

**IMPACT OF PEAK OIL ON MODERN CONSTRUCTION MANAGEMENT:
ASSESSING STAKEHOLDER PERCEPTION BASED ON FORECASTING MODELS
OF FOSSIL FUEL USE**

A Project & Report submitted to the Faculty of
Virginia Polytechnic Institute and State University
in partial fulfillment of the requirements for the degree of

Master of Science
In
Building Construction

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May 5, 2010

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Abstract

Peak oil theory maintains that the world's supply of oil is finite by nature. This work uses the Hubbert peak to triage modern best practices of construction management in terms of peak oil, creating a lens through which to view the future of the construction site in a peak oil economy. In establishing a foundation of proper systems thinking, the author examines throughput in terms of construction as well as other frameworks aimed at sustainable corporate development. Various business models in use today attempt to mitigate the myriad of ecological impacts and relieve the industry from oil's grip. The outcomes of those models are variable per organization, but consequences of ignoring oil's diminishing returns will impact the construction industry in ways yet to be discovered. Construction management themes are applied to a backdrop of peak oil in a survey that attempts to highlight elements of corporate behavior and compiles stakeholders' responses, allowing for future research in organizational behavior specific to other industries.

Introduction

The late eighteenth century ushered in the Industrial Revolution. With it, global society would transform from a sluggish rural economy to a booming urban economy. Manual farming gave way to textiles and manufacturing as the predominant means of wealth and further advancement in a new economy. Two hundred years later, we find ourselves swimming in unprecedented technological achievements amidst a newer *Information Revolution* (Drucker 1999) that praises white-collar intellect in lieu of blue-collar labor. Notwithstanding the infinite number of modern marvels we take for granted in today's culture, we have since evolved as hyper-consumers relying upon one source of energy that is finite by nature. Quite literally, we are a culture overly dependent on fossil fuels in order to sustain the comfortable standard of living we have become accustomed to since man was replaced by machine. The accessibility, transportability, versatility and low cost of oil have all helped create its well-established, elaborate infrastructure that currently dominates the supply chain (Mabro 2006).

Simply put, the essence of the term sustainable is "that which can be maintained over time" (Heinberg 2007). Merriam-Webster defines sustainable as *being a method of harvesting or using a resource so that the resource is not depleted or permanently damaged* (Merriam-Webster 2009). However, ample research is available to call into question the idea of all things sustainable regarding the behavior of modern industrialized nations (Wuebbles and Jain 2001; Ediger et al. 2007; Hertwich and Peters 2008). Likewise, one cannot discuss fossil fuel exploitation without the primary bi-product of burning this cheap source of energy: carbon dioxide (CO₂), more commonly referred to as a 'carbon footprint' in mainstream media (Buchanan and Honey 1994). It is worth noting that carbon dioxide is among six chief greenhouse gases, the others including methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride (EIA 2009). While it is not a central theme to this work, the carbon footprint is a useful way to index ecological impacts as well as dictate environmental policy (CBO 1990). Industry, when used in a generic sense, is now becoming vulnerable to unsustainable consumption of fossil fuels. Until recently, the unabated use of fossil fuels has created a misplaced sense of everlasting progress and wealth despite finite resources. At present, more than 88% of the commercial energy used in the world comes from

fossil fuels (Meadows et al. 1992). It is this newfound exposure of modern industry sensitive to depleting oil reserves that is the author's focus within the realm of construction. This paper uses the term *industry* to mean that pertaining to construction. Industry stakeholders, detailed later in this paper, are those who have a personal impact on the industry, owners being of particular interest. In other words, to examine the corporate mindset useful for any functional decision-making framework, those who are actual decision makers on behalf of the company are the focus. While subordinates in any organization have influence, a succinct measure of top executives affords this work the clearest picture of the corporate mindset present in construction today.

Thomas Friedman lionizes the global economy of a 'flat' world (Friedman 2007). Today, prefabricated modular building materials are shipped all over the world virtually overnight. This is how we have come to embrace most industries in an era of instant gratification – the end product or service is independent from the vast amounts of energy used to create it. The objective of this research is to paint a different picture of the twenty first century. That carbon emissions plays a direct role in a nations' ability to sustain economic growth (Holtz-Eakin 1995) is key to understanding how industries will react to inevitable amendments to current policies. How will the construction industry, let alone whole countries, react to new restrictions of carbon emissions? To understand this question fully is to extrapolate organizational behavior from the very business practices of those surveyed for this work. This relationship between individual and organization within a system is illustrated below in Figure 1.

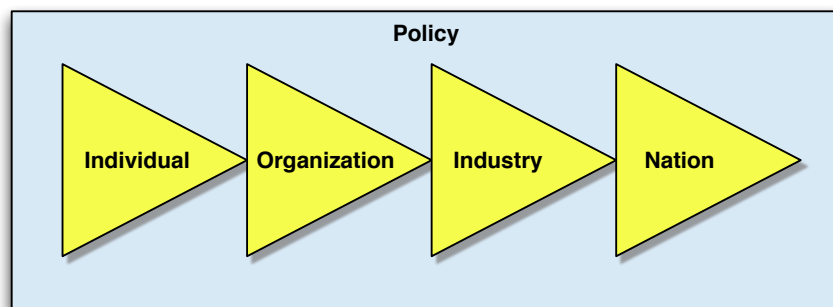


Figure 1. The dissemination of knowledge as thoughts, ideas, or construction management best practices begins with an individual. Organizations within the industry implement those ideologies, and eventually industry functions on a national level. Nations will inevitably be affected by environmental policy. So too, individuals within their respective construction firms will feel the repercussions of rising energy costs.

Increases in population are evidence of this system functioning beyond its intended means (Vitousek et al. 1997; Speth 1989). Figure 2 is an example of a self-reinforcing feedback loop (Meadows 2008), reflecting the behavior of industry as it keeps up with population, technology, and demand. Richard Heinberg illustrates this feedback loop from a broader perspective. Yet, suffice to say the same can be applied to the construction industry as a whole. Beginning with the first step in the cycle, fossil fuel extraction allows for the others to perpetuate. As more energy becomes available via fossil fuel extraction, the construction industry benefits and is able to build, renovate, and continue business as usual. It is in this third step that the construction industry plays its most impactful role as a medium through which the built environment is manipulated for good or bad.

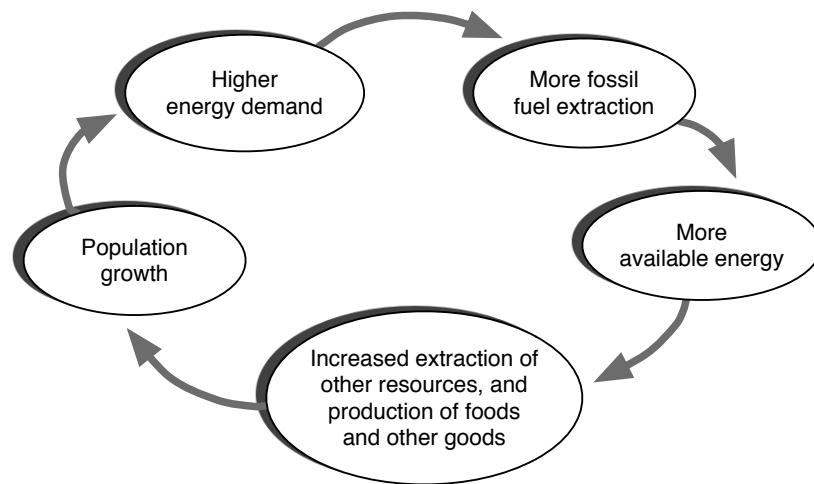


Figure 2. Consumption of fossil fuels cannot continue unabated on a finite planet. Source: Heinberg (2007).

Continuing with systems and feedback dialogue, it is important to also appreciate how energy flows through such a system as throughput. In *Beyond the Limits*, Donella Meadows presents the notion of sources and sinks in relation to a finite planet. To further understand the limits to growth, we must recognize the fundamental issue facing growth itself as the limits to throughput – the flows of energy needed to keep people, cars, and buildings functioning (Meadows 1992). Earth has only a limited supply of energy sources [oil]. Likewise, we are currently grappling with a shortage of sinks to absorb the pollution and waste created as a byproduct of the extraction, manufacturing and use of those sources. To summarize, the sources are declining and the sinks are overflowing (Meadows 1992). Figure 3 offers a clarification of throughput patterns. Throughput seen here is not specific to the construction

industry, but situates the process of energy consumption in perspective given a closed system. Focusing on the bottom three boxes begins to close the gap between what the author later refers to as the economy – sustainability spectrum. In theory, sustainability is often not closely considered within the realm of finance. To the contrary, the bottom three boxes in Figure 3 represent three stages in which the fossil fuel extraction and refinement process require capital. It costs money throughout the entire lifecycle of fossil fuel use – from exploring and discovering new reserves, the production of those reserves, to the capital required to process and resulting combustion [use] of the fuel.

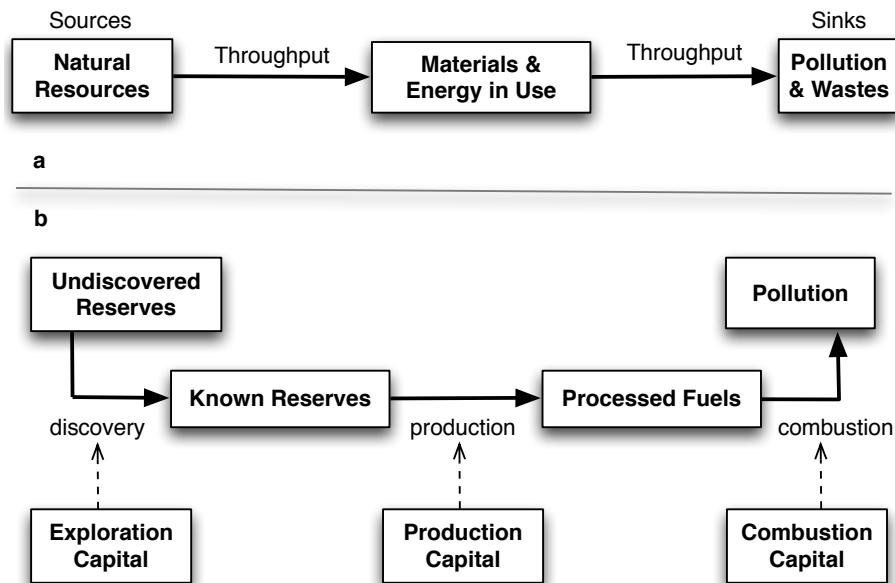


Figure 3. Throughput in terms of sources and sinks. The top (a) depicts usage of materials and energy in terms of a finite system. Below (b) offers a more complete visual of sources and sinks in terms of fossil fuels. Source: Meadows (1992).

Human activity over the last century alone has impacted the Earth more so than any other time in history (Vitousek et al. 1997; Speth, 1989). A result of the appropriately coined “Golden Century of Oil” (Campbell 1991), there exists a current lack of awareness within the construction industry of not only its myriad of ecological impacts, but more importantly what the industry itself will look like in a future host to ever-increasing fuel costs. The supply of conventional oil [used for fuel] will soon be unable to keep up with demand (Campbell C. and Laherrere J. 1998). The key players in the construction industry, namely general contractors and construction managers alike, may not be prepared to handle a drastic shift in the way materials are shipped,

nor are their organizations equipped to successfully manage valuable assets into a new economic landscape.

In the 2007 Integrated Project Delivery (IPD) Guide, the American Institute of Architects called attention to the construction industry's energy consumption habits while fostering 30% waste in the US alone. A US Bureau of Labor Statistics study shows construction decreasing in productivity since 1964 (AIA 2007).

Robert Mabro (2006) speculates what the twenty first century will look like with limited oil. Speaking to transportation specifically: "...oil continues to dominate in a sector which is rightly considered as the network of blood vessels of the economic organism". What will become of entire industries that depend on transportation when those vessels are restricted? Heinberg uses another vivid analogy: "Human societies, like ecosystems, are fundamentally just energy processing systems. With the Industrial Revolution, human beings discovered an energy subsidy like no species has ever found before in the history of our planet" (Ross 2004). The challenge to the construction industry is this: how will industry adapt to a supply and demand economy after oil relinquishes control over progress and energy becomes more expensive each passing day? As James Kunstler so eloquently put it, "the cheap fossil fuels fiesta is ending" (Kunstler 2005). The "Energy Descent Economy" has begun (Morris 2007).

It is the author's conviction that today's construction managers are not apt to deal with the impact peak oil will have on the entire architectural, engineering and construction (AEC) industry. At least, no formal research exists that highlights this lack of preparation for managing in the construction industry beyond what is readily accessible as energy sources, and furthermore what is readily available as tools, frameworks or other methods of preparing those industry leaders. It is now only the most foolish of company directors that ignore the issue of energy efficiency and all the associated impacts (Reeves 2006). The construction industry's focus is the pavement on which it walks, not on the cliff looming in the distance.

Background

Oil is a finite resource. The fact that there is only so much of it available in the world, and that once used, it is gone forever, is rarely discussed in the media and often denied outright (McQuaig 2006). In order to put this into perspective, a brief overview of fossil fuel's short life above the surface is best shown in a timeline, seen in Figure 4 below.

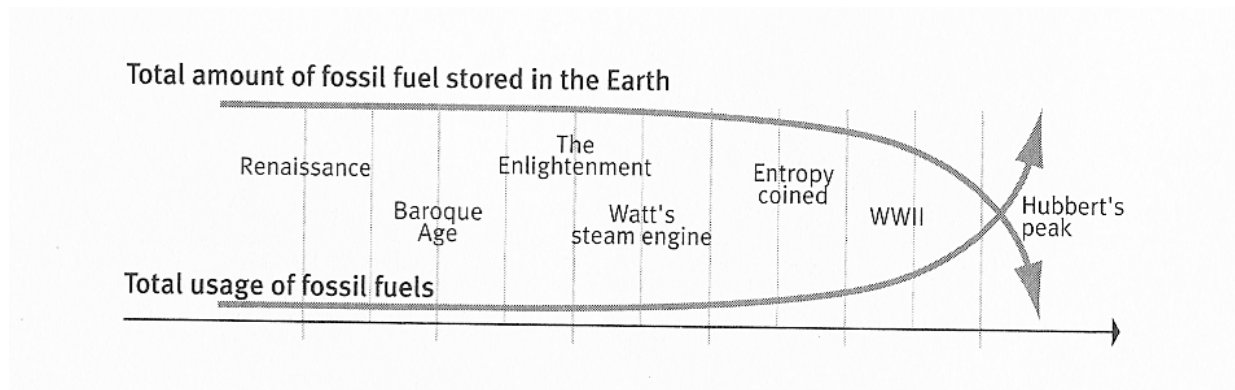


Figure 4. Hubbert's Peak preceded by an aggressive, albeit brief use of fossil fuels over time.
Source: Goodstein (2005).

In the 1950s, the United States was the world's leading producer of oil (Kunstler 2005; Goodstein 2004). Marion King Hubbert was a geoscientist from Texas, worked with Shell Oil Company, and was the first to present an intuitive theory of what is now understood as peak oil in 1956 to the American Petroleum Institute (Hubbert 1956). Hubbert observed the production curve over time in a known oil province. Starting from zero, production grows over time until it peaks when half of existing recoverable resources have been extracted. At this stage, production tends to decline at the same rate at which it grew (Maugeri 2006). Thus, we have the famed Hubbert model seen as a traditional bell curve in Figure 5 as the first of the peak oil ideologies.

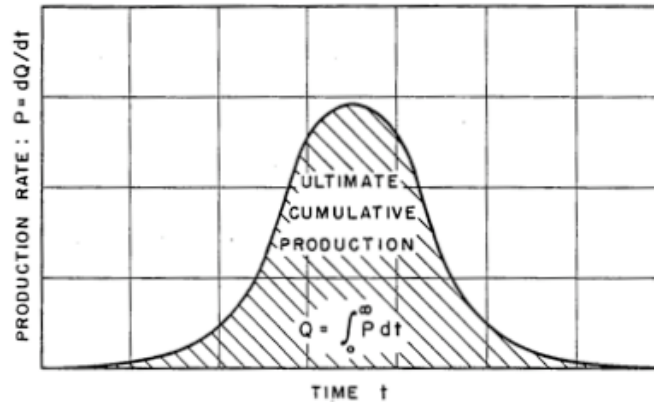


Figure 5. The original Hubbert model plots oil production as a bell curve over time in any known province. The above chart includes the mathematical relations involved in the complete cycle of production of any exhaustible resource. Source: Hubbert (1956).

Hubbert predicted that US oil production would peak sometime between 1965 and 1972, based on computer models used in his research on petroleum. The US oil production peak occurred around 1970 (ASPO). This work does not attempt to explicate the multitude of opinions as to whether Hubbert and his successors, supporters and other peak oil theorists are correct in their claims. The author merely holds the Hubbert model as the primary foundation upon which global energy use via fossil fuels has been further explored. As history would ultimately prove, estimating the total remaining oil reserve is not an exact science (Campbell and Laherrere 1998). Peak oil theory is host to a plethora of its own problems as oil production is very complicated in its extraction and refinement processes, figures are based on estimations, and deceit blurs the truth due to the vast amounts of money and political ties associated with the oil industry (Hirsch 2006). And although the construction industry has exhibited potential for the use of renewable energy, the Hubbert model is unwavering when predicting a short lifespan of oil as our main source of fuel. Hard bids driven by corporate profits still maintain precedence above sustainable energy and fuel costs, a paradox that will continue to permeate throughout the construction industry so far as its leaders remain naïve to its significance.

The bulk of the world's oil is believed to have been formed some 90 to 150 million years ago (Vernon C. 2009). Again, because the dates are estimates, different scientists and authors claim a larger window in prehistoric time (Kunstler 2005; McQuaig 2006) as far reaching as 65 to 300 million years ago. Organic matter, namely algae from decayed plants, was formed in rifts under

lakes during the Mesozoic Era when the earth was covered with swamps, huge trees, and ferns (McQuaig 2006). The dead plant matter, called kerogen, was eventually subject to tectonic shifts and plate movement to depths between 7,500 and 15,000 feet. This depth has since been referred to as the “oil window” (Kunstler 2005).

It was not until recently that mankind was able to exploit fossil fuels for energy. From oil’s first appearance in an American well in Titusville, Pennsylvania in 1859 to Los Angeles basins in the 1920s (Image 1), the oil industry has experienced unprecedented growth and expansion. And in this short window of time, less than 200 years, the industry has found (but not extracted) about 90 percent of it (McQuaig 2006).

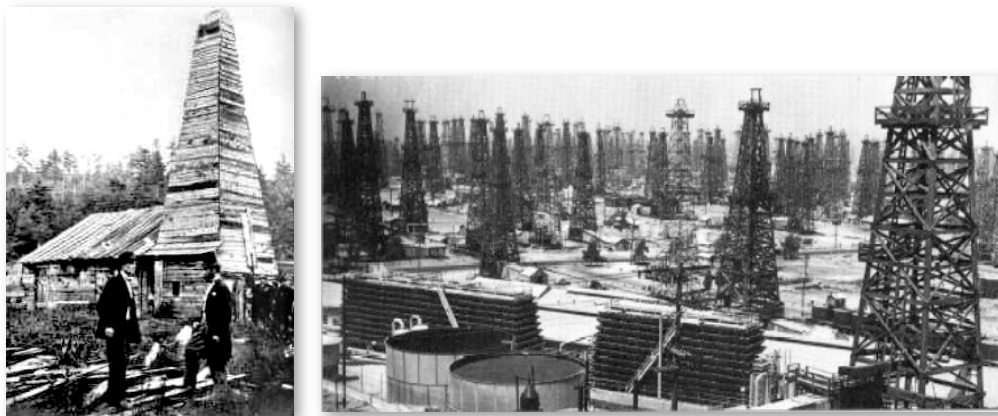


Image 1. The world’s first commercial oil well in Titusville, Pennsylvania in 1859 (left), and a Los Angeles oil basin during the 1920s (right). Source: Campbell and Laherrere (1998).

Organizations of all corporate stature large or small invested in the construction industry should by now be aware of fluctuating fuel costs. Yet most organizations have not embraced the necessary changes in top-down management that promotes sustainable business practices and since moved away from placing design over constructability (AIA 1998). So too, architects have a key role to play in this paradigm shift. This research refrains from exploring the relationship between architects and contractors, but instead considers the influence the design community has within the construction industry as a whole (Krier L. 2009). Input from architects was not directly sought for this initial step in applying peak oil to the architectural, engineering, and construction (AEC) industry. However, future research certainly allows for this work, and in particular the survey, to be adjusted to cater to designers’ influence and perception of peak oil’s impact within the industry. More detail can be found in the future research section of this

paper. Like construction managers, architects must make decisions based on an economy sensitive to finite resources, e.g. fuel. When the world runs completely out of oil is not the most important question. Of greater significance is how industry will react when production begins to taper off (Campbell C. and Laherrere J. 1998).

Economy of extraction is defined by a greater input of both energy and money to extract oil from various depths underground. Colin Campbell summarized the premise of oil economy by citing a limited amount of crude oil in the world (McQuaig 2006), and logically the deeper that oil is, the more difficult it is to attain. The oil closer to the surface, known as light oil, is easily pumped directly from the ground. It takes more advanced technology and thus more energy to extract the oil held deep within pockets of oil sand deposits, known as heavy oil. In essence, heavy oil is mined and the oil is extracted from the ore rather than just pumped out of the ground (Goodstein 2004). Peak oil deniers and doubters rest on the hopes of new discoveries. These new discoveries continue to appear, but certainly not without conflict. Economy of extraction dictates that while additional technology and refinement processes are apparent at these provinces, significantly more carbon dioxide is emitted as a result of the immense energy input needed to extract the same amount of light oil, in conjunction with a net energy loss over longer periods of time. Canada's tar sand deposits are the latest of these new discoveries thought to provide relief from peak oil (Potter, M. 2010; Macalister, T. 2010; Vernon, C. 2009). As Americans continue to consume fuel at five times the average per capita rate of the rest of the world (Goodstein 2004), the American construction industry is not immune to the consequences. This work however, is not focused on any one nation in particular (Hertwich and Peters 2009) but has begun assimilation of a construction management best practice framework catering to top executives with respect to peak oil.

Construction Today

Congruent with the implications of peak oil, this paper must also take into consideration the traditional management styles of construction and how its leaders have ushered in modern advancements in means and methods to change the built environment we see today. This work ultimately seeks to find the point at which executives in the construction industry prepare themselves and their organizations for a post-peak oil industry. As stated earlier, the term

leadership offers ample room for interpretation. Therefore, predominant themes in modern construction management are used in lieu of leadership and any notion of decision-making – themes capturing the attributes of both. The outcome here is not prescriptive in nature, but is meant to draw attention to key threats in corporate business plans embraced by the very stakeholders who envision them. The question this research attempts to answer is what connections can be made between scientific data supporting peak oil and the construction industry's traditionally held best practices? Furthermore, this work serves as somewhat of a compass to guide future research in exploring specifics within that question, e.g. peak oil and construction management.

Taxonomy of management styles within the construction industry occurs on a high level, incorporating the more publicized and widely embraced best practices over the last several decades: scheduling, change orders, profit margins, payroll, etc. This is due to the fact that more and more companies are changing the way data is stored and information is shared amidst the aforementioned Information Revolution (Brynjolfsson and Hitt 2000). Thus, for the purpose of this research, simplicity of themes means understanding their meaning. Additionally, what are owners doing to stay proactive in such a temperamental economy? Investment in Information Technology (IT) has become an indispensable piece in the modern corporate repertoire, demonstrated by a recent Lend Lease Corporation IT overhaul of 40 core management processes (Hamblen 2004). Technology is paramount in key decision-making processes, and it is yet to be determined how IT will respond to a more volatile market deprived of its lifeblood: oil. More insight as to how technology influences corporate policy as it relates to peak oil can be found in future research.

Systems theory fosters the understanding of how individual elements are interconnected by a larger purpose within a given system (Meadows 2008). In this case, it is important for business leaders to acknowledge that while decisions made on a localized and immediate level are easiest to implement, those same companies are part of a larger system of entities that together make up the construction industry. That very system, like all others, will certainly be subject to the repercussions of a peak oil economy. The behavior of a system cannot be known just by knowing the elements of which the system is made (Meadows 2008). Put into context: the

construction industry is well aware of global warming, but its behavior suggests it remains overwhelmingly naive to peak oil.

Existing Frameworks

Tier 4

Not all is bad in the construction industry, however. Current policies are in use today reversing the trends in energy consumption and emissions. Tier 4 is one model example aimed at reducing emissions from non-road diesel engines. EPA estimates that by 2030, controlling these emissions would annually prevent 12,000 premature deaths, 8,900 hospitalizations, and one million workdays lost (EPA 2010).

Tier 4 is just one of several policies that the global construction industry embraces to counter the consequences of an impending peak oil economy. The Renewable Fuel Standard (RFS), another EPA policy implemented in 2005, aims to ensure that all fuels sold in the United States used for transportation have a minimum volume of renewable fuel. California has utilized its own clean air act to mitigate air pollution via California Air Resources Board (CARB). Through this organization, one state's initiative to better control carbon emissions from transportation, improve use of diesel, and enforce corporate regulations can serve as a model for entire industry-wide adoption (CARB 2010).

The Natural Step

This work shares a similar motive with that of The Natural Step (TNS), a framework designed to provide a compass for strategic direction among those who adopt its principles (Broman et al. 2000). Those principles are based on the ideas of simplicity and sustainability. Like TNS, this work is meant to provide business leaders and managers with a clear understanding of how economic behavior is interdependent with environmental systems – specifically in terms of peak oil. This work, like TNS, does not prescribe detailed actions as part of its objectives. The purpose is to reveal potential threats to current business models by thinking about how that same business will/can operate in the future. The survey was designed to produce high-level points of interest in industry perspective that support a gap between peak oil and traditional best practice. TNS framework guides corporations by 1) visualizing a means to achieve business goals

more sustainably, 2) understanding how economic, environmental and social systems are interdependent and how to use this understanding to drive business strategies that will lead to a competitive advantage, and 3) using the proven, science-based framework to perform a gap analysis through the lens of sustainability (TNS 2010). And while TNS is scientifically supported and well researched for broad adaptation, this work marks the birth of further organizational behavior studies relevant to the construction industry in terms of peak oil.

It is with a clear understanding of sustainability that TNS operates. The Natural Step framework embodies four main system conditions of sustainability that govern our planet as a system, and further provide a frame to achieve a desired goal. By placing a *not* in front of these mechanisms we get the system conditions of sustainability (Broman et al. 2000):

1	In order for a society to be sustainable, nature's functions and diversity are not systematically subject to increasing concentrations of substances extracted from the earth's crust.
2	In order for a society to be sustainable, nature's functions and diversity are not systematically subject to increasing concentrations of substances produced by society.
3	In order for a society to be sustainable, nature's functions and diversity are not systematically impoverished by over harvesting or other forms of ecosystem manipulation.
4	In a sustainable society resources are used fairly and efficiently in order to meet basic human needs globally.

For purposes of this research, the author does not promote these conditions as paramount, nor are they dismissed entirely, but acknowledged as viable benchmarks for which companies can attain sustainable best practices within their own field. Again, the foundation of this work is to be used through a lens of peak oil specifically, not sustainability in general.

The Natural Step uses a compelling metaphor to summarize the nature of supply and demand within our planetary system. Walls of a funnel (Figure 6) represent the supply of natural resources and our daily use of those resources. TNS funnel is presented here because it is favorable to this work as a visualization of how peak oil can hamper the functionality of the construction industry, among others. Think of oil as the blood that supports a very intricate

system, and as stated by Robert Mabro earlier (Mabro 2006), the supply chain will react according to those constricted blood vessels that support it.

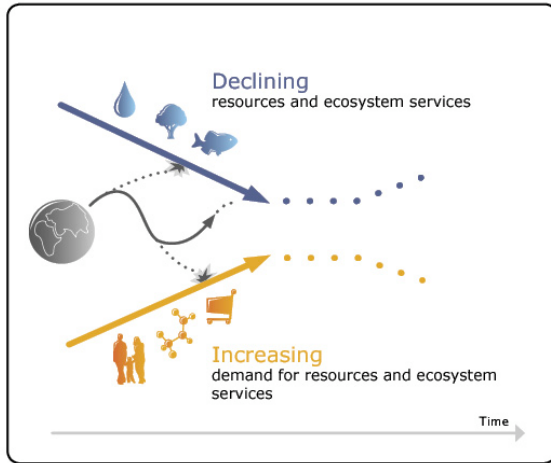


Figure 6. The idea of supply and demand as a funnel, from which the construction industry can visualize strategic business practices to avoid ‘crashing’ into the walls. Source: TNS (2010).

ISO 14000

Skanska is among a sizable group of construction firms that have adopted another environmental management system (EMS) in use across the world since 1996, the ISO 14000 series of environmental regulations (Valdez and Chini 2002). The International Organization for Standardization (ISO) enables a consensus to be reached on solutions that meet both the requirements of business and the broader needs of society (ISO 2010). Companies can use an EMS to look introspectively in two ways: 1) provide assurance to management that it is in control of the organizational processes and activities having an impact on the environment, and 2) assure employees that they are working for an environmentally responsible organization (ISO 2010). ISO 14000 is yet another example of the tools the construction industry currently uses to mitigate its myriad of negative impacts on the environment.

Lifecycle cost analyses are also in use in facility planning and equipment management throughout the industry. A life cycle cost analysis (LCCA) is an invaluable tool when considering the overall long term cost of a piece of equipment and justifying individual operations of a given building. In many respects, the LCCA accounts for energy costs in terms of fuel, electricity or other means of powering a facility. However, this work is more specific in its focus on oil as the

sole contributor of cost. Nevertheless, a cost-benefit analysis of the building over the course of its intended lifetime is critical where sustainability is practiced.

Objectives

Those who have the largest influence on the direction the construction industry takes today do not typically possess the ability to maneuver entire organizations in preparation for a new economic climate foreshadowed by peak oil theory. Many companies are currently struggling to win bids and make payroll, much less concerning themselves with problems of the future. Therefore, the objective of this work is close somewhat of an abstract gap in management practices as they relate to a peak oil economy.

There exists a need for peak oil to be presented in a context relevant to the construction industry. If the validity and success of an industry accounting for roughly 4% of the U.S. GDP (Lindberg and Monaldo 2008) is to embody true sustainability, its decision makers must be made aware of inevitable implication of their actions. In a basic address, to quote Marshall Goldsmith, “what got you here won’t get you there” (Goldsmith 2007). The corporate landscape has evolved from mundane white-collar repetitive tasks to a burgeoning IT-dominated hypersensitive economy. The construction industry echoed with its own delta in the form of faster delivery of goods and services, saving time and money as a result. A concise, functional survey has exposed much of this uncertainty about peak oil and what it means for the construction industry.

Construction managers, general contractors, owners of capital projects and entrepreneurs all have a stake in the ideology that shapes the industry. Its supply chain, materials, and fiscal behavior are all subject to peak oil. The development of a survey will enable those stakeholders within the industry to appropriately manage companies into a prosperous, sustainable future. The components of such a tool will have to capture the true essence and reality of the AEC industry and its subsectors, e.g. civil, transportation, commercial, etc.

The terms construction manager, general contractor and program manager are used in a generic sense to encompass likely stakeholders in the construction industry. Small startup business

owners have a role to play, albeit more focused and localized, just as the top players such as Bechtel, Fluor, and the Turner Corporation (ENR 2009a). The outcome of this work is a survey and its results addressing high-level key management issues relative to peak oil. Companies can then use this information introspectively in order to adjust business models appropriately.

The objective here was to triage the construction industry by surveying stakeholders within the construction industry. This was done through an online survey with two main foci. The first is peak oil; it is necessary to gauge the level of understanding of peak oil among the aforementioned stakeholders within the construction industry. Second, well-documented best practices maintained in the construction industry, herein referred to as themes, are to be cross-referenced with peak oil. The outcome is a gap analysis capable of identifying potential weaknesses and pitfalls associated with current business models and trends.

A snapshot of the industry is presented, gathered from a questionnaire used to compare responses collected from a survey population. Construction management themes are presented alongside peak oil theory context. In doing so, the results offer insight into the level of preparedness among the respondents. In other words, we are able to discern, from a high level, what the industry thinks of peak oil and how it is perceived to impact the construction site of the future. In an effort to avoid a linear process of thought in assuming all management themes are directly impacted by peak oil, it is necessary to acknowledge the themes as independent management concepts. This work takes the conscience step in applying peak oil to each theme in order to organize assumptions drawn from the survey findings. This construction management theme matrix is presented in more detail in the following methodology and outcome sections of this paper.

Methodology

This research converges the heavily publicized energy dilemma with the low profile of its chief contributors, vis-à-vis the construction industry. Specifically, the author implemented a brief survey meant to gauge the preparedness of the construction industry's key stakeholders: contractors, project managers, entrepreneurs, etc. In the approach to developing the survey, the author maintained a focus on the research question, and how can future research use the

survey findings to further explore peak oil in the construction industry. A solution to this emerging energy crisis is not feasible within the scope of work, though further research into collective organizational psyche could reveal interesting behavioral traits that reveal an industry's perception and anticipation of such a global crisis.

Peak oil maintains the realization of industry's infrastructure reliant upon a finite source of energy. The outset of this research saw management and construction as separate entities from which a relationship could be examined in the context of peak oil theory. Each taken as individual components of the three main foci as seen in Figure 7 produced too vague of a scope for this work. Ultimately, *leadership* and *decision-making* are of another topic entirely, from which this research can only draw trivial conclusions. As a result, management and construction were later combined to capture the essence of the construction industry in its entirety. This inclusion will therefore encompass traditional best practices in the construction industry, herein referred to as themes.

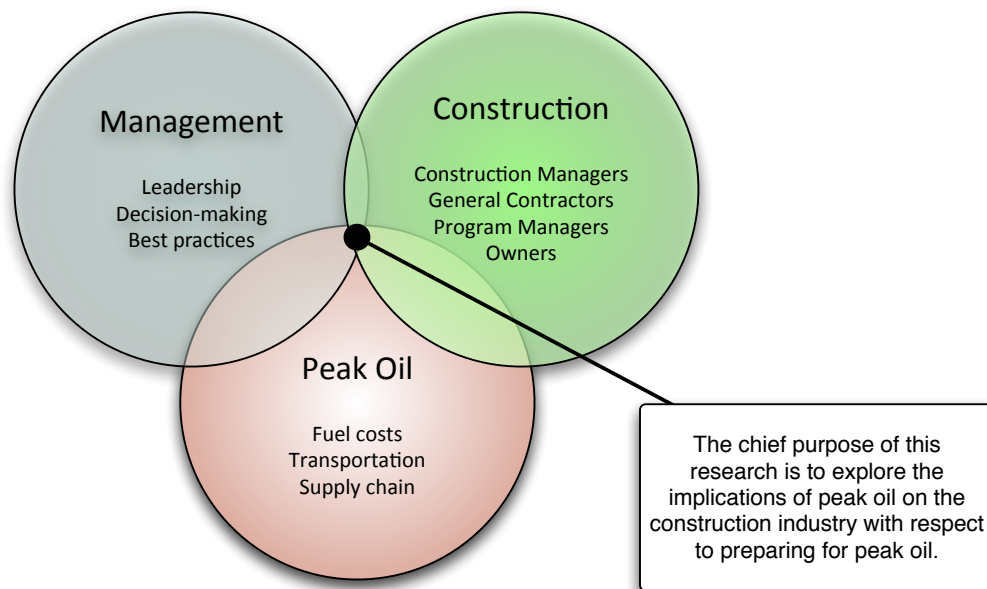


Figure 7. This image captures the initial aim of the research: a concentration of the relationship between modern construction managers and current best practices in relation to peak oil. In other words, the intention of the author was to highlight the potential weaknesses of the construction industry regarding fluctuating energy costs via industry leaders' responses to a preparedness survey.

The diagram was then edited to foster a more specific understanding of the construction industry. By replacing ambiguous flag words (e.g. leadership) with themes more so relative to the construction industry, this work immediately benefited from another tool that supports its reach into the realm of corporate management jargon. The subsequent organization of themes is detailed in the methodology section of this paper as the Construction Management Theme Matrix. Figure 8 is a more concise version of the same idea. It benefits from a two-way flow of information between peak oil and the construction industry. The elements within each focus share in a cause and effect relationship, allowing for direct comparison between various combinations. For example, this survey looks at traditional construction scheduling techniques by means of rising costs of transportation. How will industry executives change their scheduling tactics in ten years when a fleet of trucks is no longer a viable option with growing overhead? Conversely, how will the relationship between the cost of materials impact total quality management (TQM), and how will variable supply chain management affect jobsite safety? This survey is designed to bring these questions to light.

The construction industry as seen in Figure 8 contains six construction management themes that are the result of a literature review of construction management sources. While the six themes contained within the realm of the construction industry seen in Figure 8 and used for the survey are not collectively exhaustive, the author holds these to represent a valuable overview, although not comprehensive. These themes are the elements with which peak oil is applied to create a gap analysis, with each theme offering insight to the preparation of the construction industry as seen from survey respondents.

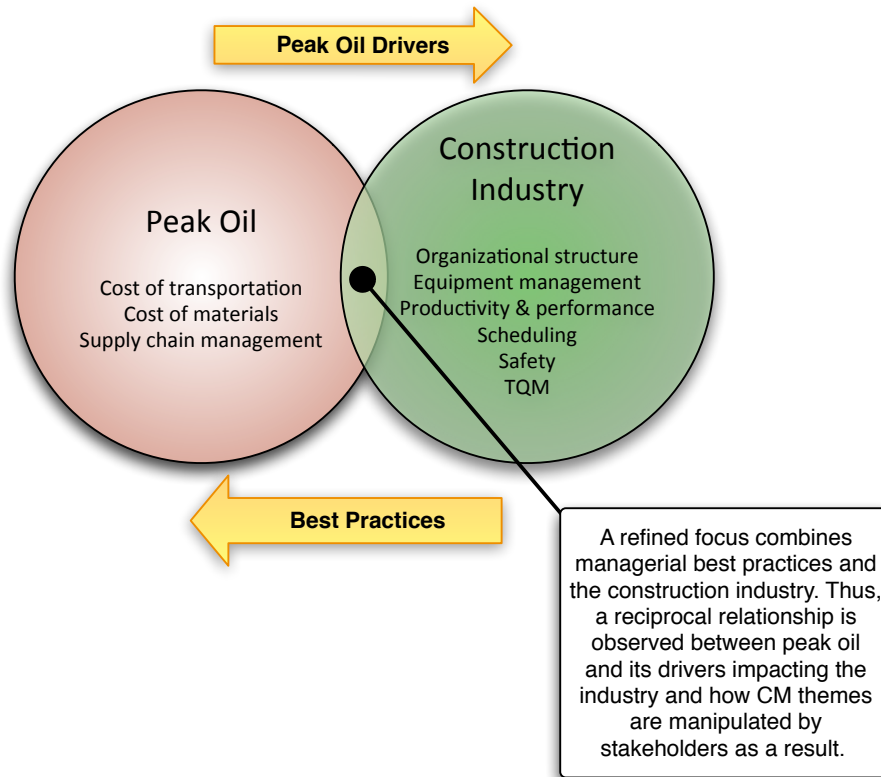


Figure 8. The approach taken to develop an organizational preparedness survey. Peak oil and the construction industry maintain direct influence over one another, detailed further by these sub categorical themes and drivers for change.

Developing a survey meant to reflect the thoughts and instincts of industry stakeholders requires the input of those stakeholders up front. The scope of this work includes a concise survey to determine the key managerial facets facing construction leaders today. A literature review collected the predominant issues or themes from various construction management sources. These are presented as themes and their subcategories in Table 1. Of these, organizational structure, construction scheduling techniques, productivity and performance, health and safety, total quality management (TQM), and equipment management and maintenance were used for the survey as flagship themes. Further methodologies are expanded upon in the survey section that follows.

The task of assembling data to support the two main foci of this work meant first collecting information on peak oil. More important than simply reviewing the latest scientific research from geologists and statistics from the Department of Energy and oil companies was the responsibility to avoid overly speculative work of opinion, as peak oil is host to a plethora of theorists and refutes. The author reviewed ample literature relating to the oil industry, modern economy and its energy habits, and an underlying foundation was instilled that defined the origins of oil as a fossil fuel. It took months of extensive background research to develop a solid foundation of what peak oil is, and begin to speculate how peak oil may in fact impact entire industries. Focus then shifted to the construction industry specifically. Of importance was determining how to approach creating a means to survey the industry's existing knowledge of peak oil in a way that creates avenues for further exploration.

Table 1. Construction management themes and their subcategories.

Theme	Subcategories	Source
Scheduling	Critical Path Method, resource loading, linear scheduling, Gantt chart	Nunnally, S.W. (2001)
Economics	equipment costs, decision to rent - lease - buy	
Contract	bid, plans and specifications	
Safety & Health	OSHA, safety programs, environmental health (off and on the job site), equipment maintenance	
Productivity & Performance	work improvement, computers (IT)	
Organizational Structure	organizational needs, size of firm, executive roles and responsibilities	Volpe, S.P. (1991)
Financial Capabilities	capital, line(s) of credit, bonds, cash flow, joint ventures	
Estimating	bids, estimates, specifications, quantity takeoffs	
Contracts	lump sum, cost plus, GMP, CM, unit price, design-build, IPD	
Accounting	cost-keeping systems, field records, cost to date, balance to complete, change orders	
Equipment	own, lease, buy decision, maintenance	
Safety	safety programs, cost of safety, OSHA, insurance	
Marketing	proposals, public relations	
Organizational Structure	objective, characteristics of organization, specialization, hierarchy, centralization vs.. decentralization	Fryer, B. (1985)
Performance	employees, subcontractors, feedback, motivation,	
Managing Change	recognizing need for change, implementing change, corporate planning, marketing, organizational development	
Health & Safety	risk mitigation, health hazards, responsibility of individual vs.. organization, PPE	
Value Management	function analysis, cost	McGeorge, D and Palmer A. (1997)
Constructability	design, construction	
Benchmarking	best practice, organizational improvement, competitive comparison	
Total Quality Management	customer satisfaction, total systems approach, continuous improvement	
Organizational Structure	company objectives, size of company, training	Harris, F. (1977)
Marketing	customer needs, marketing strategy, SWOT analysis, promotions	
Bidding	bid strategy, estimating	
Cash Flows	forecasting, IT	
Economics	interest, profitability, inflation, estimating	

A literature review of various sources, mainly books on construction management, produced many managerial elements throughout the industry that were categorized into the CM Themes seen in the far left column of Table 1. With subcategories that offer more detail and support the theme, further refinement was needed to meet the succinctness required of a survey meant for an executive audience. Admittedly, the CM Themes used herein have potential to miss some intricacies involved in the day-to-day construction management. Each theme is capable of further scrutiny because this survey is targeting organizational behavior from the individual's perspective, and one individual may perceive one CM Theme more important than another. Yet, this work is using a literature review to provide the flagship themes. Other sources can lead to other findings, but the author believes any other management themes will be found to be similar in nature to those presented in Table 1.

The next task was the organization of peak oil background information and construction management literature into a survey that captures the essence of both. The survey questions had to capture the two foci, peak oil and construction management, and follow in a structure that presented peak oil and energy use first, followed by construction management concepts and themes. Rearranging the questions with construction management preceding peak oil was not considered, but could produce different results.

The Survey

The Virginia Tech Industry Board was of great use in administering the online survey. The Industry Board is comprised of construction industry executives, business owners and other stakeholders – a valuable cross section of the AEC industry. By utilizing this pool of respondents, this research benefits from a concentrated snapshot of industry leaders of all ages and backgrounds. The author, having met some of the respondents through Virginia Tech, is somewhat familiar with the demographic personally, affirming a range in age and background. Of those surveyed, entrepreneurs, contractors and construction managers of various capacity and position were included. This made it possible to cast a broad net to capture the most feedback relative to peak oil in construction.

Developing the actual survey meant superimposing peak oil theory over the traditional construction management (CM) themes seen in Table 1. The resulting composition was two-fold: (a) assessing respondents' knowledge of peak oil and (b) its ramifications within the construction industry. The second was derived from the selected CM themes. In soliciting participation for the survey, an email with the link to the online survey was sent to the Industry Board. The email can be found in Appendix B. Survey questions are presented in Appendix C, with the following peak oil primer preceding:

Peak oil theory rests on the simple premise that the energy we use to fuel entire industries is finite in nature. As we produce less oil in the future, how will this impact the construction landscape? This survey is meant to extrapolate a gap analysis of the best practices in the construction industry in terms of peak oil.

To elucidate the survey, word choice, question arrangement, and the overall composition of the survey throughout its development is provided with references to individual questions in parenthesis. The survey was arranged in such a way to extract key pieces of information from respondents. As previously mentioned, peak oil and construction management themes are chief concepts that the survey absolutely must capture. As the survey was further developed, four categories emerged that clarified other important perspectives relative to the two chief concepts (Figure 9). First, for the survey to establish any topical grounds within peak oil theory, a distinction must be made between peak oil and other concepts of a similar vein: climate change, global warming, etc. There exists a clear difference in vocabulary that if misused could skew the results of the survey. Therefore, along with acknowledgement of the type of work preformed by all participants [stakeholders] (2), questions appear at the forefront of the survey gauging the individual's perception of peak oil, climate change, and global warming (9,10). It is also important to understand the extent to which their particular business contributes to those factors (peak oil, global warming, etc.) in the eyes of each participant (3,4,5).

The third of these subsections is labeled innovativeness, as it refers to any preemptive efforts to mitigate rising energy costs. The survey offers respondents an opportunity to explain what actions are currently being taken to control costs through innovation or other means (18, 19). Ultimately, what was intended to capture a sense of innovation is reduced to simple cost reduction by means of transportation restrictions and a more responsible use of energy. This is interesting because while the construction industry can be a platform for innovation (Slaughter

1998; Nam C. and Tatum, C. 1997), the responses were held to transportation alone, to include telecommuting as well.

The fourth subcategory of survey arrangement is the comparison of peak oil to the actual construction management themes from Table 1. It is here that questions are seeking the *how* from stakeholders (20-25), whereas the innovativeness questions focus on the *what*. Similarly, questions pertaining to the stakeholder are meant to define *who* (1,2). Four subcategories within two larger concepts suffice in capturing the central idea of this research. The apparent brevity of this survey is necessary. Given the deliberate restraint of this work's reach, the survey scratches the proverbial surface, creating guideposts for use in a future survey more comprehensive in scope and depth. This work provides a thorough, albeit nascent view of peak oil's implications within the realm of modern construction capable of much elaboration. Figure 9 illustrates the arrangement of the two main foci of the work, CM Themes and peak oil, along with the four subcategories.

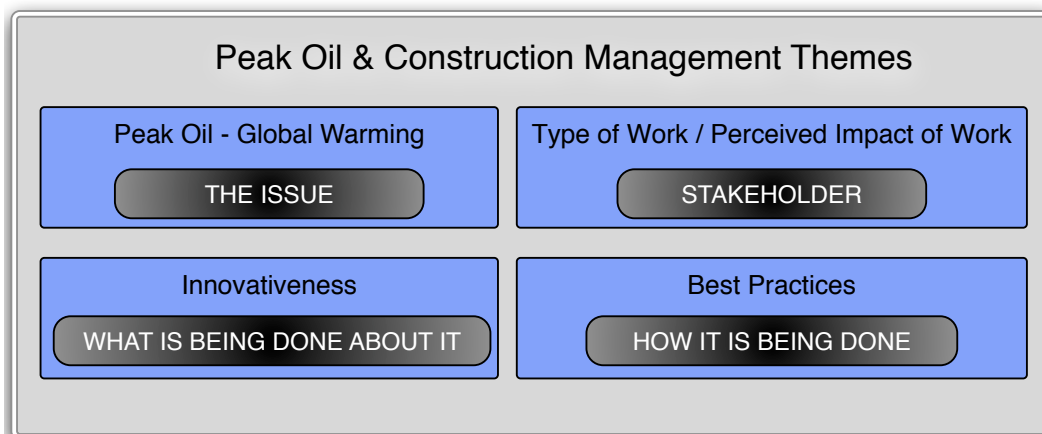


Figure 9. Arrangement of the survey from its two chief concepts Peak Oil and CM Themes to the four subcategories used to organize the desired output of the survey.

The construction site is of particular importance when providing a constant point of reference within the survey. When asked about change given time (15,16,17), participants are asked in terms of a construction site in the most generic sense, including commercial, residential, heavy highway, etc. This provided a constant from which this work can base comparisons of change relative to peak oil. Another point of interest is the time scale that is used when asking about

change. The construction industry is slow to change on a large scale (Reeves 2006). Therefore, a construction site 20 years ago is perceived similarly to that of today. Notwithstanding technological advances previously discussed, construction sites of today look quite the same as those sites did 20 years ago. The question is then posed about what the construction site will look like in 10 years (16), and whether any change therein will be a result of peak oil (17). The majority of survey participants agree that the construction site looked different 20 years ago, and will in fact look and function differently in 10 years compared to today's construction site. The details of these questions are explained in the outcome section.

A Likert scale was used for its simplicity and convenience for 19 out of the total 25 survey questions. The stakeholders (commercial contractors, engineers, entrepreneurs) targeted for this survey do not have much time during workdays to commit to a survey of much length. As a result, a large number of questions were revisited and edited to condense the survey to a total of 25 questions taking no more than 7-10 minutes. Using a Likert scale enables the author to easily compile and compare responses of a similar vein.

A collection of follow up phone calls offered additional insight to the individual's assessment of the construction industry relative to peak oil, discuss primarily through corporate energy costs. Among the focus group was Ken Lanford of Lanford Brothers Company, based in Roanoke, Virginia. Lanford Brothers does highway construction, repair, and road signage projects along the east coast. The work performed is mostly in Virginia, Maryland, and the Carolinas. Their newly finished headquarters is LEED Silver, a testament to Ken Lanford's commitment to a sustainable approach to running a business. Merchants Fixture is a commercial contractor in Richmond, Virginia manufacturing custom fixtures for retail owners. As president, George Wright has valuable thoughts on how his business has survived economic change, much of the dialogue revolving around the rising cost of energy – from acquiring and using raw materials to the energy demanded from labor costs. These two executives were met with in person to gain a more personal feeling for how businesses are using energy, and specifically viewing peak oil. Beyond these two meetings, it would behoove future work in the realm of peak oil in construction to meet with others in various sectors. For example, to meet with urban planners and others in the design community would provide valuable insight to the initial stages of pre-

construction, long before material costs become hindsight and constructability is at the forefront of collaboration.

The construction industry, like all other industries, has undeniably experienced remarkable change in the last century. Much of that change is the result of mankind's capacity to operate more efficiently due to advancements in technology. More globally, however, modern construction exists because of oil. Tantamount to the mere existence of oil is preparation for a time when oil becomes too expensive to extract and we can no longer reap the benefits of such a cheap energy source. The outcomes from the survey results begin to capture the implications of peak oil within the construction industry. The following graphs represent the survey results in order of their appearance, reflected in the survey arrangement discussed previously.

Outcomes and Impacts

Data collection afforded certain observations of the construction industry as a whole, as well as some more keen realizations about individuals' perception of how a given company performs in terms of energy use. Because the survey was developed with brevity and succinctness in mind, its results only reveal so much about corporate behavior and peak oil comprehension.

Nevertheless, the survey discloses that which Figure 8 targets and was the objective of this work: confusion exists where corporate policy and organizational behavior meet peak oil theory and its implications within the construction industry.

The following charts summarize the survey results visually, with an explanation provided to help interpret the responses in terms of this work's thesis.

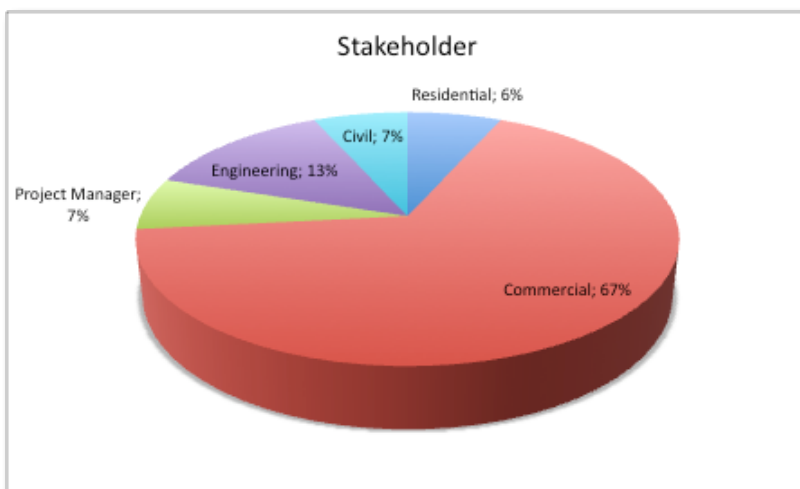


Figure 10. Type of work as a snapshot of the survey participants.

Of the total number of respondents, the majority (67%) are involved with a form of commercial construction. Additionally, among the survey respondents are residential contractors, civil contractors, those who specified themselves as project managers or construction managers, and engineers as well. This survey did not stipulate any clarification of work performed – the author assumes companies did so as a means of distinction within a sector or further specification of a corporate portfolio. Engineering (13%) was second to commercial contracting, seen as complimentary in nature as many commercial firms are now home to in-house engineering and other such services once subcontracted out. These categories were offered to capture the majority of the construction industry stakeholders, with an additional free response option allowing for further clarification.

Although an in-depth analysis of a company's carbon footprint is not within the scope of this work, a high-level interpretation of a given company's carbon emissions is of some value here as it reveals how the individual within the organization perceives their respective company's impact on the environment. It is interesting to note that companies of the same type of work possess varying degrees of perceived carbon emissions. For example, of the commercial contractors who were surveyed, the perceived carbon footprints of these companies range from very low to very high. Figure 11 illustrates the perceived carbon footprint of survey respondents.

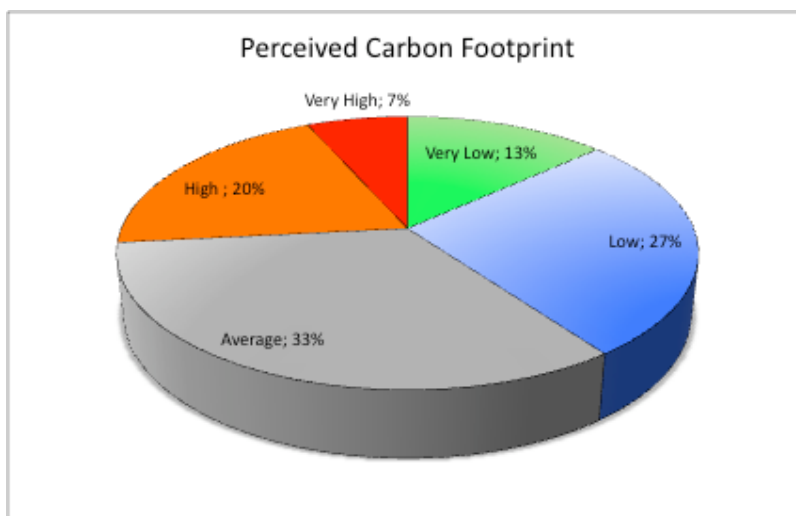


Figure 11. Perceived carbon footprint of survey respondents.

Although size of individual companies was not accounted for, it appears that a vague understanding of an organization's carbon footprint is ubiquitous within the construction industry. The impact this has towards further environmental degradation was not speculated with research relative to peak oil. However, as long as stakeholders remain naive to their carbon footprint – personal or corporate – this behavior ultimately leads to complacency and hinders change to the contrary. Ignorance of environmental impact may promote unsustainable behavior on both individual and organizational levels.

In collecting the data from the survey results, some parallels were made immediately between industry and peak oil. Profits drive decisions due in large part to competition and shareholders' interests. Privately owned companies also concern themselves with similar financial goals and fiscal deadlines. The economic landscape of recent years lends itself to additional stressors contributing to tighter bid margins and smaller budgets. Of the copious number of issues facing construction firms today, the survey results confirm the economy as the highest priority among stakeholders. Other issues were mentioned, including unions and healthcare costs, more easily accessible bank loans, and a depressed private market. Environmental issues were mentioned with no distinct correlation between these environmental issues and the effects organizations such as the United States Green Building Council (USGBC) have on awareness. EPA regulations were also included, reflected in Figure 12 and paired with the mention of environmental issues. A more drastic distinction could be made between issues pertaining to money and those that do not. Of those reflected in Figure 12, *environmental issues* can be considered the sole issue not directly contingent upon monetary measurement. Labor, manufacturing and of course lending concern money. Environmental issues include global warming, climate change, and peak oil, having been clustered together for simplicity. While the argument can be made against this distinction with regard to [EPA] regulations consequently inhibiting traditional behavior and thus creating budgetary changes, the economy and sustainability reside on opposing sides of the construction spectrum.

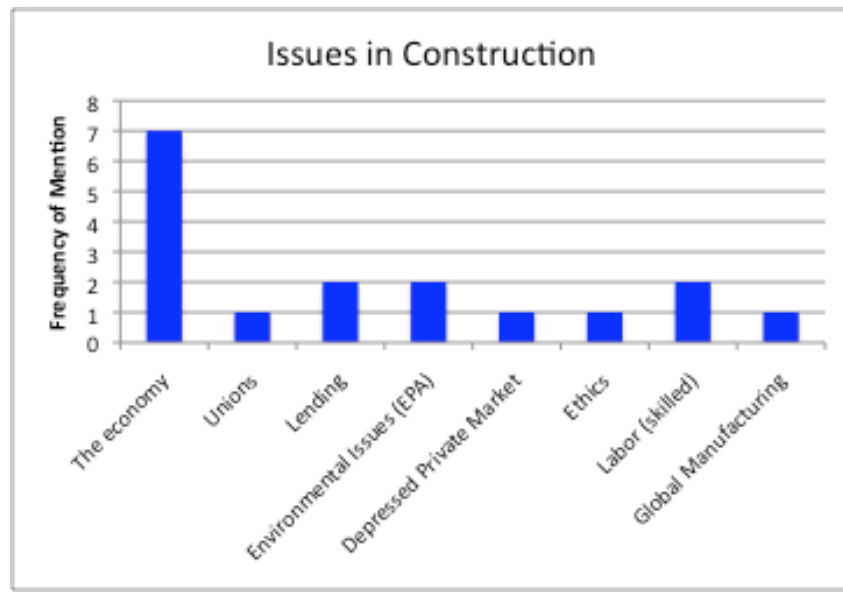


Figure 12. Most important issues facing the construction industry today.

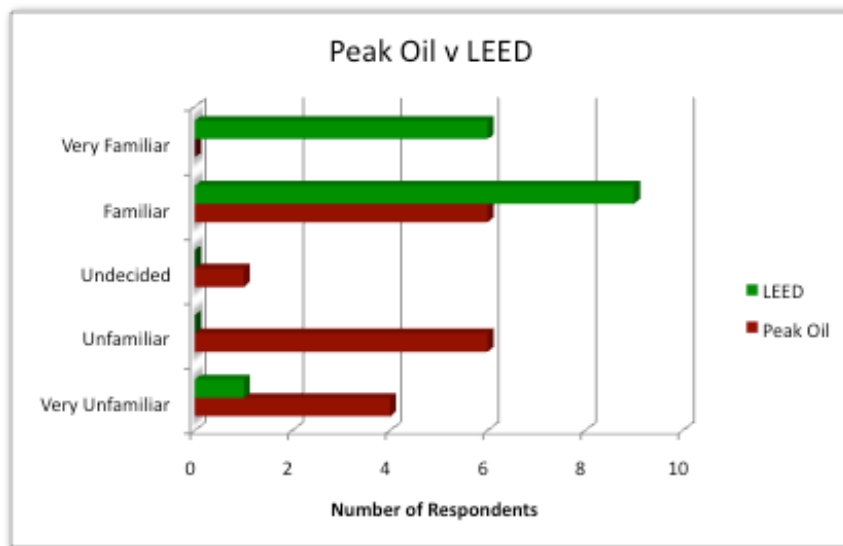


Figure 13. Stakeholders' familiarity of peak oil compared to LEED.

Prior to a comprehensive analysis of the impacts this research has on the construction industry, it is important to first assess the stakeholders' familiarity with peak oil and LEED. The author chose to compare peak oil with LEED because of its accessibility and support from such a reputable organization like USGBC. LEED is advertised, promoted and endorsed across the globe as a popular medium for sustainability. In contrast, peak oil has no endorsements helping promote any message for a cohesive cause or purpose. Far less attention is paid to peak oil, as expressed in Figure 13.

What does this mean for the construction industry? News outlets the world over are capable of reporting unemployment rates and flashing onscreen images of melting icecaps. Peak oil lacks coverage (Figure 14). Global warming and climate change were specifically chosen as choice jargon as references to this dichotomy. Not until very recently have few news outlets begun to disclose relative peak oil theory and share the facts with the public. Even still, these stories lie dormant on back pages of newspapers. Not surprisingly, the construction industry absorbs this available information, or lack thereof, just as Wall Street, Capitol Hill or other collective groups – all part of a larger system. Industry behavior reflects that of the people who constitute it. If the construction industry only knows global warming, its actions remain specific to only that which involves global warming, e.g. carbon emissions. Peak oil is left behind in education, resulting in a lack of preparedness of individuals, organizations, and entire industries.

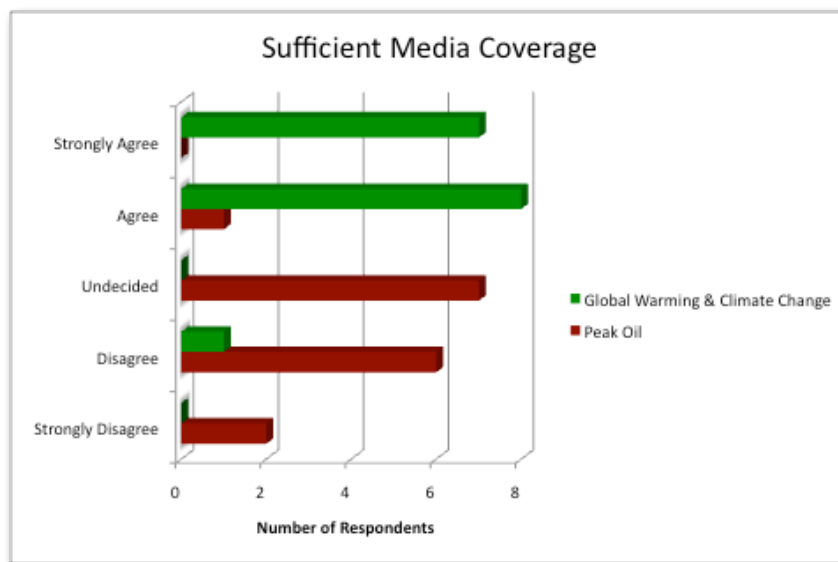


Figure 14. Amount of perceived media coverage for peak oil and global warming, climate change respectively.

Question three of the survey asks the participants about the impact their business has on global warming. The next question asks the impact global warming has on their respective business. The questions aim to gauge the understanding of how business may impact global warming, and in turn see if, at any rate, global warming influences business as usual. The results are shown in Figure 15 below.

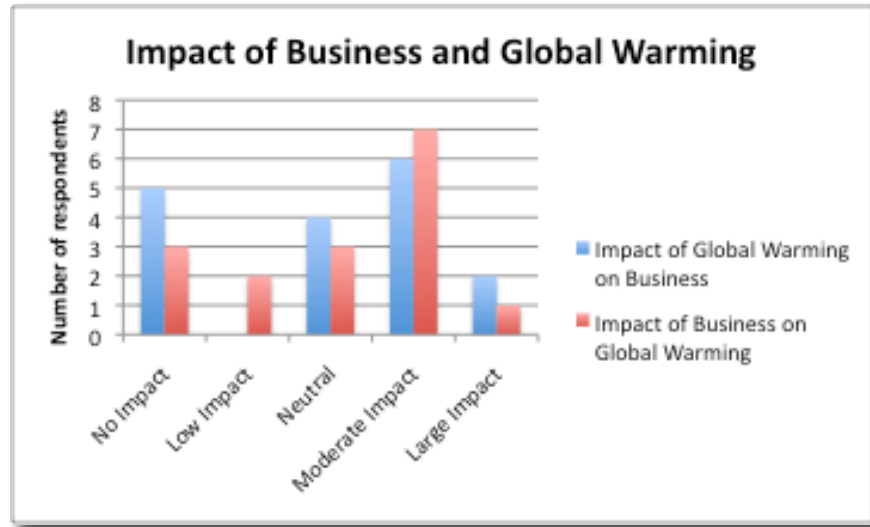


Figure 15. The impact business has on global warming according to individual stakeholders, and how global warming impacts respective businesses.

Labor is exhibited as an important contemporary issue at the forefront of the construction industry in Figure 16. As part of the survey’s goal to deduce different costs for construction organizations, present-day expenses were compared with the anticipated expenses of 10 years. In doing so, the author hoped to use foreshadowing to draw some conclusions about executive mindsets. Foreshadowing is used instead of backcasting here because stakeholders are stating their biggest cost today while using that same contextual information to predict future costs of similar nature. The outcome is labor.

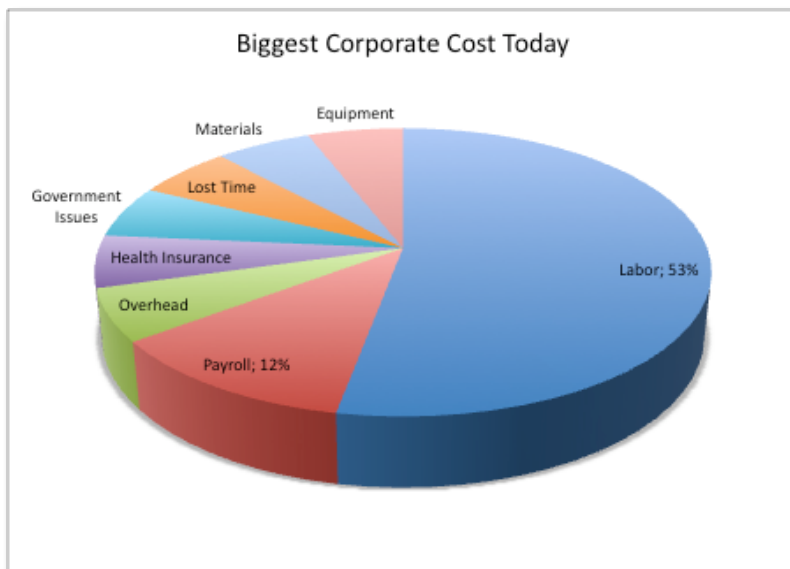


Figure 16. A snapshot of construction firms’ biggest cost today.

Not only do a large number of respondents (roughly 50%) hold labor as a principal cost today, nearly 60% of those surveyed maintain that labor will also be the leading cost for construction firms in 10 years. Payroll was second, among material and equipment costs, each at about 6% of total responses. Figure 17 shows this slight increase in labor as the biggest corporate cost in ten years.

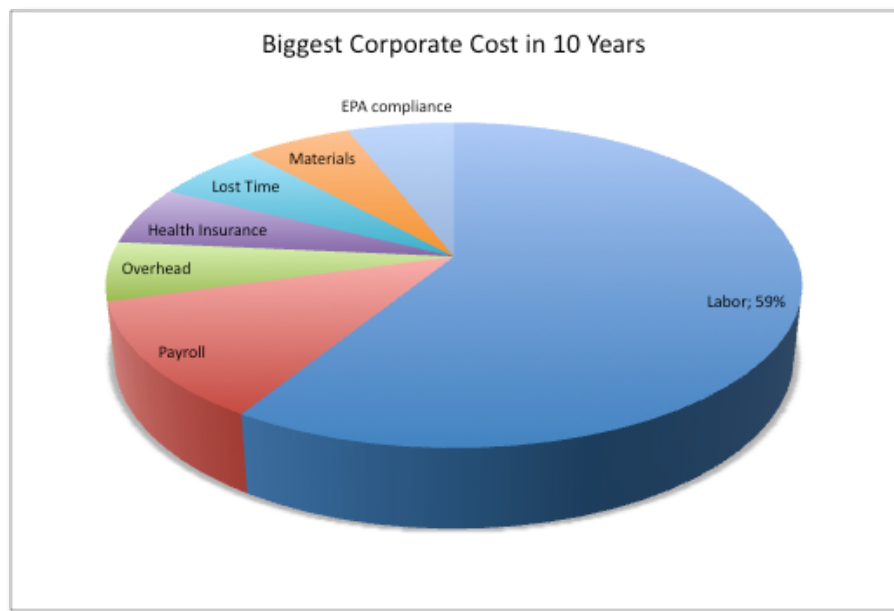


Figure 17. The biggest anticipated corporate cost in 10 years of survey participants.

Stakeholders were asked to briefly explain any measures taken to mitigate the impact of rising energy costs currently have on their business. Resoundingly, the responses involved transportation of some fashion. Whatever the means, construction firms are taking action to control the cost of doing business. It is among the many ways organizations are preparing themselves for a more tenuous fossil fuel economy.

56% of those surveyed agree that peak oil will be a driver for change in the construction industry. What is more surprising is that roughly a quarter (25%) of survey participants are undecided as to whether or not peak oil will provide any change to the construction landscape.

Oil is of limited supply, this we know for certain. However, the consequences of an oil shortage are less evident. In considering the above reaction to peak oil, Figure 18 summarizes the more central theme to this work. This graph serves as one of the central gap analyses meant to provide the foundation for future research, exploring each theme individually in more detail.

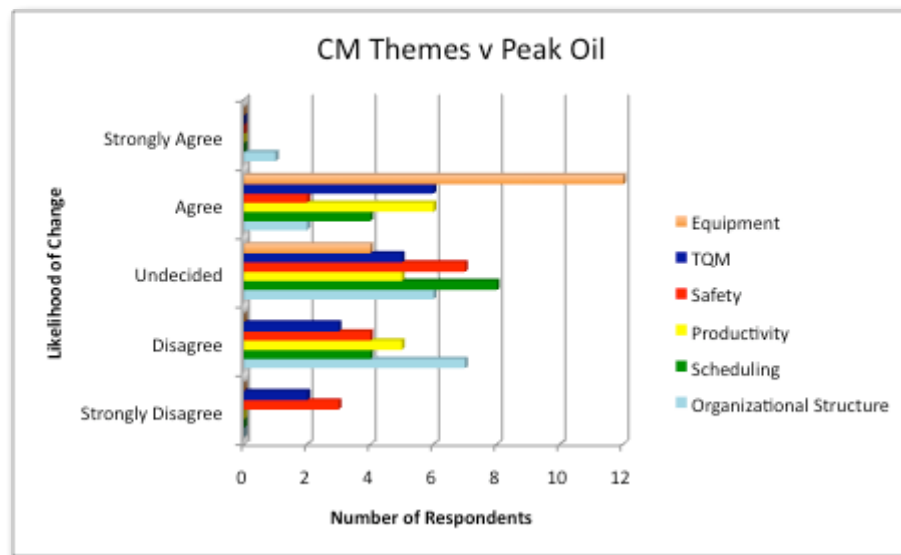


Figure 18. Likelihood of change to construction management themes given peak oil.

Visually, Figure 19 can be dissected into extremes given the Likert scale used in the survey. How strongly any one respondent agrees or disagrees is thus tallied into a bar chart. Prior to analyzing any extremes however, the sheer concentration of any one category's responses is first to be discussed. And as captured in Figure 18, construction organizations hold equipment as the primary theme to see change in light of peak oil.

The scope of this research involves oil as a means for fueling construction equipment. It comes as little surprise that despite any lack of awareness of peak oil or lingering confusion existing in the industry, its stakeholders are cognizant of gasoline and its unpredictable [economic] nature. Innovative companies have begun to ask questions in attempt to solve problems associated with fueling construction equipment. Caterpillar's latest diesel-electric bulldozer is just the beginning. Corporate vehicles are designed as tough-green hybrids. Of course, many of the solutions begin with the manufacturer. The AEC industry is already designing and erecting

sustainable buildings all over the world, each trying to outdo the previous. The need for more sustainable equipment is also apparent, but not yet fully realized among those firms incapable of utilizing new technology at its high cost. Perhaps this will change given time, as more construction equipment is retrofitted with efficient engines burning cleaner fuels. At any rate, the equipment used for years past will no longer suffice – the future of construction will introduce drastic change to equipment manufacturing, management and maintenance.

Safety is another interesting point of agreement among stakeholders. Safety is seen as a construction best practice that is not susceptible to change as the others may be. Although safety shares its varied change potential across the Likert scale as others do, a noticeable number of respondents strongly disagree with peak oil having any impact on construction safety. So out of all the predominant CM themes, safety is perceived to remain immune to peak oil. This is a significant claim in regards to what the construction industry considers most important. In conducting this gap analysis several aspects of corporate strategy have been discussed through a peak oil lens, yet safety continues to be somewhat of a hallmark for the construction industry despite the high risk associated with it. Companies continue to boast clean safety records and strive for accident free projects. This work reaffirms the importance of safety, as it appears most stakeholders believe peak oil will have little to no affect on safety's esteemed reputation.

While few CM best practices reside on the extremes of being strongly agreed or disagreed upon, the majority of themes are clustered in the center of the graph. Subsequently, the question becomes what this means for the construction industry in terms of peak oil. Seeing the responses summarized in Figure 19 as separate colors, one can determine how one theme is skewed for change (agree or disagree). Yet most responses appear unsettled in their claim to change respective themes. In other words, there is still confusion as to whether peak oil will generate change in the construction industry. At least for the CM themes used for this research, stakeholders are relatively undecided on how peak oil will influence scheduling and productivity, among others.

These charts are not an exhaustive insight into specific factors that create change or provide a degree of resiliency to peak oil theory, but function as the first step in conducting a more

comprehensive study of how the construction industry will make decisions based on peak oil in the years to come. Industry's past is well documented. Its future can be forecasted using traditional knowledge and skill sets. The author maintains that using this conventional forecasting approach will not create the much-needed sustainable guidelines for a healthy individual, organization, industry, or planet. This work is intended to be the frame to which a new blank canvas is affixed, and the construction industry can use backcasting to make the proper decisions for a sustainable future. Peak oil was chosen and researched to be a catalyst for change.

Limitations

This work attempts to identify the high-level concepts that potentially show more susceptibility to peak oil. Specifically, the management themes involved cater to the construction industry. For several reasons, this work is limited in its scope and level of detail attainable given the timeframe involved and lack of peak oil in construction-related literature.

Because progress begun at the initial stage of collecting raw data for both peak oil and construction management themes, there was a need to establish a foundation of peak oil more so than management concepts. Nevertheless, a complete lack of literature relating peak oil within the realm of the construction industry created a limitation of reach. The author would have to develop a new idea using a highly debated and consequential topic such as peak oil.

The majority of this work's limitations were generated from the actual comparison between the collective construction management themes and peak oil. The author was limited to a somewhat conceptual approach, reflected in the survey and its results, all of which remain on a high-level and lack a desired depth of research. Future research will allow for the continuation of this work in the extrapolation of the survey, thus collecting more precise data on the influence of peak oil in the construction industry.

Another limitation was the survey population. For this work, the Virginia Tech Industry Board was utilized as a snapshot of the AEC industry. It was discovered, however, that the majority (67%) of respondents were commercial contractors. This work would benefit from a broader

survey pool to include more specifically architects and owners. Insight from these and other groups would be valuable when determining the extent of peak oil's impact on the AEC industry. Likewise, architects and owners likely possess a unique set of management best practices.

Future Research

The survey can be further adapted to cater to any number of sustainable methodologies relative to the construction industry. For example, if residential contractors desired to better understand the opportunities of solar panel installation on homes, a survey of this capacity could be developed to serve as a cost-benefit analysis comparing the relationship of homeowner and contractor in terms of a sustainable technology; in this case solar panels are used as the driver for change in lieu of peak oil. Questions can be formulated such that homeowners are responding to a needs assessment from which the contractor bases a decision.

Further research can expand this gap analysis into a more functional decision-making framework in terms of peak oil. Analyzing managerial best practices allows for opportunity to develop a step-by-step decision making map within the context of peak oil. The AEC industry would benefit from not only knowing the potential threats to the system via peak oil, but also having a series of guidelines based on scientific research through studying energy use per sector. The economy – sustainability spectrum needs to be placed front and center in order for industry executives can equate sustainable practices with dollar amounts.

Additional work in the arena of peak oil in construction could lead to a decision-making framework that is specific to the supply chain. At what stages throughout the industry supply chain does peak oil have the most impact? Future research could potentially explore the cost implications at each step of the supply chain, maintaining peak oil as the driver for cost fluctuations. This is an extension of the previously mentioned decision making map, in this case specific to the supply chain and not generalized for wider adoption intended for corporate executives perhaps.

Of particular concern is the economic growth elsewhere in the world, namely China. The domestic construction industry must be aware of China's growth if it is to prepare for a peak oil economy. How does China's construction industry impact the AEC industry in the United States? Using a systems approach to understanding the construction industry helps to clarify how demand in one area creates limitations in another, in this case China's influence on the United States.

Labor is shown to be the biggest corporate cost today among the survey pool. Future research could explore cost in more detail. What exactly is included in this category, and what role does peak oil play in influencing cost for construction organizations? To what extent will transportation be hindered due to rising fuel costs resulting from peak oil? These are questions that can shed more light on the subject of cost within the context of peak oil in construction. Overall, future research should attempt to capture more detail in continuing where this work started, laying the groundwork for peak oil research in the AEC industry.

Lessons Learned

Should this work be given more time for stronger survey development, the results would provide additional clarification as to the direction managerial practices can and should go within the context of peak oil. More attention to detail and premeditated thought would have provided the survey with a more precise structure, lending itself to better data collection.

The survey as it is presented in Appendix C is a good start in what should prove to be useful research into peak oil in modern industry, but it is not without faults. If more time was spent on developing survey questions with a specific data point in mind, then the results would not be subject to as much ambiguity, as seen in some of the charts and graphs.

Beyond the actual work performed, another lesson learned pertained to the general knowledge base of those surveyed. This work took for granted certain information that may or may not have been privy to industry stakeholders. For example, LEED was not defined, nor given any reference or context within the AEC industry. Civil engineers are not concerned with LEED

certification or education as much as the commercial contractor installing the work would be. Defining these terms would have caused the survey to expand, or could perhaps be contained within a primer sent out prior to the survey.

Conclusion

Where a Texan geoscientist began in 1956, others have continued in exploiting modern culture's dependence on cheap fossil fuel (Deffeyes 2005, Kunstler 2005). This work was challenged with disregarding peak oil theory's political and financial attachments. In doing so, the author was able to applied modern construction management best practices against a backdrop of peak oil. This meant first painting a clear picture of what peak oil is and how it came to be a circumstance of vital importance. This work relied on a foundation of knowledge not readily discussed outside of geological fields. The background research provided a strong frame of reference for both peak oil and the CM themes that the survey incorporated for a gap analysis.

This work is subject to underlying conflict of fact and interest. Scientific research and extensive literature provide support for peak oil theory and construction management themes contained herein. Yet, confusion is widespread throughout the industry, as no clear answer to peak oil yet exists. So whereas it rests on factual observations, the outcome remains vague. This work cannot prescribe a solution; it calls attention to problems foreseen in a peak oil corporate environment. While lacking a clear finish line, the survey was developed as the first of many filters through which stakeholders can begin to understand how their corporate policies stand up to the finite nature of fossil fuels.

Concluding this work is to some effect merely a temporary point from which to continue researching peak oil theory for use in other industries. While the author investigated the construction industry generally, additional analysis into more specific facets of construction could potentially reveal the pieces needed for a decision-making tool for stakeholders. For example, exploring alternatives to diesel powered equipment, or developing a decision matrix for corporate restructuring via sustainability could also be of practical use in the industry. More detailed analyses of specific sectors could involve specifically industrial, heavy highway, or

residential construction. Ideally, this work can be manipulated to accommodate any level of management in any industry.

People are the most valuable corporate asset. Industry leaders know this, and willingly admit to the challenges entailed. This survey sought to expose what will ultimately become an even greater challenge in realization of peak oil. That is to say, of all the costs driving the industry today and in the future, people are the grease to the organizational wheel. And thus, the construction industry will have to stand prepared to manage labor pools and company payroll in light of inevitable change in the peak oil economy. How will labor, in this sense, get to the jobsite on a daily basis when gasoline is too expensive for some to afford? Construction firms will indeed have to adjust bids to accommodate more localized projects. Peak oil will curtail transportation of the industry's people, and owners will have to adapt.

The apparent correlation between fluctuating fuel costs and the need for a more fuel-efficient fleet of vehicles (diesel and non-diesel, for daily travel and construction site use respectively) is self-evident beyond this survey's data. The construction industry has for a long time sought a more efficient way to fuel its equipment. Caterpillar recently handed over the keys to the world's first diesel-electric bulldozer (ENR 2009b), proving a company's desire to embrace sustainable innovation within the industry. Less travel and less wasteful travel habits were mentioned as well. No longer can companies afford to have trucks idle for what amounts to hours on end per year, accounting for wasted gas and higher fuel costs. Smarter companies will enforce more responsible driving habits. Shorter driving distances will result in less money spent on fuel for employees commuting to and from project sites every day. Other companies are embracing a more technologically driven approach to lessen the burden of commuter cost. Telecommunications, including voice conferencing and video connections, enable firms to conduct meetings from the comfort of their own offices. No longer do CEOs or project managers have to travel to meet with clients for regular progress meetings. Meetings can join two or more parties from any distance with the click of a mouse, share files and compare drawings all on screen. The construction industry is slowly adopting this technology and beginning to see its benefits from a savings standpoint.

Nearly 60% of survey participants agree that the construction industry has adopted sustainable practices. Incentives are in place to encourage employees to adopt more environmentally friendly ways to achieve results. Other companies mentioned restrictions on vehicle use and increased awareness of more energy efficient equipment.

Different organizations interpret their perceived (unofficial) carbon footprint in very different ways. Because organizations are made up of individuals with different backgrounds and knowledge, there will be a varying degree of perceived impact the company has on the environment. Furthermore, no clear definition exists that outlines how much energy is used for a respective company in terms of electricity, gasoline, petroleum, etc. beyond simple dollars. This work assumes few CEOs keep real time records of their firm's energy consumption habits. Peak oil continues to evade the conference room.

For all the publicity given to global warming, we understand its effects cannot be reversed overnight. Construction industry leaders need to first be made aware of their energy habits before a solution catering to their business model can be realized. The CM themes used for this research are relevant today as they were 20 years ago. The construction industry will soon find itself standing in the middle of the cheap fossil fuels fiesta and have to make a move towards sustainability beyond solar panels and recycled waste. Construction is an industry of energy consumption; its supply chain demands huge amounts of energy from raw materials to installation. Stakeholders delight in the incremental steps already taken to alleviate fuel costs, and LEED (Leadership in Energy and Environmental Design) has never been more popular among the design community. Nevertheless, we can no longer remain ignorant to peak oil.

Peak oil will likely change the face of the construction industry. Whether natural consequences to diminishing supplies lead the way or innovative leaders champion new business models into a more sustainable future is yet to be fully realized. This research set the guideposts for stakeholders in the industry to determine how prepared an organization is for peak oil. How successful corporations are will be left to those who adapt to a changing construction landscape.

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Appendix A – Backcasting

Another concept promoted by TNS and complimentary to this work is the notion of backcasting. It is mentioned here to offer another method for construction industry leaders to develop sustainable plans for future economic growth and success. Backcasting is beginning with the end in mind. While forecasting is simply extrapolating based on current trends, backcasting is deciding on where we want to be and figuring out how to get there. Forecasting often takes place on an organizational level because past information is used to establish trends and then projected into the future. Backcasting, however, is more commonly used on an individual level with regard to day-to-day occurrences. Backcasting is more effective when attempting to diagnose the problem and create a solution of necessary steps to accomplish goals (Baxter K. et al. 2009).

There is potential to further develop the results of this research with greater focus on backcasting and its particular steps. The author recognizes the importance of developing a comprehensive step-by-step decision making tool for construction industry leaders. However, it is beyond the scope of this initial work, and serves as the foundation for future research in the realm of peak oil. Backcasting is discussed herein because it is favorable to the desired outcome for the stakeholders whom the tool surveys.

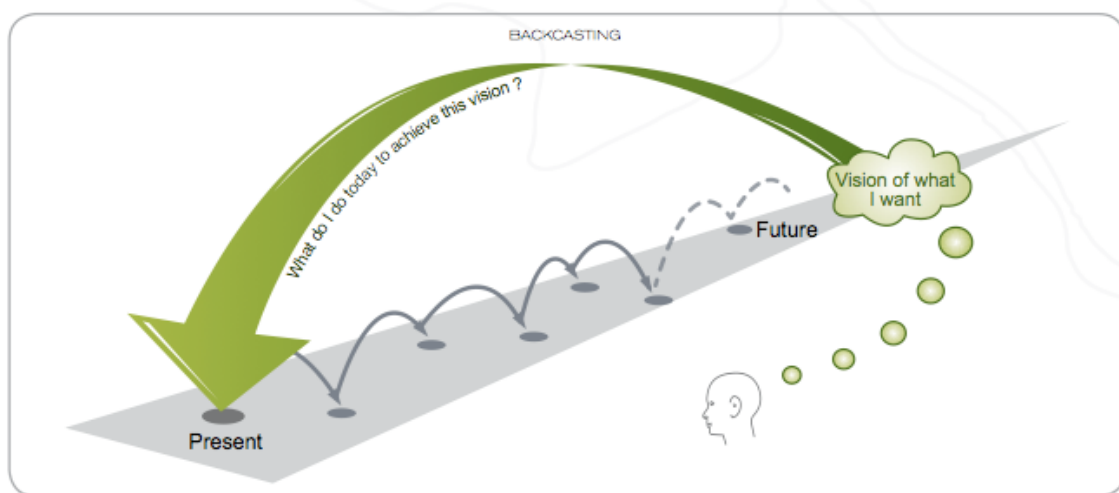


Figure 1. Backcasting presented in terms of The Natural Step framework.
Source: Baxter K. et al. (2009)

Appendix B – Survey Email

Mr./Ms _____,

I am working towards completing my masters degree in building construction at Virginia Tech.

My research focuses on the implications of peak oil within the construction industry. More specifically, how are corporate best practices influenced by rising energy costs? In an effort to gather the most relevant data, I have developed a brief survey meant to capture this information from key stakeholders.

This short survey should take approximately 7 – 10 minutes, and responses will be kept anonymous. Your participation is greatly appreciated; thank you in advance for your time.

Please use the following link to access the survey at your earliest convenience:

<https://survey.vt.edu/survey/entry.jsp?id=1266955638019>

Regards,

Neil Wright

Masters Student

Myers-Lawson School of Construction

Appendix C – Survey

- 1. Company** Free response
- 2. Type of work** Multiple answer
 - Architecture/ Design
 - Engineering
 - Commercial Contractor
 - Civil
 - Transportation
 - Other:
- 3. To what extent does global warming impact your business?** Single answer
 - Large Impact Moderate Impact Neutral Low Impact No Impact
- 4. To what extent does your business impact global warming?** Single answer
 - Large Impact Moderate Impact Neutral Low Impact No Impact
- 5. What is the best estimate of your business' carbon footprint?** Single answer
 - Very High High Average Low Very low
- 6. In your opinion, what is the most important issue facing the construction industry today?** Free response
- 7. What is the single biggest cost for your company today?** Free response
- 8. What will be the single biggest cost for your company in 10 years?** Free response
- 9. Please identify your level of understanding of Peak Oil** Single answer
 - Very Familiar Familiar Undecided Unfamiliar Very Unfamiliar
- 10. Please identify your level of understanding of the LEED program** Single answer
 - Very Familiar Familiar Undecided Unfamiliar Very Unfamiliar
- 11. How much impact has rising energy costs had on your business?** Single answer
 - Very High High Undecided Low Very Low
- 12. Global warming and climate change receive sufficient news coverage in the media** Single answer
 - Strongly Agree Agree Undecided Disagree Strongly Disagree
- 13. Peak oil receives sufficient news coverage in the media** Single answer
 - Strongly Agree Agree Undecided Disagree Strongly Disagree
- 14. Coping with a limited supply of oil will be a driver for change in the construction industry** Single answer
 - Strongly Agree Agree Undecided Disagree Strongly Disagree
- 15. The construction site of 20 years ago looked and functioned significantly different than the construction site of today** Single answer
 - Strongly Agree Agree Undecided Disagree Strongly Disagree
- 16. The construction site in 10 years will look and function significantly different than it does today** Single answer

- Strongly Agree Agree Undecided Disagree Strongly Disagree
- 17. This change will be a result of the supply of oil for energy (e.g. gas)** Single answer
Strongly Agree Agree Undecided Disagree Strongly Disagree
- 18. Briefly explain any steps taken to alleviate rising fuel costs**
Free response
- 19. The construction industry has adopted sustainable practices** Single answer
Strongly Agree Agree Undecided Disagree Strongly Disagree
- 20. Your organizational structure will change as a result of peak oil** Single answer
Strongly Agree Agree Undecided Disagree Strongly Disagree
- 21. Construction scheduling techniques will change as a result of peak oil** Single answer
Strongly Agree Agree Undecided Disagree Strongly Disagree
- 22. Productivity and performance within the construction industry will change as a result of peak oil**
Single answer
Strongly Agree Agree Undecided Disagree Strongly Disagree
- 23. Construction safety (accidents, regulations, etc.) will change as a result of peak oil** Single answer
Strongly Agree Agree Undecided Disagree Strongly Disagree
- 24. Total Quality Management will change as a result of peak oil** Single answer
Strongly Agree Agree Undecided Disagree Strongly Disagree
- 25. Construction equipment management and maintenance will change as a result of peak oil**
Single answer
Strongly Agree Agree Undecided Disagree Strongly Disagree