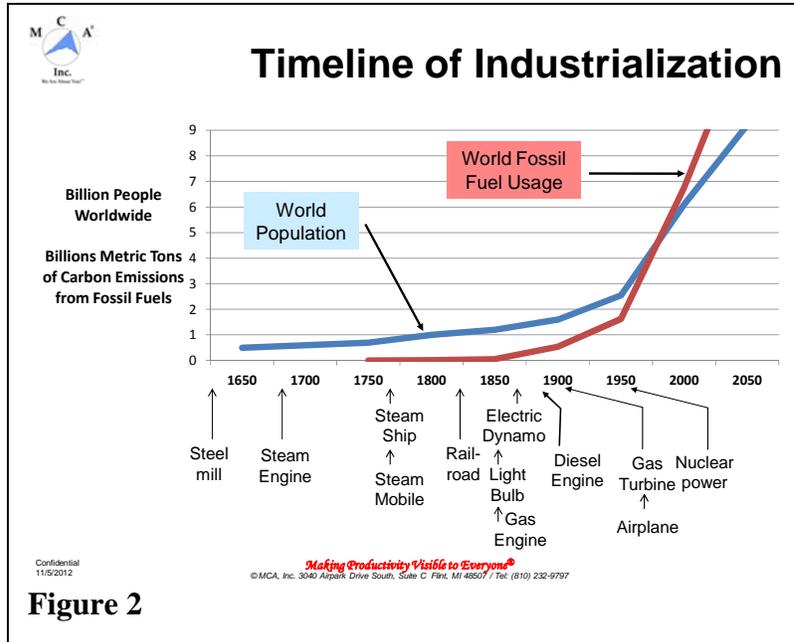
1. ***Widespread deployment and use of interoperable technology applications.***
2. ***Improved job-site efficiency through a more effective interface of people, processes, materials, equipment, and information.***
3. ***Greater use of pre-fabrication, pre-assembly, modularization, and off-site fabrication techniques and processes.***
4. ***Innovative, widespread use of demonstration installations.***
5. ***Improved performance measurement to drive efficiency and support innovation.***

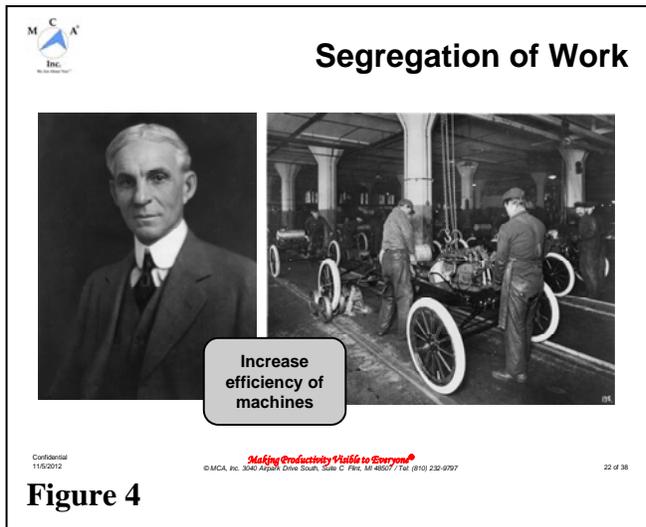
These findings are very much in line with what the manufacturing industry had realized after the advent of industrialization. The Industrial revolution, which started in mid 1700 (**Figure 2**), led to an increase in population due to the first time in the human history that production levels were higher than self consumption of the working man. Increase in population changed its

characteristic from a liability in the traditional Malthusian economy to an asset in Adam Smith’s view, or capitalistic economy.

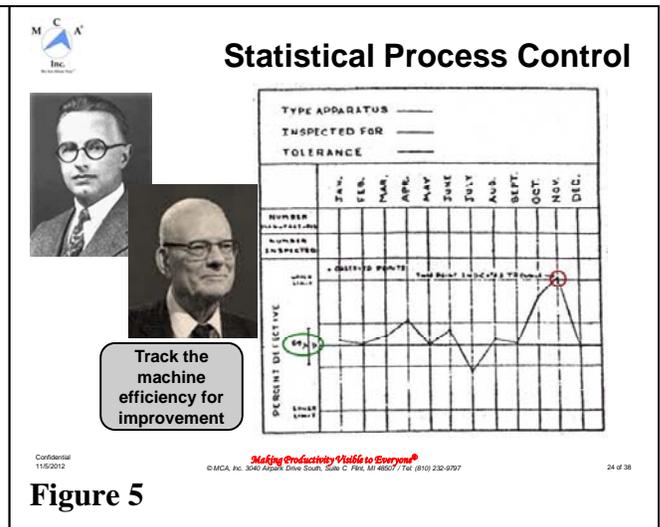
With higher population also came new markets and customers. The production facilities had to become more productive. Henry Towne introduced the concept of “Engineer as an Economist.” and led the path to the application of “Principles of Scientific Management” by Fredrick Taylor (Figure 3) for discovering the means of managing labor and work. Continuing with giants of productivity improvements such as Frank and Lillian Gilbreth for efficiency, human factors, and measurement; Henry Ford for efficiency of the machine

(Figure 4); Dr. Shewhart and Deming (Figure 5) for statistical process control; and ending with Toyota’s Taichii Ohno (Figure 6) for application of effectiveness of labor, the manufacturing gained its four to five fold productivity.





**Figure 4**



**Figure 5**



**Figure 6**

In today’s construction environment the value transferred to the customer for every dollar spent is only around 46 cents. More than 40% of the tradesmen’ time on a jobsite is spent on material handing; most of the work on a jobsite is performed by highly trained and paid skill tradesmen. To achieve comparable results as have been seen in the manufacturing and other industries the construction industry has to take the same steps:

1. Segregation of work
2. Externalizing Work®
3. Application of Statistical Process Control (SPC)
4. Application of Lean Process Design to improve Labor Effectiveness
5. Application of 3D Modeling and Simulations and Feedback

## **1. Segregation of Work**

The most important contribution of Fredrick Taylor's work to industrialization of manufacturing was his ability to observe the skilled and unskilled tradesmen at work for a long period of time and being able to breakdown the conducted work. Once the work was broken-down it could then be managed by better management of time, location and contributing resources. Once the work was visible and understood, it could be designed in the most optimal manner, and segregated amongst the resources available. Translating the segregation of work to the Architecture, Engineering and Construction (AEC) environment of today's world would be using the work breakdown structure from the skilled trades' perspective. Skilled tradesmen need to break down the work based on the required sequence of installation. These installation packages would enable creation of work packages to be built and assembled by non-skilled workers.

## **2. Externalizing Work<sup>®</sup>**

Henry Ford's contribution to industrialization was to use the approach developed by Fredrick Taylor and create the work packages separate from the point of assembly of the final vehicle. Externalizing Work<sup>®</sup> in construction is using prefabrication process and techniques to improve reliability, safety, predictability and productivity of the work performed and labor usage. In a recent example, Chinese used this method to construct a 15 story building in 6 days, where the traditional methods would have taken 9 to 12 months. There were zero accidents on the job site and the building was certified for 9.5 Richter scale earthquake resistance.

## **3. Application of Statistical Process Control (SPC)**

Application of SPC was declared impossible in the AEC industry, until the ASTM Standard E2691 (Job Productivity Measurement -JPM) developed based on the JPAC<sup>®</sup> (Job Productivity Assurance and Control) proved everyone wrong. The main purpose of SPC was to predict the outcome of a project early on, and measure the deviation from the expected output as an ongoing measurement of progress and correction. As part of the Agile Construction<sup>®</sup> methodology, JPAC<sup>®</sup> uses the knowledge based developed based on Drs. Shewhart and Deming's approach in using ongoing production data to predict the deviation from expected output and project the end of the job outcome deviation. Using SPC, JPM/JPAC<sup>®</sup> is able to issue early warning signals for

any common or special causes of deviation. Using segregation and externalization of work this tool will enable higher effectiveness of the labor usage both at the production and final construction assembly site.

#### **4. Application of Lean Process Design to improve Labor Effectiveness**

Toyota's approach to Lean Manufacturing Process design helped the manufacturing industry to focus on reducing waste, and activities which did not transfer value to the final customer, reducing their cost of production. Application of Lean Processes in construction will require the usage of the three steps explained above. To reduce waste the work has to be segregated, externalized and tracked.

#### **5. Application of 3D Modeling and Simulations and Feedback**

To reduce the cost of design, development, prototyping, manufacturing and product life cycle durability, the next step in the industrial revolution was to manage the required information in an electronic modeling format. Modeling and simulation of all the product development and life cycle management was the outgrowth of the physical modeling. Modeling works as an enhancement of the physical understanding and design of the final product and its usage. The accuracy of the modeling can only be improved by a real life feedback process. The feedback mechanisms in manufacturing are typically sensors, servos and synchros, where in construction due to its manual final assembly nature the feedback comes from the final installer. Short Interval Scheduling (SIS<sup>®</sup>) as part of the Agile Construction<sup>®</sup> process plays the role of the feedback sensor, servo or synchro. The "Lean Construction Solution Experience" developed by Dassault Systemes is the models, simulations and life cycle management platform which enables the ability to get feedback from the final installer and model information within the work environment.

For the construction industry to match the productivity increases achieved by manufacturing the work has to be studied, segregated, externalized and commoditized. To reduce the cost and improve the productivity, lower-skill and non-skill workers have to be able to find work in the industry. In order to effectively use a lower composite rate to reduce construction cost, lower-skilled workers have to be employed and used on the jobsites as well as off the jobsite in prefabrication or material management services such as vendor-managed inventory. To manage

the lower-skill levels the construction work has to be broken down into manageable chunks and the type of work has to be segregated. To allow lower skilled labor to contribute to work, the work has to be modularized and brought to the most common denominators.

To answer some of these challenges facing the industry, Dassault Systemes in collaboration with MCA Inc. have joined forces to apply the lessons learned from Design, Engineering and manufacturing to Architectural, Engineering and Construction industries. The 3DEXPERIENCE Platform will support this monumental undertaking through applications of:

- Product modeling (BIM-CATIA<sup>®</sup>, SOLIDWORKS<sup>®</sup>)
- Process Modeling and Feedback (JPAC<sup>®</sup>, SIS<sup>®</sup>, EAE<sup>®</sup>, CPAC<sup>®</sup> DELMIA<sup>®</sup>, SIMULIA<sup>®</sup>, CATIA<sup>®</sup>)
- Information & Social Network/Interactions Modeling (ENOVIA<sup>®</sup>)

The initial sparks of Industrialization of the industry is already evident in such examples as:

1. Construction of a 15 story building in 6 days in China
2. Skanska's usage of Enovia
3. Construction of world tallest building in 90 days in China
4. Construction of totally modularized hospital in Dayton, OH by Skanska

## **Conclusion**

Need for shelter and improvement of the human well-being will force the construction industry to produce more with fewer resources. Unbalanced availability of work force in different regions of the globe will make the modularization and preassemblies a necessity of constructing buildings across the globe. Lessons learned from manufacturing and other industries will help accelerate the industrialization of the construction industry without having to go through the same sequence of events. Building modeling and simulation, the application of feedback processes, and products in hand with social network environment will enable the 3DEXPERIENCE, which has not been seen before. The question then becomes, what is next. Every labor and skilled trade heavy industry will have to go through this change to provide better, cheaper and higher quality service to the human race for the betterment of the societies. Healthcare is the next natural step.