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Adversarial Project Stakeholders. Influencing Projects With Options

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Stakeholders are considered the key driving force and most important critical success factor on every project. They fall into two basic categories, namely, the internal or primary stakeholders who are contractually or legally bound to the project and normally have a vested interest in its success, and the external or secondary stakeholders who have no active role in the project but who are being affected by it in the positive or negative sense and who consequently may adopt a supportive or hostile stance towards the project. The entities in the latter group, known as the adversarial stakeholders, may actively seek the project's prevention, disruption or even premature termination by excercising their power and influence against it through application of several 'options' which lie at their disposal. It is thus important for project practitioners to be aware of these options in order to prevent their application or at least seek to minimize the detrimental effects on their projects which may result therefrom.

Based on an in-depth analysis of over fifty high-profile, well-documented and controversial completed and on-going projects primarily in construction and in civil infrastructure in several developed and developing countries, this research has identified a broad spectrum of soft and hard options which adversarial stakeholders have used, often successfully, against the projects studied. Our research has determined that while some options are universally applied regardless of project location, others tend to be country and/or context specific. Effectiveness of the options depends on myriad factors such as the stakeholders' access to information, their awareness and ability to network and organize against the project, and enlist media and public support for their cause. Furthermore, adversarial stakeholders have a higher likelihood of achieving their objectives in countries where democratic as opposed to authoritarian systems are prevalent.

Introduction

In their paper *Understanding Project Stakeholder Psychology. The Path to Successful Project Stakeholder Management & Engagement* the authors discussed six psychological attributes which determine the course of action all stakeholders adopt towards a project. The authors research showed that external or secondary stakeholders fall into three distinct categories – neutral, supportive, and adversarial – the last of which represents a potentially severe risk for the project if these stakeholders are not engaged by it appropriately. The fact that even many larger projects encountered severe and sustained stakeholder opposition to an extent that, in some instances, forcefully brought about their premature termination, lucidly demonstrates the possible existential challenge posed by actively adversarial external stakeholders and the criticality of effective adversarial stakeholder engagement for project owners, managers, planners and executors.

Consequently, in order to confront and at least seek to successfully overcome the challenges adversarial stakeholders pose to projects, it is imperative to understand how and to what extent they can adversely affect projects. External stakeholders, individually and collectively, possess power and influence which they can excercize in the form of ‘options’ against the project per se or against its constituent phases, technical and managerial activities and processes and deliverables, consequently jeopardizing attainment of its goal and/or its scope, cost, schedule and other objectives. This gives rise to several questions: What are these options, can they be categorized, how effective are they when excercized individually or collectively, are they applicable on a global level, and how can the project counteract these options proactively as well as reactively in order to safeguard itself? In this research the authors have attempted to provide answers to these questions and in doing so achieve a twin objective, namely, to provide awareness and insights to key project stakeholders which can help to significantly reduce their project risk while simultaneously prompting them to pursue collaborative instead of confrontational strategies vis-à-vis their stakeholders and in doing so to achieve a win-win solution for both sides.

For this exploratory empirical research study the authors have carefully reviewed over fifty medium to large completed, prematurely terminated or still on-going projects in both developed and developing countries across the globe, focusing primarily on projects in construction and civil infrastructure development. The choice was not arbitrary; projects involving spatial development tend in general to be more controversial in stakeholder perspective because the external stakeholders affected, regardless of whether they are supportive or adversarial towards the project, are often numerically comparatively larger, are compositionally more heterogeneous, and their range of motivations and especially their concerns broader than those of the external stakeholders of other project categories. Moreover, the life-cycles of medium and larger projects in construction and civil infrastructure development tend to be longer-lasting during which offers more opportunity for opposition to emerge, develop, spread and increase in intensity and because of their high-profile visibility, coupled with often poorly conceived and implemented stakeholder engagement, court considerable media publicity which is often of the negative sort. Projects across the globe and in both developed and developing countries were chosen in order to determine whether any locational differences in adversarial stakeholders access to options exists. However, due to resource limitations a comparative analysis of option effectiveness in either country category was not performed.

Whilst undertaking this research, two aspects became apparent. First, the more stakeholders expect they stand to incur a net loss in consequence of a project - irrespective of whether their expectation is real or imagined – then the higher is the likelihood they will attempt to hinder or obstruct the project by excercizing the options available to them. Sometimes, fearing for their livelihoods, homes, communities or even their very existence, desperate stakeholders tend to be more receptive to the use of ‘harder’ options and may resort to acts of violence and intimidation in the hope of preventing, stopping or changing a project to the extent that they are satisfied it poses no existential or major threat to their interests.

Adversarial stakeholders are not a homogeneous entity but are like a microcosm of society. They comprise individuals, groups, communities, associations and organizations – even countries. Some adversarial stakeholders are powerful, others are not. The intensity of their adversity can vary significantly. Some stakeholders feel much more passionately than others about the project and its current or anticipated impact on them as well as on the people, places and things they hold dear and may excercize all options which are available to them with a view to causing maximum damage, disruption or embarrassment to a project. Other stakeholders may refrain from doing so. Adversarial stakeholders may have diverse interests, goals, backgrounds, abilities, education, awareness, intelligence, outlooks on life, belief systems and so forth but they all share one common objective, namely, their opposition to the project. As the authors suggested in their paper *Understanding Stakeholder Psychology: The Path to Effective Stakeholder Management and Engagement*, stakeholder opposition to a project normally stems from the disequilibrium which arises between their respective expectations and perceptions. Consequently, unless and until the project can convince its adversarial stakeholders otherwise, which it can attempt to do by designing and executing well-crafted engagement strategies, their opposition will persist and possibly gain momentum over time. It is clearly not in the interest of any project to have a large number of adversarial external stakeholders, especially powerful and influential ones, arrayed against it and the more numerous these become, the greater is the potential danger for the project when they exercise their options. Thus, the onus rests with the project to identify and analyze the causes of stakeholder opposition and to proactively attempt to eliminate or reduce opposition to the maximum possible extent. Projects cannot prevent adversarial stakeholders from excercizing their options but they can discourage them from doing so through effective, creative, flexible and sustained stakeholder engagement, based on a robust and in-depth stakeholder analysis, which directly and convincingly address both general and specific stakeholder concerns, and ensure that preferably all or at least most stakeholders ultimately stand to gain, not to lose from projects.

Second, the number of options available to stakeholders appears to be country and culture-specific. In democratic and enlightened societies where most people are educated and aware of their rights and empowered by law, where judiciary is generally impartial and grievances can be redressed promptly by courts, where the media is independent and where public administration is less corruption-prone and civil society is very strong, the stakeholder option spectrum is broader and more potent than in non-democratic or in authoritarian/totalitarian states and non-enlightened societies where the above features are generally lacking if not altogether non-existent. The inability of stakeholders in such situations to seek and gain redress for their grievances against projects through conventional options – coupled with the sheer and frequent disregard for their concerns and lack of engagement by the projects - however, renders them more susceptible to adopt forms of violence to express their opposition and this is borne out by numerous widely publicized incidents which have occurred in recent years.

Adversarial External Stakeholder Options

The authors' research shows that the adversarial stakeholder option spectrum comprises four distinct categories: *General Options* which are frequently encountered on construction and civil infrastructure projects, *Visible Public Opposition* which involves an open and usually organized open display of adversity by a large number of stakeholders towards a project, *Acts of Intimidation and Violence* against the project and its proponents, and *Transnational Options* which find application solely in the context of projects having transnational character. In addition, the authors have determined that there is a fifth category, *Special Options*, which are usually country-specific, rarely excercized and apparently few in number, and which due to its rather exotic nature was excluded from this study.

General Options: Commonly encountered in the context of construction and civil infrastructure projects, these options are numerous, diverse in nature, and legally and ethically non-contentious. While many are collectivist in character, i.e., they tend to involve a large number of stakeholders all acting against the project in a coordinated manner according to the 'strength in numbers' principle, some can also be excercised by stakeholders acting individually or in a small group. From their research the authors ascertained that it is typical for most, and sometimes even for all these options to be excercised at some point in time against projects. By excercising multiple options a project the stakeholders can drastically increase their potency potential and consequently the threat level to the project. Seventeen of the more prominent options are introduced and briefly discussed below:

Disputation of the project need and/or outcomes are frequently raised by adversarial stakeholders. They view the project either as probably ineffective or even likely to worsen the deficiency it is intended to overcome, impossible to undertake or simply unnecessary and constituting a wastage of resources which could be utilized on other schemes higher up on their need priority list. Likewise, the intended outcomes may be considered too optimistic and non-commensurate with the resources invested in the project and in future may even be eclipsed by the negative foreseen and/or unforeseen consequences of the change brought about by the project. A case in point is the I-270 highway widening project in Maryland's Montgomery and Fredrick counties whose enormous estimated cost of approximately 3.5 billion Dollars far exceeded other feasible traffic decongestion options under consideration. Opponents of the project claimed that widening the interstate would encourage rampant sprawling in both counties in future which in turn would result in traffic congestion in time, thereby negating the positive outcomes the project is supposed to deliver. In the event that project adversaries can produce convincing scientific evidence to support their claims, which they often tend to do, then the pressure on projects to refute or disprove such evidence increases, failing which the projects will be portrayed in a negative light resulting in more public opposition to them. However, the authors' research findings indicate that need and/or outcome disputation and good argumentation by stakeholders per se appears to be largely ineffective in transforming or halting projects.

The adversarial stakeholder option *proposition of alternative project design* is usually used with the objective of minimizing the anticipated adverse social and environmental repercussions anticipated from the execution of the design adopted by the project owner and planners. Developing one or more 'superior' alternative designs for consideration may require a high level of technical and engineering expertise and experience in addition to quality informational input on the part of the adversarial stakeholders or those entities commissioned by them for this purpose. Though non-binding on the project owners, alternative designs which appear superior to the project's own design may attract the attention and the support of other stakeholders, including highly influential ones, which consequently may compel the project owners to adopt or at least consider using them. Stakeholder-proposed alternatives are common on construction and civil infrastructure projects but while noted, in most instances they go unheeded. Exceptions are there, however. A notable case in point concerns the famous Serengeti National Park in Tanzania. Keen to construct a commercial road through the park's northern section, which would have heavily disrupted the eco-system and in particular the migration of wildlife, the Tanzanian government agreed in the wake of fierce internal and international opposition to modify its plans by considering the construction of an unpaved road through a remote northern section of the park and also by reviewing the possibility of constructing an alternative southern road, financed by the World Bank, which would bypass the eco-system.

Public Hearings and Consultations are mandated by law in many countries for public and commercial construction and civil infrastructure projects. They provide adversarial stakeholders with an excellent opportunity to voice their general and specific concerns about the project and if they can, to suggest alternative design proposals through the processes of consultation and participation. While the recommendations of the stakeholders usually are non-binding and the events themselves have some serious inherent organizational and other shortcomings, their input does enable a critical reflection about project in question and the possibility that changes to the project design are carried out in order to ease the level of observed and anticipated opposition to the project or to incorporate valuable insights that may not have been apparent initially to the project owners or planners.

Another common option used against projects by adversarial stakeholders is *non-cooperation*. This can assume several manifestations such as refusal by stakeholders to sell their land, goods or services to the project or to work for the project, withholding information which can be beneficial for it, or declining to give consent and approval which may be a legal or procedural requirement in the project approval process. An excellent case in point is Michael Forbes, the Scottish farmer in Aberdeenshire who made world headlines in 2007 for refusing to sell his 23 acres plot of land to the billionaire property developer (and now incumbent US President) Donald Trump. Forbe's strategically located land was needed for Trump's highly controversial project to construct a golf course, luxury hotel and other facilities in the scenic coastal spot despite intense opposition from environmentalists. Despite heavy pressure bordering on harassment and intimidation exerted over a prolonged period of time on Forbes and his co-resident aged mother both by Trump's project team and the Scottish authorities, he has to this day successfully fought to retain ownership of his property.

Boycotts are another option occasionally resorted to by stakeholders. Boycotts in some manifestation or the other have occurred across the world for over a century. After the second world war and, in particular, since the last thirty to forty years these have been used increasingly as a means of collective protest against practices by commercial organizations whose practices are deemed unethical or at odds with acceptable contemporary standards, especially in regard to human and animal rights, preservation of the environment, and sustainability. In some places – India for instance - nationalism has driven calls for a public boycott of foreign companies and multinational's products and greater reliance instead on local substitutes. Though boycotts usually target the operations of organizations it seems reasonable to conjecture that on-going and under consideration projects of these organizations – for example, factory construction and product marketing campaigns - may be affected by boycott calls if management deems them a threat to future business and revenue in which case the projects may be redesigned or executed in a manner which seeks to incorporate the misgivings expressed by its opposing stakeholders.

Land acquisition, parcelization and ownership distribution is a novel and creative adversarial stakeholder option that has cropped up on at least a few occasions, most notably with the objective of thwarting the extension of Heathrow Airport in London through the addition of a third runway. Dubbed 'Airplot!', supporters of the environmentalist organization Greenpeace, including an Oscar-winning actress and an acclaimed comedian, purchased a plot of land half the size of a football field in direct proximity of the proposed runway, and subsequently invited the general public to attain co-ownership rights at no cost by adding their names to a form posted online. Several thousand promptly did so raising the possibility of legal gridlock in the event of a compulsory purchase order being passed by the British government and which consequently would significantly delay the new runway's construction.

To prevent the proposed destruction of cherished buildings and structures stakeholders have sometimes excercised a financially costly but very effective option – they *purchased the project site/place* in question. The house where the famous musician Ludwig von Beethoven lived in the German city of Bonn is a case in point. It was saved from demolition and converted into a museum back in 1889 by a concerned group of citizens. Similarly, the acclaimed British author Sir Arthur Conan Doyle's residence at Undershaw near London, which was slated for conversion into flats in 2010 after it was used as a hotel for decades, was purchased by a charitable foundation in 2014 which gave a commitment to restore the estate to its original Doylean state. Several recent cases of residents pooling their resources to purchase historic properties destined for demolition came to light in Portland, Oregon.

Another way of preventing building demolition or undesired building modification projects is for stakeholders to seek *landmark* or *protected status* for the effected buildings and structures. Landmark or protected status are typically accorded to buildings or structures which possess cultural, historical or aesthetic value and/or are considered historically or architecturally significant, thereby warranting their protection against demolition or structural alteration. Many countries have laws in place for this purpose. In the United States demolition review laws adopted by hundreds of cities and towns across the country are credited with preserving hundreds of properties earmarked for demolition through the intervention of concerned stakeholders. A high-profile - albeit unsuccessful - recent attempt by stakeholders to have a building designated as protected concerned the project to develop an Islamic cultural center "Park51" in close proximity of the destroyed World Trade Center in New York City.

Stakeholder opposition to projects can also be expressed through *Petitions*. These are requests by stakeholders for action to be taken – in the project context for or against some project, either in its entirety or some aspect thereof - and are usually directed at the public agencies on which the project depends on for its approval and who under certain circumstances, such as widespread public opposition, may be empowered to re-evaluate, halt or prevent it. Petitions are frequently used within and outside the project context across the globe and the petitioners seeking redress of their grievances against projects sometimes number in the tens of thousands. Such petitions and the projects which are the target of their opposition and hostility hence attract considerable public attention and interest which increases the pressure on public agencies to possibly intervene in it whereby the possibility and degree of intervention depends on the project context, location and the regulations applicable there. In recent years the internet has become an increasingly popular medium for stakeholders to reach out quickly and efficiently to a large audience and to create, post and collect signatures for petitions for and against projects, small and large, on specially designated websites such as petitions.moveon.org and change.org where several petition-based 'victories', including against several projects in the US and in other countries, are outlined.

Celebrity Activism offers stakeholders another option to oppose projects. Numerous celebrities across the globe, notably in the entertainment industry, in art and in sport, have over the years taken up the cause of championing themes of contemporary major interest and concern such as preservation of the natural environment, wildlife conservation, global warming, clean energy, human rights, combatting poverty and improving access to education and health. Celebrity activism brings with it considerable media attention to an extent which may not be possible otherwise and on several occasions celebrities have spoken out against specific projects. A good and very recent case in point is the controversial Dakota Access Pipeline project against which several Hollywood actors and actresses joined hands to express their solidarity with and support for the native American Sioux tribe's campaign to stop the crude oil pipeline's construction. A less recent case in point is South African Archbishop Desmond Tutu's support for the bushmen who in court successfully fought their forced eviction by the Government of Botswana from their ancestral hunting grounds in the Kalahari desert in order to make way for a diamond mine project.

Negative publicity in the print and electronic media – particularly if it is extensive, sustained and based on sound logic and scientific argumentation by knowledgeable and respected individuals and organizations -

has on many occasions had a negative impact on construction and civil infrastructure projects. In particular the electronic media presents stakeholders with the opportunity, quickly and cost-effectively, to address a global audience to an extent which was not possible before the advent of the internet and emergence of social media. In project perspective such wide-scale adverse publicity brings unwanted attention and applies indirect pressure on other stakeholders who are actively involved in the project or who have sanctioning power over it and are keen to steer clear of controversy. The controversial Illusu Dam project, one of 22 planned dam projects termed ‘Southeastern Anatolia Project’ on the river Tigris in eastern Turkey, is a case in point. Much of the media-driven criticism against Illusu centered on the consequent inevitable inundation of the 10,000 years old ancient historical town of Hasankeyf and resettlement of its inhabitants. Consequently, British, German, Swiss and Austrian participants in the project dropped out, seriously delaying the project. Negative media publicity is also credited with having played a role in the revision of the Avanca Brasil project under which the Brazilian government earmarked some 40 billion Dollars for development schemes over the period 2000-2020 in the Brazilian Amazon river basin region. In Bolivia negative global media coverage – and a 264-mile protest march by thousands of people to the capital La Paz - resulted in the controversial TIPNES road construction project in a national park and indigenous lands being put on hold for four years.

Stakeholders sometimes create *Associations* whose specific mission is to oppose projects. Often they have their own website outlining, inter alia, their goals and concerns about the project’s anticipated adverse impacts (sometimes suggesting alternatives to the project) and/or the way it was conceived and planned, a timeline of events, and extending an invitation to other stakeholders to join their anti-project campaign. Associations are hence a quick, cost-effective and public way to mobilize adversarial stakeholders and to draw critical attention towards the project, thereby adding to the pressure on it.

Alliances and Coalition Networks are a very potent option which stakeholders have excercised on numerous occasions. These are formed when stakeholders, which can be individuals, associations or organizations, leverage their respective strengths and resources in a jointly coordinated campaign, sometimes lasting years, with the objective of obstructing construction and civil infrastructure projects. An example – and just one of many – is the Vancouver-based Mining Justice Alliance which brings together civil society organizations, community members, students and activists, to fight Canadian mine projects inside Canada and across the globe. In a widely publicized case in Latin America, support from a coalition of national and international campaign groups and the dogged determination of a Peruvian subsistence farmer were instrumental in bringing the 5 billion Dollar open-caste Conga mine project by the US Corporation Newmont to a halt. Similarly, coalition networks were instrumental in halting a large open-caste mining project at Phulbari in Bangladesh. In the Pacific region, where sea-bed mining has attracted much controversy in recent years, a campaign by a coalition network prompted the Government of Vanuatu in 2013 to announce a moratorium on experimental sea-bed mining projects.

In order to proceed, construction and civil infrastructure projects typically require official permits, licenses, concessions etc. in addition to fulfilling a plethora of conditions. Failure to satisfy the conditions or violation of the terms stated in the official documents or in the project approval process and procedures can lead to serious administrative and/or legal complications for the projects. A case in point for the *administrative option* of adversarial stakeholders is the Canadian-based Bear Creek corporation’s Santa Ana silver mine project in Peru whose license was revoked by the government following seven weeks of civil unrest by local communities upset at lack of consultation by the project owners and fearing for their environment and livelihoods. In neighboring Brazil, the licensing process needed for construction of the 8000 MW Sao Luiz de Tapajos Dam, the country's second largest, were put on hold in April 2016 given concerns over its possible impact on indigenous Munduruku community. In 2014 the energy minister for the Australian state New South Wales announced that the resource company Metgasco's license to drill for gas at Bentley off the coast would be suspended because of its failure to undertake genuine and effective consultation with the effected community.

Litigation constitutes one of the most potent options available to adversarial stakeholders to challenge projects. Over time numerous construction and civil infrastructure projects across the globe have been severely impacted by litigation brought on by adversarial stakeholders in the sense that they were compelled by courts to amend their design or scope in order to address stakeholder concerns, were delayed for months and sometimes years through stay orders and injunctions granted due to procedural or legal violations, and, in several cases, were cancelled at or before their initiation or, in more drastic instances, were obliged to prematurely terminate while in execution. Many of the legal challenges were mounted on behalf of indigenous people, pitting them against powerful companies allied with state governments, local administrations and security agencies. A prominent example where adversarial stakeholders secured a legal victory against a large project followed the almost decade-long and internationally publicized struggle between an indigenous tribe in the Indian state of Orissa, the Dongria Kondh, and their supporters around the world, and the British-based mining company Vedanta Resources over a planned one billion pound open-caste bauxite mine on the mountain deemed 'sacred' by the tribe. India's Supreme Court decided in favour of the Dongria Kondh in a landmark ruling in April 2013. In a similar case involving indigenous people seven years earlier, the High Court of Botswana ruled in favour of more than one thousand Kalahari bushmen forced off their hunting grounds and ancestral lands by their government which sought to develop the lands for mining and other projects. Citing the Canadian government's failure to consult with effected aboriginal tribal groups, a Canadian federal court in June 2016 quashed the Government's approval of the 7.9 billion Dollar Enbridge Northern Gateway Pipeline project under which oil from Alberta was to be sent to an export terminal on the west coast of British Columbia. A more recent (though less spectacular) example is a court decision in the US state of New Jersey delaying the South Jersey Gas Pipeline project because its opponents, the Pinelands Preservation Alliance, claimed it violated New Jersey's State Administrative Procedure Act and the State Utility Board's comprehensive management plan. In February 2017 the Austrian Federal Administrative Court ruled against the construction of a third runway at Vienna's international airport on the grounds that it would inevitably result in a drastic increase in carbon monoxide emissions and thereby conflict with Austria's commitments and regulations on emission reductions and climate change. A month later a South African high court blocked construction of the Thabametsi coal-fired power station on the grounds that the Department of Environmental Affairs's environmental authorization for the project failed to adequately take its climate change impact assessment into account and ordered it to do so and review public comments. In late March 2017 a judge in New York city handed stakeholders opposing the construction of a 200 hundred million Dollar performing arts center on a pier along the Hudson river a victory when she revoked the permit issued by the US Army Corps of Engineers for the project.

Political Pressure for and against projects is an option frequently excercised by project stakeholders. Politicians are partly influenced by their own and their party's ideological leanings and partly by their concern at losing public support in the event that they opt to champion or endorse unpopular projects or fail to vigorously oppose them. Consequently, negative sentiments on a broad-scale towards projects often result in a decrease in political support for the projects in question, and vice versa. An excellent case in point is the proposed Kalabagh Dam on the river Indus in Pakistan. Under consideration for decades the project to develop a 3600 MW hydropower dam proved politically too contentious to pursue given the enormous opposition it encountered from Pakistan's smaller provinces and the uncertainty caused by the divergent expert opinions regarding its multi-dimensional implications. A clear political divide also revealed itself in connection with the Keystone XL pipeline project between Canada and the US with Democrats tending to oppose the project which culminated in Barrack Obamas decision to decline the requisite presidential permit in 2015 and Republicans tending in favour of it, consequently leading to President Donald Trump's passage of an executive order in January 2017 followed two months later by his grant of the presidential permit. Political differences, in particular over funding, are also playing a crucial consideration in the CALTRAIN electrification project in California.

The *electoral process* has on occasions been used to challenge construction and civil infrastructure projects deemed highly controversial. Large-scale public opposition to the relocation of US naval base facilities on the Island of Okinawa resulted in the election of Governor Takeshi Onaga in November 2014 who ran his campaign on an anti-base platform. In Taiwan, construction of the 2600 MW Lungmen nuclear power plant near Taipei became an important election issue in 2000 with Taiwan's Democratic Progressive Party, then in opposition, pledging to scrap the project if elected which it was. In March 2016 the people of the Columbian town of Cajamarca voted almost unanimously against a project by Anglo Gold Ashanti Corporation to create what was termed 'the world's largest open pit gold mine' in their municipality. And in a controversial national referendum held in Switzerland on November 29, 2009, the majority of Swiss voters endorsed an amendment to their national constitution prohibiting the construction of mosque minarets in their country.

Visible Public Opposition: The options in this category differ from the core options discussed above in that the opposition towards the project is expressed by a large number of stakeholders acting collectively and very publicly. Specific options included in this category are (peaceful) rallies, marches, protests and demonstrations, sit-ins and blockades, site occupations, strikes, self-inflicted injuries and suicide.

Rallies, *marches, protests* and *demonstrations* against the project are closely related and organized public events which usually are accompanied by considerable media publicity. Rallies are a frequent and normally peaceful means of expressing opposition to the project by a gathering of persons. Large turnouts may attract considerable attention, possibly prompting other stakeholders who are positively inclined towards the project to reflect upon and reconsider their attitude towards it. Marches, protests and demonstrations exhibit a relatively more forceful character. Marches typically involve the movement of persons towards pre-designated places of significance for the project which is often the project site itself or the offices or residences of its owners or key advocates and facilitators. Protests and demonstrations may likewise involve the movement of participants or they may confine themselves, voluntarily or involuntarily, to a specific location but they leave no doubt about the level of their participants' opposition to the project. Oftentimes as experience with several projects has shown, marches, protests and demonstrations can rapidly escalate into serious rioting and clashes between project opponents and project supporters or law enforcement personnel, causing extensive material damage and resulting in arrests, injuries or even deaths. Such was the situation when rioting which resulted in several fatalities prompted the Peruvian government to put on hold the 1 billion Dollar Tia Maria copper mine project in 2011 on the grounds that its environmental impact assessment was inadequate. Although a new EIA was approved in August 2014 the construction permit for the project is still pending.

An excellent high-profile case in point for rallies, marches, protests and demonstrations which have stayed mostly peaceful concerns the proposed relocation of the US Marine Corps Air Station Futenma on the Japanese island of Okinawa to Henoko Bay. Under consideration for almost half a century, interest in the project surged in the late 1990s when the US and Japanese governments decided to pursue the relocation project in order to relieve the social pressure and tension caused by maintaining a large military base in a densely populated civilian area. Heavily criticized for its anticipated adverse environmental impact, and also due to other considerations, the project has encountered stiff public opposition from the majority of Okinawan citizens and its governor which resulted in the halting of construction work until 2015. Public protests in Lianyungang in China's Jiangsu province, rumored to be the site of a joint Franco-Chinese 15 billion Dollar nuclear fuel recycling project, reportedly led to the project's 'suspension' in 2016. Three years earlier mass protests halted the construction of a similar facility at Jiangmen in China's Guangdong province. An interesting current case involving large-scale public opposition to a major project and which has attracted global attention concerns the Keystone pipeline extension project Phase IV which envisages construction of an oil pipeline from Alberta in Canada to the US state of Nebraska. Much of the public controversy about this project centers on environmental concerns. Years-long opposition to the project, accompanied by mass arrests of protestors, stalled the pipeline's construction and the project itself was declined the requisite presidential permit by Barrack Obama in November 2015 after six years under review – a veto that was promptly reversed by the Trump administration in January 2017.

On occasions project sites, facilities and access routes are subjected to *sit-ins* and *blockades* by adversarial stakeholders. To stage sit-ins stakeholders enter and temporarily occupy the project site in whole or in part whereas a blockade results in barring of entry to and from the project site for project employees and project supplies. Stakeholders hereby sometimes resort to dramatic measures such as chaining themselves to gates or other heavy objects to prevent their forcible removal easily. Project activities are consequently delayed, in some cases for months, as negotiations to lift the sit-ins and blockades are held or law enforcement personnel are finally called in which not infrequently culminates in violence, arrests, injuries and deaths. Many of the instances of sit-ins and blockades encountered by the authors in their research for this paper concern tribal or indigenous people. In December 2007 about 100 members of the Enawene Nawe tribe in the Brazilian Amazon occupied the site of a dam construction project and nearby highway to protest about the construction of a series of dams, supported by large companies, on the Juruena river upstream of their land which they claim would destroy their livelihoods. In August 2016 in Papua New Guinea traditional landowners blockaded a liquified natural gas facility at Hides in Hela province in response to their government's years-long failure to meet its financial benefit sharing obligations from the facility's operations. The blockade was promptly lifted when the Government promised to meet its commitments to the landowners. An interesting sit-in occurred in the Australian city Sydney where aboriginal activists erected a 'tent embassy' for fifteen months at a project site to protest at what they perceived was the Aboriginal Housing Company's prioritization of commercial interests over the provision of affordable housing for the indigenous community. The tent encampment was dismantled in August 2015 after the Federal Government brokered a deal with the Company which assured the protestors that the project's social housing component would be expanded. A two-year blockade by indigenous people led to the declaration of a moratorium on construction of the controversial Baram dam in Sarawak state on the Malaysian Island of Borneo.

Hunger strikes are an interesting option used occasionally by stakeholders to express opposition to projects. Because of their rather dramatic effect, especially when a large group of individuals opt for a hunger strike, they garner widespread attention and generate very negative publicity of the project. Interestingly, all instances (of which there were several) encountered by the authors relate primarily to energy infrastructure projects undertaken in India. Hundreds of villagers affected by the planned construction of an international container transshipment port at Enayam in Tamil Nadu state staged a day-long hunger strike against the project in September 2016. Also in Tamil Nadu state several hundred people, including prison inmates, staged a hunger strike in February 2017 against a hydrocarbon exploration and extraction project at Thilegar Thidal. Professor Agarwal, a devout Hindu and one of India's most venerated scientists, commenced a hunger strike on June 13, 2008, in Uttarkashi to protest at several dam projects on a 125-kilometer stretch of the Bhagirathi river which runs into the Ganges river, considered sacred to Hindus who believe its unimpeded flow must be maintained. Following 18 days of fasting and an assurance by the Indian Central Government to determine a mutually acceptable solution, Agarwal broke off his fast but resumed it in New Delhi on January 14, 2009, when no solution was forthcoming. Nearing death after 38 days of fasting, the state government of Uttarkhand ordered immediate suspension of work on the Loharinag-Pala hydropower project which was considered most contentious of the dam projects on the Bhagirathi river. Agarwal's campaign was taken up at the political level and the Ganges was subsequently declared a 'national river'.

The most extreme expression of opposition by adversarial stakeholders in this option category are *self-inflicted injuries* which can on occasions result in their death. Self-immolation is perhaps the most dramatic form of this. Frustration, anger, desperation, isolation and a sense of utter helplessness all converge in this disturbing phenomenon. Most of the known self-immolation incidents occurred in China and appear to be a direct consequence of the rapid modernization and urbanization which have characterized its development over the past few decades. A sad case in point – and just one among several - is Tang Fuzhen, a 47-year old woman who doused herself with petrol and set herself alight following a three-hour violent stand-off with officials in the Chinese city of Chengdu on November 13, 2009. She died in hospital from her injuries two weeks later. Trigger for this horrific incident, which was captured on a mobile phone video and broadcast on Chinese national TV and on the internet, was Fuzhen's forced eviction from her home earmarked for demolition as part of a development project. Public shock at this and other self-immolations in protest at forced evictions prompted a small group of influential academics from the University of Peking to press for a revision to Chinese law on urban housing demolition with the objective of curtailing forced evictions and which was subsequently taken up for consideration and opened for public comments.

Acts of Intimidation & Violence: This set of options encompasses actions employed by adversarial secondary stakeholders and directed against the project and its facilities, infrastructure and logistics, as well as against those stakeholders directly and/or indirectly participating in it. Such acts are hence both property- as well as person-oriented and, unlike the options falling under the visible public opposition category, are both criminal and unethical in nature because of the evident willingness of stakeholders to consciously employ coercion and violence and to transgress laws in order to express their opposition to projects. They symbolize the highest intensity of adversarial stakeholder behavior and opposition towards projects and occur globally although their occurrence evidently tends to be comparatively more frequent in less developed states. *Pilferage, theft, vandalism and sabotage*, and *rioting, arson* and *bombing* and other physical destructive activities by adversarial secondary stakeholders that target projects are typical examples of 'property-oriented options'. An insightful article published in the Journal of Construction Engineering and Management in 2005 revealed the immense extent theft and vandalism occurs in the construction industry. Though less frequent, riots have frequently taken place against large controversial projects – Narita airport in Japan being a long-running and especially notorious example. Plans for urban renewal projects in economically deprived suburbs of Paris may have played a role in sparking serious rioting there in 2005.

'Person-oriented options' include *verbal abuse, threats, blackmail* and *extortion, harassment* and *bullying, physical assault* (with or without causing injury), *abduction, forced detention, torture* and *murder*. As these involve temporary or permanent physical and/or psychological damage to people they are more serious than the property-oriented options. In the event that both these options are employed by adversarial stakeholders then, consequently, due to the ensuing physical damage and the fear effect which deters primary stakeholders from pursuing their project responsibilities or which causes them to abandon the project completely out of concern for their safety, project activities can be significantly delayed with costly implications. The complications for projects are especially high when they enter their execution phase and material, technical and human resources are mobilized and start collecting at the project locations.

Several projects reviewed for this research indicated being afflicted with acts of intimidation and violence, spontaneous or organized, in some form or the other and usually well-planned and executed, either targeting property or persons, often both. In the late 1970s opponents of the CU-Powerline project in the US state of Minnesota toppled twenty power line towers and damaged ten thousand electrical insulators. Often the hostility displayed by secondary stakeholders towards projects appears to have political or ideological underpinnings. An excellent case in point is the Indian state of Bihar which for decades has been plagued by a violent Maoist insurgency. Over years many infrastructure projects there, notably in road and railway construction, were systematically attacked resulting in damage to and destruction of project machinery and equipment, and injuries and deaths of project employees, and halting work on the projects for months. Also in India, rioting by locals and violence and threats directed against project employees resulted in the abandonment of Tata company's project to set up a car manufacturing plant in Singur in Gujarat state. The mayhem was eloquently summed up by Tata Group Chairman Ratan Tata who stated: "You cannot run a plant when bombs are being thrown at the site. You cannot ruun a plant when workers are being threatened and intimidated". In remote areas of northern Pakistan, functional and under construction secondary schools have often been targeted by religious extremists angered by the provision of education to girls and at co-educational teaching. In Afghanistan Taliban insurgents attacked several road construction projects resulting in the deaths of dozens of Indian, Chinese and other foreign engineers and workers in addition to Afghans. Likewise, US and foreign contractors working on projects in Iraq after the second Gulf War in 2003 were a prime target of insurgents resulting in several hundred deaths. Opponents of the Shell oil company's activities in Nigeria have on occasions damaged Shell's pipelines.

Transnational Options: In their paper *Stakeholders and Transnational Projects* which was presented at the University of Maryland's third annual project management symposium in May 2016 the authors showed that countries and their populations also can be stakeholders on many projects, usually of a larger-scale, which are undertaken in other countries and jointly between countries. Sometimes projects are opposed at country level by other states, neighbouring or distant, which may harbor security, environmental, economic or other concerns about the projects which they believe stand in serious conflict with their national interest. In this case the opposing (or adversarial) states have an arsenal of options at their disposal which are briefly presented below in ascending order of intensity.

The mildest and probably most frequently excercised option is the lodging of a *Formal Complaint* against the project which is conveyed usually discretely and usually at ministerial level by the opposing state to the project-executing state. Since most projects of transnational significance are planned and undertaken in the public sector by the relevant ministry, a direct communication against a project from one or more opposing states' counterpart ministry will normally have to be reviewed and formally responded to in accordance with protocol. Consequently, the project-executing state can either accept the reservations expressed and suspend or cancel the project or at least undertake a critical plan and design review of it with consequent modification to satisfy some or all of the expressed misgivings, or dismiss the reservations altogether and simply proceed with the project.

Official Protest is a stronger and more public means of expressing concern by a state or states opposing projects in or by other states. It is usually conveyed at ministerial level or through diplomatic and ambassadorial channel in letter form. The exercise of this option conveys a sense of urgency coupled with an assumption that proceeding with the project may lead to a disruption in bilateral relations between the project-executing and project-opposing state/states. Cambodian protests to Vietnam in 2015 over road construction and infrastructure development projects in a contested border region, Chinese objections to Indian road construction work in the Himalayan territory Ladakh in 2016, and stiff protests by Turkey and Turkish-administered northern Cyprus to the Republic of Cyprus over the latter's oil and gas exploration activities in the eastern Mediterranean are cases in point.

Passing a *Resolution* is a formalized, official and public expression of opposition to projects undertaken by states. Resolutions are often passed by representative bodies such as national parliaments or regional institutions (for instance, the European Parliament, and European Council), and the United Nations. The latter's resolutions against the construction of new housing settlements and expansion of existing ones in Israeli-administered East Jerusalem is an enduring case in point.

Third Party Mediation can be used to attempt to solve an issue which arises between states when one state seeks to undertake a project which is opposed by the other. This, off course, is contingent on both sides accepting the mediation effort by another (state or non-state) entity which acts impartially and is chosen because of the credibility it commands. The Acta de Brasilia negotiations between Peru and Ecuador in the late 1990s is a case in point.

Arbitration and *Litigation* are options which states have occasionally resorted to in order to settle disputes arising out of controversial projects. In the course of its over one hundred year history the Permanent Court of Arbitration in the Hague, Netherlands, has inter alia decided several cases between contesting governments. A recent and interesting case in point is a dispute between India and Pakistan regarding India's decision to proceed with the construction of a dam (Kishenganga Hydro-Electric Project) on the Kishenganga/Neelum river. In this case the Court was approached by the government of Pakistan which expressed concern at the anticipated reduction in its river water inflows given Pakistan's location downstream of the dam site. The International Court of Justice, which is the United Nation's judicial branch and, like the Permanent Court of Arbitration is based in the Hague, presided over a dam dispute between Slovakia and Hungary over the Gabčíkovo–Nagymaros Dam, which arose when Hungary stood in breach of its commitment to participate in the bilateral project. Another inter-state project-related dispute presided over by the Court was the Pulp Mills dispute between Argentina and Uruguay which was prompted by

Uruguay's grant of permission to foreign companies to set up factories which Argentina feared may have resulted in the pollution of a border river.

Condemnation is a harsh verbal expression of opposition by a state or states to a project being undertaken by another state. An example is the condemnation voiced especially in the West and in East Asia following the development and testing of a nuclear explosive device and missiles by North Korea in 2016-17, and the international condemnation voiced at a new Israeli Regularization Law which legalizes the expropriation of private Palestinian land and construction activities there.

Sometimes states perceive projects to constitute a challenge and a danger of such proportion that they warrant a forceful response. Egypt, whose survival historically is primarily dependent on the Nile River, has on past occasions resorted to issuing *Threats* against Ethiopia, where three of the river's four main tributaries originate, in the event that the latter should halt or drastically reduce the flow of river water into Egypt. In the past few years, however, threats have given way to cooperation and a more coordinated water resource management strategy between Egypt, Sudan and Ethiopia. Similarly, between 1975 and 1991 Syria and Iraq reportedly twice threatened Turkey with war over its damming projects on the rivers Tigris and Euphrates.

More action-oriented options include imposition of *Sanctions*, *Incentive Programs*, *Sabotage*, *Assassination*, and pursuit of direct *Military Action*. The most famous contemporary instances of sanctions concern the nuclear programmes of Iran and North Korea, the goal of the sanctions being to prevent both states from developing, testing and deploying nuclear weapons and ballistic missiles. Sanctions can assume many forms in several crucial spheres - diplomatic, trade, financial, insurance, investment, political, cultural, technological, arms sales, travel, and so forth. Though the impact has been quite severe in terms of the overall economic and social hardships caused the sanctions apparently may have delayed but have failed to eliminate either states' nuclear and missile programs with North Korea testing several nuclear devices and missiles in 2016.

Incentives – the counterweight to sanctions - have been used on occasions as a softer means to encourage states to abort or freeze controversial programs and projects. Under the Clinton Presidency, an incentive program was offered to North Korea in exchange for a freezing of its nuclear programme in consequence of which the Korean program was put on hold for some years until its subsequent resumption. Incentives were also offered to the Libyan government and were instrumental in bringing about the abandonment of its nuclear weapon program in 2003.

An interesting application of the Sabotage option in the post-Cold War context is the use of cyberspace to disrupt Iran's nuclear program, in particular its Uranium enrichment infrastructure, in 2010. A malicious computer worm dubbed 'stuxnet' – which was reportedly developed jointly by the US and Israel as a secret intelligence operation - targeted Iranian nuclear centrifuges destroying almost one-fifth of them and causing a significant and unexpected setback to the program besides attacking Iranian air defenses, communication systems and power grids. Suspected sabotage under a covert US cyber and electronic warfare program initiated by Barack Obamas's administration reportedly may also have played a role in the failure of several North Korean ballistic missile tests since 2015.

Assassination as an option of disrupting projects has been employed on a few recent occasions, most notable being the murder between 2010-12 of four Iranian nuclear scientists working on Iran's nuclear program and which Iran promptly blamed on Israel and the US although no concrete evidence to this effect has been discovered.

The option of direct military action in the form of a *Military Strike* embodies the most forceful response by one state against another. An excellent case in point was the Israel's destruction of Iraq's Osirak nuclear reactor facility near Baghdad on June 07, 1981. Israel's apprehension that Iraq would use the facility to develop nuclear weapons which would be used to obliterate it prompted it to resort to this drastic measure which it repeated by destroying Syria's Al-Kibar nuclear facility in September 2007.

Concluding Remarks

The authors' research shows that adversarial external stakeholders typically have access to a broad spectrum of options that can severely disrupt CCID projects and on occasions threaten their very existence. In most cases they seek to do so because they believe that the projects conflict with their interests and more often than not this appears to actually be the case empirically. Stakeholder opposition however is not a constant but can increase or decrease over time depending on myriad factors. Since these stakeholders are outside the project's control, the onus lies on the project to devise engagement strategies with the purpose of discouraging adversarial stakeholders from excercising their options (prevention) or, if they do so, which minimize the damage to the project which stems from exercising of the options. Doing so necessitates, especially in the project design and planning phase, very careful consideration of the project's stakeholder dimension which usually tends to get sidelined by the traditional and heavy focus on the project's technical and administrative work aspects. Sincerity, empathy, and a robust stakeholder analysis and assessment constitute the first step towards acquiring an understanding of the adversarial external stakeholders, the reasons for their opposition to the project, and the potential adverse consequences this could entail. Legitimate stakeholder grievances must be decisively addressed and resolved by the project. Doing so is the ethical responsibility of the project and, moreover, ensures a win-win solution for both the project and its stakeholders because it benefits the project materially by significantly reducing or eliminating stakeholder opposition and its consequent risks, and at the same time it also benefits the stakeholders by ensuring that most, if not all of them, experience a net gain or at least no or minimum loss from the project.

Application of an interrelated UAS - BIM system for construction progress monitoring, inspection and project management

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ABSTRACT

Construction progress monitoring and constant comparison between “As-planned and the actual state of the project “As-built” is a critical task for construction project managers to keep projects on track. Currently, progress and inspection reports are based on manual input and observation of each and every phase of the construction projects, such processes are costly and time consuming.

Unlike the traditional method for project control, integrating advanced technologies such Building Information Modeling (BIM), Unmanned Autonomous Systems (UAS) and real-time cloud based data modeling and analysis, enable real time project control, monitoring and inspection. Advanced BIM encompasses project As-Planned information such as design, specification, cost, and schedule which enables CPMs to have an accurate comparison between as As-Planned and the UAS based As-Built states of the project. This paper describes:

- The current state for building information modelling and unmanned aerial system in construction projects.
- A strategy for the application and integration of BIM and UAS throughout progress monitoring of the construction of a recreational facility.
- The challenges and opportunities for full automation and data analytics towards real time project control and monitoring of Construction projects.

INTRODUCTION

In the knowledge era and time of Artificial Intelligence (AI) the world is changing much faster than ever before. In a time of disruptive technologies, rapid social, political and environmental changes it is the moral obligation of each and every industry to transform (WEF, 2016). While this transformation will have positive impacts on construction cost, schedule, productivity, efficiency and environmental, the construction industry has remains one of the least efficient industries with an unimpressive track record in the world.

Even though other industry sectors have embraced fundamental changes over the last few decades, and have gained the benefits of advanced technological achievements, process and product innovations, the construction sector has been hesitant to fully embrace the latest technological opportunities, which has thus far resulted in stagnation of productivity in major global construction projects.

Technological advancement and market maturity of digitalization such as 3D scanning and virtual reality, in addition to Building Information Modelling (BIM), Unmanned Aerial and Ground systems (UAS and UGS), autonomous machineries and equipment and advanced building materials has provided a potential for fundamental changes to boost construction sector productivity and efficiency. While new technologies and innovation have emerged to some extent on the enterprise or company level, the rate of innovation and overall productivity in construction sector has remained nearly flat for the last 50 years (Beck, 2016).

According the World Economic Forum report in 2016, the unimpressive record of the construction industry is mainly caused by:

- *Lack of innovation and delayed adaptation*
- *Informal process or insufficient rigour and consistency in process execution*
- *Insufficient knowledge transfer from project to project*
- *Weak project monitoring*
- *Little collaboration with supplier*
- *Conservative company culture*
- *Little cross functional cooperation*
- *Shortage of young talent and people development*

Despite all the above mentioned issues and dominant conservative culture in construction sectors, few construction companies have adopted a progressive and innovative approach to pioneer the integration of advanced technologies such as BIM and UAS. This research and its outcomes herein have been the result of a collaborative approach between progressive construction industry partner/owners and academic Scholars/practitioners to: a) study the integration of the advanced BIM UAS based data into the progress reporting, technical inspection and safety analysis of the construction sites, b) demonstrate the advantages of implementing of the integrated strategy and c) identify the technical barrier to advanced technologies such as UAS in the construction sector.

WHAT IS THE STATE OF THE ART?

BIM as an integrated design and construction process is being increasingly incorporated into the construction sector as a tool for advanced design and to provide higher quality, and interactive project plan to improve construction project management (CPM) productivity (Eastman, 2008). The advanced BIM (3D & 4D) and high computerisation level of construction interactive virtual modeling and simulation enabling CPMs to accurately generate project schedule, cost loaded schedule (CLS), and progress reporting plan (Abourizk, 2010). This high level automated process from design to management will impact the overall cost of the project by reducing the number of requests for information (RFI) and change orders. This will results in improved return of investment, Earned Value (EV), and minimize the project cost/schedule contingencies (Barlish & Sullivan, 2012). The integration of BIM in early phases of construction projects also reduce the design conflict, improve communication between project participants, and helps to identify possible, technical, non-technical and managerial issues through the visualization of time- control model (virtual reality) of the project (Arain & Burkle, 2011; Feng et al. 2010).

Even though BIM is mostly being used during the design phase, construction projects would benefit from the interactive updated BIM model during the implementation phase. To do so the project progress information has to be captured constantly with the same patterns by the use of UAS and UGS. Then the captured data has to be integrated into the BIM model and rendered accordingly to provide the simulation of the future steps based on the As-built data, planned and Actual value through the construction project (Moeini, 2016; Ghanem & Abdelrazig, 2006).

Earned Value Management (EVM) as a cost component adds the fifth dimension (5D) to the BIM system to study and analyze whether the budget and schedule objectives are and will be preserved before the construction starts and during each phases of project. The implementation of effective and efficient EVM through BIM also requires constant update of the project data extradited from the advanced project progress reports. However, obtaining true values for tasks' completion rate is difficult (Fleming & Koppelman, 1997) and requires advanced situational and progress reporting and up-to-date information regarding as-built state which has to be attained frequently and compared to the as-planned state. Hence integration of new data acquisition methods and modeling techniques such as UAS, UGS, remote sensing and AI rather than traditional methods (Arian & Moeini, 2016) is necessary.

Application of UAS, UGS, and remote sensing enables the CPMs to go beyond the labour- and time intensive traditional process of As-built reporting which is usually based on 2D plans. The collected As-built information acquired by High Definition (HD) cameras, laser scanning and photogrammetric point clouds as a modern approach can be used to provide the necessary information for As-built demonstration in the BIM (Ham et al., 2016; Maalek, et al., 2015; (Karsch et al., 2014; Golparvar-Fard et al., 2012).

UAS autonomous flight planning capability enable the CPM to predefined mission planning (knows flight pass in UAS) through the project and took the required measurements for collision avoidance during each pre-planned flight. The work of Freimuth and König (2015) explained the automated calculation of the UAS mission planning using a BIM by defining the secure distance to all objects during the operation of the autonomous systems to: a) improve the safety of the operation, and b) plan the UAS operation based on the latest up-dated BIM.

The work of Tuttas et al (2015) illustrates the photogrammetric point clouds which are generate based on the captured data by UAS through the projects was used used for the project progress monitoring (As-built) as well as detection of temporary objects (e.g. cranes) for future mission planning of the UAS. Integration of As-built information (captured by UAS and UGS) into the BIM enabled the CPM to: make well-informed decision, enhanced communication management, and ultimately improved the project success and productivity rate (Arain & Moeini 2016).

INTEGRATED BIM – UAS SYSTEM

The integrated BIM-UAS system is a "big data" collection with data analytical capacity. The strategy behind integrating building information modelling and unmanned aerial systems aims to firstly primarily build the capacity for real time automated visualization of project progress. Before developing an integrated BIM-UAS system, it is necessary to identify separately how the building information modeling and the UAS (drones) can be strategized separately within construction projects.

For those construction projects that incorporate BIM as part of the design and planning phase, the 3D building information model provides data and information of the ‘As-planned or As-designed” project. The BIM model as part of the integrated design process enables the creation of the 3D model benchmark information data as illustrated below.

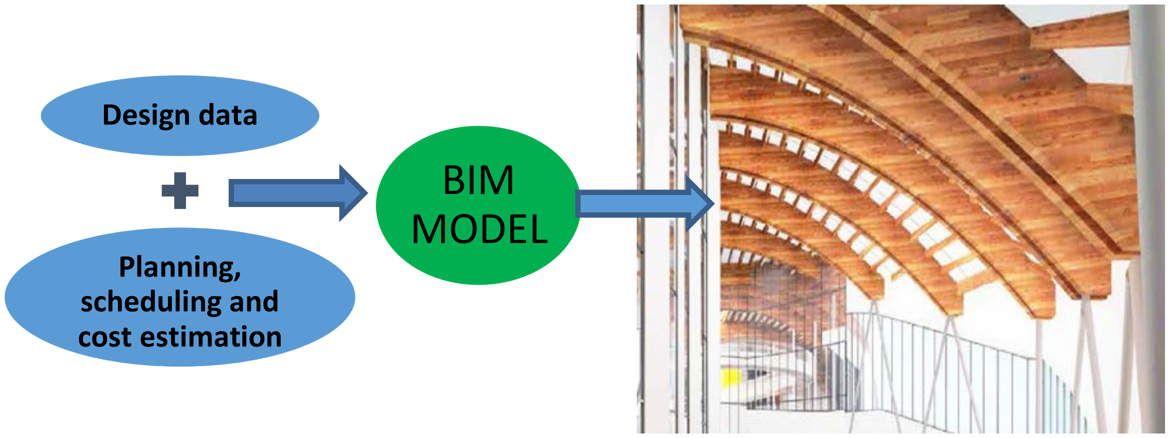

Figure 1. The building information modeling data generation

In the implementation of unmanned aerial systems for monitoring, the drones are used to capture data of the construction progress. In this context, the project site is scanned by the use of UAS at a predetermined frequency (monthly or semi-monthly) for the duration of the construction. The frequency can thus be directed on the basis of the project control requirement. The collected data is then processed before data analytics derive a cloud model representative of the “As-built” model, illustrated below.

Figure 2. The cloud point generation using unmanned aerial systems

Lastly, the integrated BIM-UAS process is the ultimate post processing of input data from: a) the BIM model, and b) the cloud model post processed from the drone input information.

The framework for an integrated BIM-UAS process as shown below, allows for the integration of site-wide survey-grade imagery, which are overlaid with BIM design data.

The integrated BIM-UAS model serves for project control by comparing the As-built” and “As -designed model. Algorithms and further data processing of the integrated model should allow the generation of project control metrics and KPIs such as earned value or cost variance.

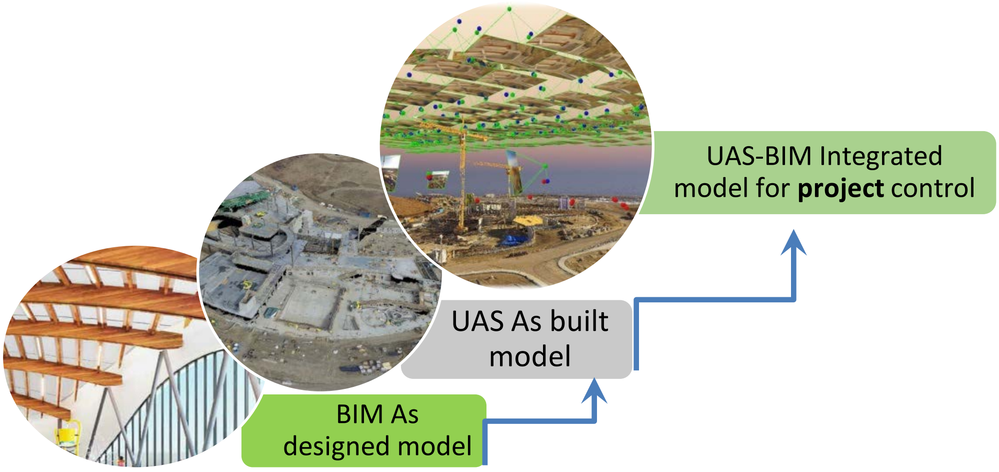

Figure 3. BIM-UAS Integrated system framework

TESTING THE UAS BIM SYSTEM

Unmanned Aerial and Ground Systems which provide the capability of low altitude aerial photogrammetry and ground based imagery can provide a unique advantage to improve the project progress reporting and quality in construction sites. The UAV and UGV technology has become the center of attention of some construction companies and expands the practical application scope. The capability of the UAS to capture low altitude aerial (airborne) photogrammetry on urban project site and the suitability of the captured images to make 3D model of project progress has made UAVs one of the most influential tools for construction project management.

Three dimensional simulation of the project site in addition to the virtual reality resulted from the overlapping of the As-planned and As-built data enable the research team to visually analyse the project progress during the implementation phase.

In order to validate the implementation of UAS in construction project monitoring, testing was conducted on a selected project. The project is a recreation facility located within the inner city of Calgary (Alberta, Canada). The site is tucked between an existing hill landscape and highest natural elevation and a reconstructed wetland.

Figure 4. The Rocky Ridge Facility in Calgary (The City of Calgary)

The project site is approximately 284,000 square feet building, designed to complement the surrounding landscape. The roof component of the structure is quite unique making it the largest wooden glulam supported roof in North America. The highway and residential neighborhood located in the southern part of the project site was one of the main risks associated with safe operation of UAS. The UAS operation was the first official and legal UAS flight with the city boundary under Special Flight Operation Certificate (SFOC) issued by Transport Canada.

The construction site was monitored by the use of UAS and the required photogrammetric data was captured since very early stage of the project on every three weeks bases. The captured combining nadir and oblique airborne (UAS) images of the project site were used to generate a georeferenced 3D cloud point and orthomosaic for further analysis.

The UAS acquisition is associated to an acquisition with several UAS platforms mainly DJI products and adherence to the regulation for UAS flights in Canada, which are among others:

- Maximal flight height of 400 Feet
- Flight was conducted within visual line of sight
- No flights was conducted over the main highway on the southern part of the site
- No flights was conducted during working hours
- No flight was conducted below -5 degree centigrade

A monthly frequency of site monitoring was implemented throughout the two year duration of the project. For executing each monthly flight in the project site the DJI Flight Planner and DJI mission planner apps were used. At beginning of the project the Industry Foundation Classes (IFC) process was used to avoid obstacle as explained by Freimuth and König (2015). Obstacle avoidance sensors were later integrated into the UAS platforms which enabled the team to move beyond the Industry IFC limitation and lengthy process of mission planning to avoid obstacles. The adoption of avoidance sensors into the drone system has reduced the UAS flight planning based on obstacle avoidance, data capturing time and also improve the flight operational safety.

The geometries of the building and site layout elements, which lay in the neighborhood of the take-off and surveying position, were extracted as bounding boxes. Using the bounding boxes and the data of the surveying job, grid points were generated. These grid points were the main basis to calculate the optimal waypoint between the take-off and surveying position. The results were stored as flight mission and were be evaluated by simulating the flight of the UAS in an interactive viewer component of the Survey Planner application.

The wide angle cameras used in UAS increased the base-height ratio (distance on the ground between the centers of overlapping photos, divided by aircraft altitude) and improved the accuracy of height measurement with the wide angle of view from the longitudinal direction. The lateral direction increased the surface width covered in the captured images and improved the efficiency of the flight. it also reduced the quantity of the control points in the project site (Feifeia et al, 2012).The image below is an illustration of the As-built images acquired during a flight over the construction site.

Figure 5. UAS “as built” construction site image

The Pix4D a photogrammetry software was used to generate 3D point cloud model from the captured photos. The geolocation and camera orientation of each picture and camera specifications was used to calibrate the photos inside the software. The image below shows the calibrated camera positions in green and the initial camera positions (GPS coordinates) in blue. Depending on the number of images used the time to generate the 3D point cloud model varies. On average it took 48 to 72 hours to generate a model as shown in the images below.

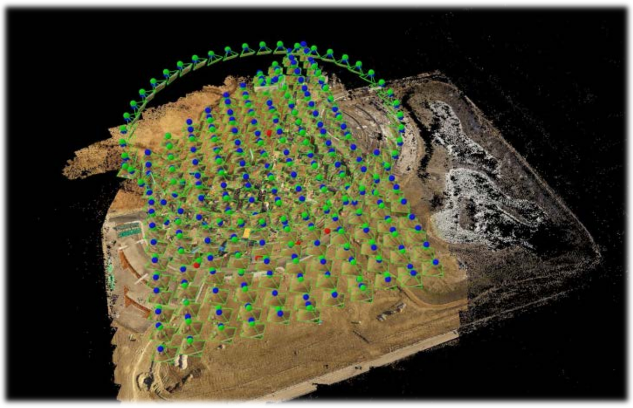

Figure 6. UAS point cloud generated model

Finally, the as-built Point Cloud model was manually overlaid over the BIM Model using Autodesk Naviswork, a 5D BIM simulation and analysis software. The point cloud and BIM models were compared visually. The latter visual matching between the As-built and As-planned models is currently the last step of data processing visualisation to allow a benchmark comparison between project up to date status and initial planned data.

OPPORTUNITIES AND CURRENT LIMITATIONS

Cost overruns and delays occur in construction projects often when the realities of the physical world are out of alignment with the plans of the digital world. The BIM-UAS integrated model and system bridges the gap between the project planned features and the completed project features. The integration of site-wide survey-grade imagery, perfectly overlaid with BIM design data is so far the closest project control and monitoring could get to enable real time visualization of progress.

The proof of concept for the integrated BIM-UAS system was successfully demonstrated with the recreational facility construction project. Indeed, photogrammetry can be used to generate a relatively accurate 3D Cloud Point Models that can be used over existing 3D design models to enable construction progress monitoring.

The data analysis and processing of the terabytes of collected data in various forms, although lengthy has provided accurate comparison between the point cloud models and the BIM 3D model. The benefits and opportunities have been well demonstrated within the framework of the selected project

Limitations however persist as the data generated is currently qualitative with a visualization of the project progress. For the purpose of validating the BIM-UAS model, in absence of any software capable of aligning the BIM model and the point cloud model, the integration followed a manual step by step process of data processing and post processing. Notably, the next step would consist in automating the data analytics.to produce quantitative and measurable data for project control and performance monitoring.

In order to optimize the BIM- UAS integrated system for project monitoring and inspection, the next development steps have to target:

- achieving an automation of the integrated BIM-UAS system to generate a real time visual of the 3D geometries over the UAS scanned model.
- a real time data processing that extracts the key project control metrics to enable project managers with the capacity to reduce risks while increasing project productivity. Linking schedule BIM model (4D) and adding project cost BIM (5D), should enable that functionality.

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Balancing the Speed of Agility with Technical Quality

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ABSTRACT

The goal of project management is the timely delivery of capabilities that provides value-add to the customer. This paper identifies a series of warning signs of Information Technology (IT) projects under stress and their potential effects on technical quality. It describes how agile software development practices can reduce the causes of these stresses. It then examines the Manifesto for Agile Software Development and how it's implementation in six key areas could also result in a reduction in technical quality and provides recommendations for Project Managers to follow to maintain technical quality while executing agile software development practices.

Key Words: Manifesto for Agile Software Development, Technical Debt, Tailoring, Customer Definition, Architecture Communications, Documentation, Self Organizing Teams

This paper is based on empirical observations, current literature, limited trails, and engineering and project management experiences.

INTRODUCTION

The goal of project management is the timely delivery of capabilities that provides value-add to the customer. In 1994, the Standish Group published their first report that measured the delivery of successful projects. In their initial report, they surveyed 365 companies and represented 8380 IT applications. "The Standish Group research shows a staggering 30.1% of projects will be cancelled before they are completed….On the success side, the average is only 16.2% for software projects that are completed on-time and on budget." They further assessed that 52.7% of IT projects will be completed but will be challenged by being over-budget, over the time estimate and will offer fewer functions than originally specified. The study also concluded that the probability of project success goes down as the size and complexity of the project increases. (*The CHAOS report.*1994)

As reported by Alan Zucker in 2016,

> "Over the past two decades, there has been very little change in the (Standish) headline results. On average:
>
> - 29% of projects "succeed" in delivering the desired functionality, on time and on budget
> - 48% of projects are "challenged" and do not meet scope, time or budget expectations
> - 23% of projects "fail" and are cancelled

While there is some year-to-year variability in these scores, the trend line is essentially flat. In other words, we are no better at delivering a project today than we were 20 years ago. However, when you dive into the data, there are some bright spots and markers for improvement:

- Smaller is better
- People are the primary drivers of project success or failure
- Agile projects are far more likely to succeed." (Zucker, 2016)

Empirical observations by the author of approximately 150 projects over a period of 20 years indicate that troubled projects proceed through a progressive set of warning signs until the project either delivers a capability or is cancelled.

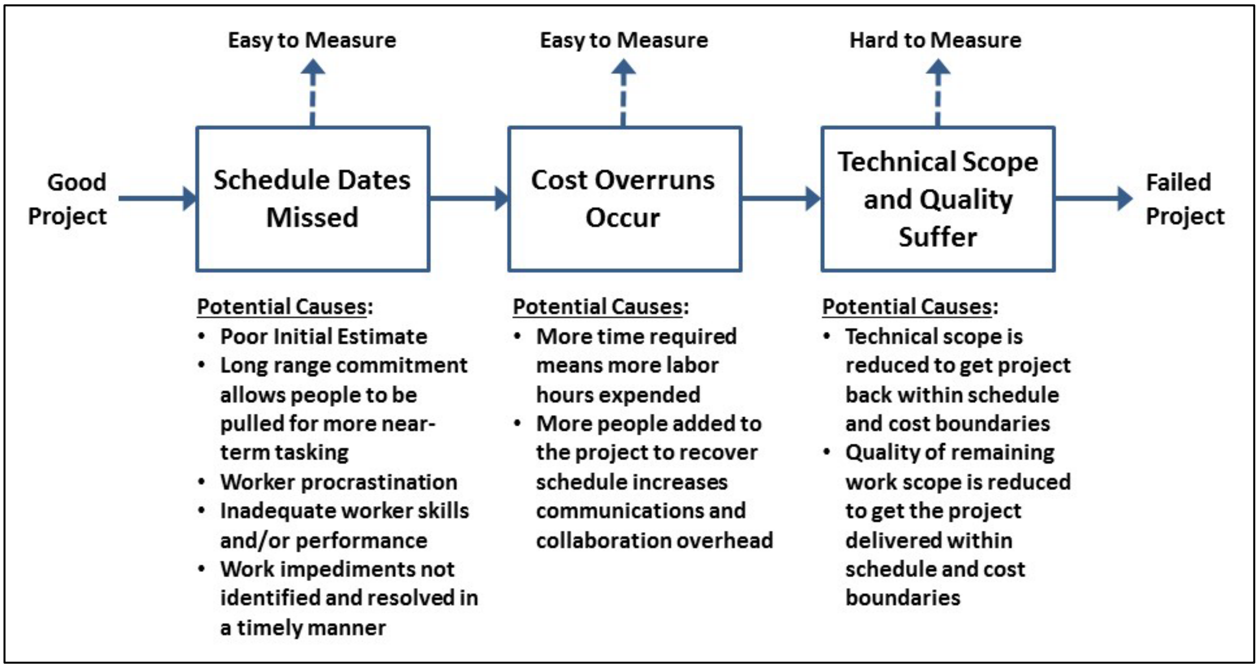

Figure 1: Progressive Warning Signs of Project Stress

The first warning sign of a project under stress is typically seen in planned delivery dates for task completions being missed, or an output is delivered on the scheduled completion date but it is of very poor quality. Figure 1 provides a set of potential causes for schedule dates being missed and nearly all of them relate to worker productivity. Most likely, the reason why missed dates is the first warning sign is because schedule, as a resource, is consumed irrespective of any working being accomplished.

The next warning sign of a project under stress is typically seen as cost overruns. To return the project to its planned schedule means that the existing workforce has to consume more labor hours, or additional personnel resources are added to the project, which again consumes more labor hours. The additional labor hours required for the project may translate into an additional cost for labor for the project. It should also be highlighted that both schedule and cost are two project management parameters that are very easy to collect, objectively measure and report. Thus, these measures provide easy to produce warning signs.

With the project now expanding beyond its bounds of schedule and cost, the last warning sign is to reduce the technical scope of the project to ensure that the most important, value-added features are delivered. But even with a reduction of technical scope, if there are still schedule and cost pressures, then the technical quality of the delivered capability is still reduced. Unfortunately, technical quality is a very difficult parameter to collect and objectively measure.

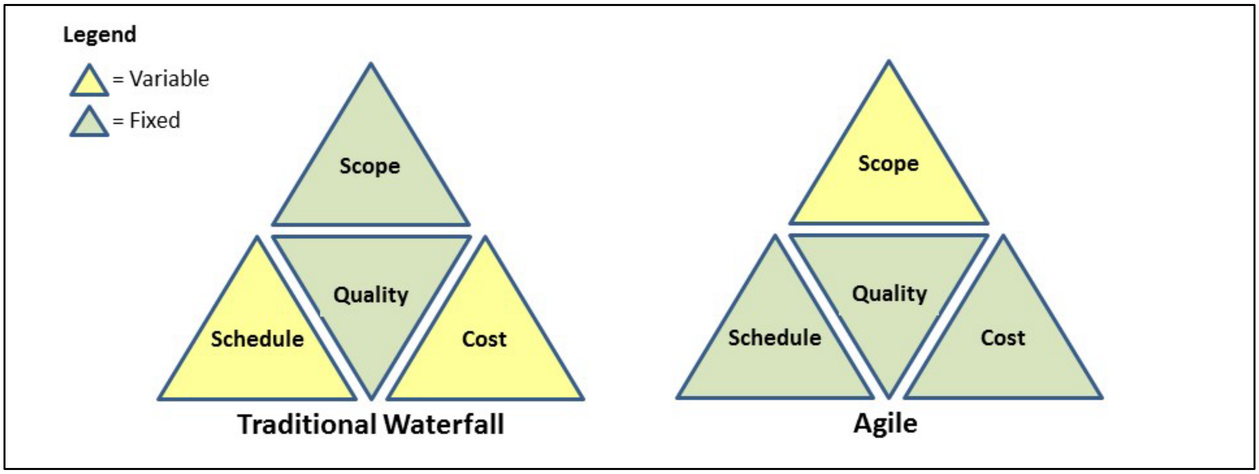

Figure 2: Differences in Traditional Waterfall vs. Agile Cost Variables (Modigliani & Chang, 2014)

Figure 2 provides a diagram that conceptually identifies the major differences between traditional, plan-driven development methodologies, such as waterfall, and agile development methodologies:

> "As illustrated….under traditional waterfall development projects, scope and quality are fixed, while schedule and cost vary and generally increase as requirements are further defined during the project. Agile development projects attempt to fix schedule, cost, and quality while adjusting the scope of specific releases to fit these constraints. The scope of each delivered release is defined by the prioritization of requirements that deliver end-user functionality within the constraints of the cost, schedule and quality parameters. As a result, treating cost as an independent variable drives the prioritization of requirements and facilitates release planning." (Modigliani & Chang, 2014)

In both methodologies, technical quality is assumed to be a fixed entity.

THE MANIFESTO FOR AGILE SOFTWARE DEVELOPMENT

Plan-driven methodologies approach a project's development methodology from a risk-adverse perspective. As Alistair Cockburn writes:

> "We have developed, over the years, an assumption that a heavier methodology with closer tracking and more artifacts, will somehow be "safer" for the project than a lighter methodology….The heavier-is-safer assumption probably comes from the fear that Project Managers fear when they can't look at the code and detect the state of the project with their own eyes. Fear grows with distance from

> the code. So they quite naturally request more reports summarizing various states of affairs and more coordination points." (Cockburn, 2007)

Barry Boehm and Richard Turner voice similar concerns:

> "Plan-driven methods have had a tradition of developing all-inclusive methods that can be tailored down to fit a particular situation. Experts can do this, but nonexperts tend to play it safe and use the whole thing, often at considerable unnecessary expense." (Boehm & Turner, 2004)

In February 2001, a group of seventeen highly knowledgeable, experienced, expert software practitioners met at The Lodge at Snowbird ski resort in the Wasatch mountains of Utah to discuss an alternative to documentation driven, heavyweight software development processes. The result was a Manifesto for Agile Software Development which defined four value statements and documented twelve principles. (Manifesto for agile software development, 2001)

Multiple software development methodologies, such as Extreme Programming (XP), Scrum, Dynamic Systems Development Method (DSDM), Adaptive Development, Crystal, Feature-Driven Development (FDD), and Test-Driven Development (TDD), implement these value statements and principles in different ways, but these software development methodologies provide many advantages to a Project Manager and addresses many of the causes of project failure listed in Figure 1.

For example, all agile methodologies implement a prioritization of requirements mechanism that focuses on the early delivery of the highest value requirements first. As Larry Apake writes:

> "The phrase 'valuable software' reminds us to always be vigilant that we are actually concentrating our efforts on the most valuable stories, those that will give the most return on investment. We should keep in mind the Pareto principle— that we receive about 80% of our benefit from 20% of our stories and that means there is a huge value in the work not done….In 2002, Jim Johnson of the Standish Group….presented findings of feature and functions used in a typical system. The number of features that were never or rarely used totaled a whopping 64% while sometimes, often and always weighed in with 16%, 13% and 7% respectively." (Apke, 2015)

These methodologies also have mechanisms that reduce and allocates the level of commitment for the delivery of capabilities to the customer. For example, the project may only commit to the features in a release that we will be delivered in three to six months. This commitment is then allocated to the features that will be delivered within each iteration of a release. The development of these features is then tracked on a daily basis by the team. From an internal perspective and on a daily basis, each team member is committing to delivering something each day and because of this, it is extremely difficult to pull a team member away to perform another task.

Daily standup meetings improve accountability and reduce procrastination, while also quickly identifying and resolving impediments. Troy Dimes describes daily standup meetings and common challenges in agile methodologies such as Scrum:

> "Every team member gets to talk about what they've already accomplished, what they're planning for the day, and what their impediments are….In the Daily Scrum, the team members aren't really reporting to the Scrum master, but to each other….If a team member consistently fails to do his task on time, it'll reflect on the backlogs. Whether it's due to poor time estimation or even lack of skill, Scrum will eventually bring that into surface, allowing the team to take the necessary steps to ensure that the next sprint happens more smoothly than the last. Scrum makes every team member more responsible since a lot of problems they have would most likely be reflected visually in charts and backlogs. While this may discourage some team members at first, in the long run it helps the team improve as a whole and makes the members more accountable in their own decisions. It teaches team members to be relatively independent." (Dimes, 2014)

Agile methodologies have mechanisms for reporting software development progress. Some methodologies use a visual board which tracks each feature or user story through the iteration to completion. The allows the entire team so visually see progress and determine whether they're about to be late in delivering the product. Similarly, burndown charts show how much work is left each day until the iteration ends. More importantly however, is that each method includes an activity whereby the team has to report the completion of an iteration with an actual demonstration of the working software, a truer measure of progress. Unfortunately, most demonstrations show that features have been developed but rarely gives insight into the actual quality of the software for achieving performance under loads, or the ability of the software to be maintained over the life time of the system.

TECHNICAL DEBT

Although agile methods can reduce the potential causes of project failures, it should be highlighted that agile methods can also introduce a new category of problems; the most significant is the accumulation of technical debt.

> "Software projects often cut corners in the rush to meet deadlines, resulting in bad code….Most of us have experienced occasions where we've been required to take short-cuts to make delivery deadlines….Taking short-cuts generally means that the next time the software is touched, it needs to be fixed before any further work can be done. So the second piece of work is even more expensive to do correctly than the original piece of work, and you can be sure that the deadlines are just as tight as they were the first time. Worse, developers generally prefer to play it safe—if someone has left them a dodgy-looking piece of code, they prefer to leave well enough alone….So, unless there are strong individuals present who are really dedicated to good engineering, the team takes another short-cut and works around the code affected by the previous short-cut. The third change invokes working around the first two short-cuts and so on. If one follows the trend to its logical conclusion, and in my experience many teams do, one finds the code complexity grows at an increasing rate. After several changes to the software, it reaches the point where nothing can be changed without significant time and risk. Usually at some point, the team begins to realize that they need to fix things they've broken. But by then, it's too late because they are spending all their time

> just keeping the fragile system running and have no spare capacity to fix the code. They've painted themselves into a classic Catch 22 situation." (Brazier, 2007)

Ward Cunningham coined the term technical debt as a metaphor for the trade-off between writing clean code at higher cost and delaying the delivery and writing messy code cheap and fast at the cost of higher cost of maintenance efforts once it's shipped (Cunningham, 1992). Frank Buschmann states "Technical debt is similar to financial debt; It supports quick development at the cost of compound interest to be paid later. The longer we wait to garden our design and code, the larger the amount of interest." He then describes various strategies for managing technical debt which includes:

- Debt repayment – initiating a large re-engineering effort to clean up the mess
- Debt conversion – executing an effort that resolves near-term performance problems and reduces maintenance cost, but does not fully retire the debt, similar to refinancing a financial debt to obtain a lower interest rate
- Interest payment – continue to incur the debt and pay the interest through higher maintenance costs
- Debt retirement – Eliminating of the debt by retiring the system (Buschmann, 2011c).

Buschmann discusses three methodologies for gardening systems; refactoring, reengineering and rewriting. Refactoring improves the development quality of a part of system while preserving its functional behavior. It may address the modularization of common code, enhancing component interfaces, or adjusting the flow of code to optimize performance. Refactoring is typically focused on small structural improvements limited to single system elements (Buschmann, 2011a). He describes reengineering as:

> "a systematic activity to evolve the software to exhibit new behavior, features, and operational quality….Reengineering alters the design and realization of software through a series of system-level disassembly and reassembly activities. Its goal can be to:
>
> - improve a system's structural quality
> - boost its operational qualities or
> - provide entirely new functionality" (Buschmann, 2011b)

Lastly, Buschmann states that "if reengineering it too costly, you could consider rewriting. This means replacing an existing system or component with an entirely new implementation….(but) it might be necessary to keep the old system alive while the new one is under development." (Buschmann, 2011b)

The Manifesto of Agile Software Development defines values and principles but does not offer any specific implementation guidance. Applying the values and principles to the specific needs and risks of a project is appropriately left for the Project Manager and team to address. If taken literally and without thought, the execution of the manifesto can introduce technical debt. The remainder of this paper discusses six topics where a Project Manager should focus his team as they initially draft an agile methodology for their project. They are:

- Defining done

- Defining the customer
- Architecture
- Communications
- Documentation
- People

Figure 3 maps these six discussion topics to the affected values and principles in the manifesto.

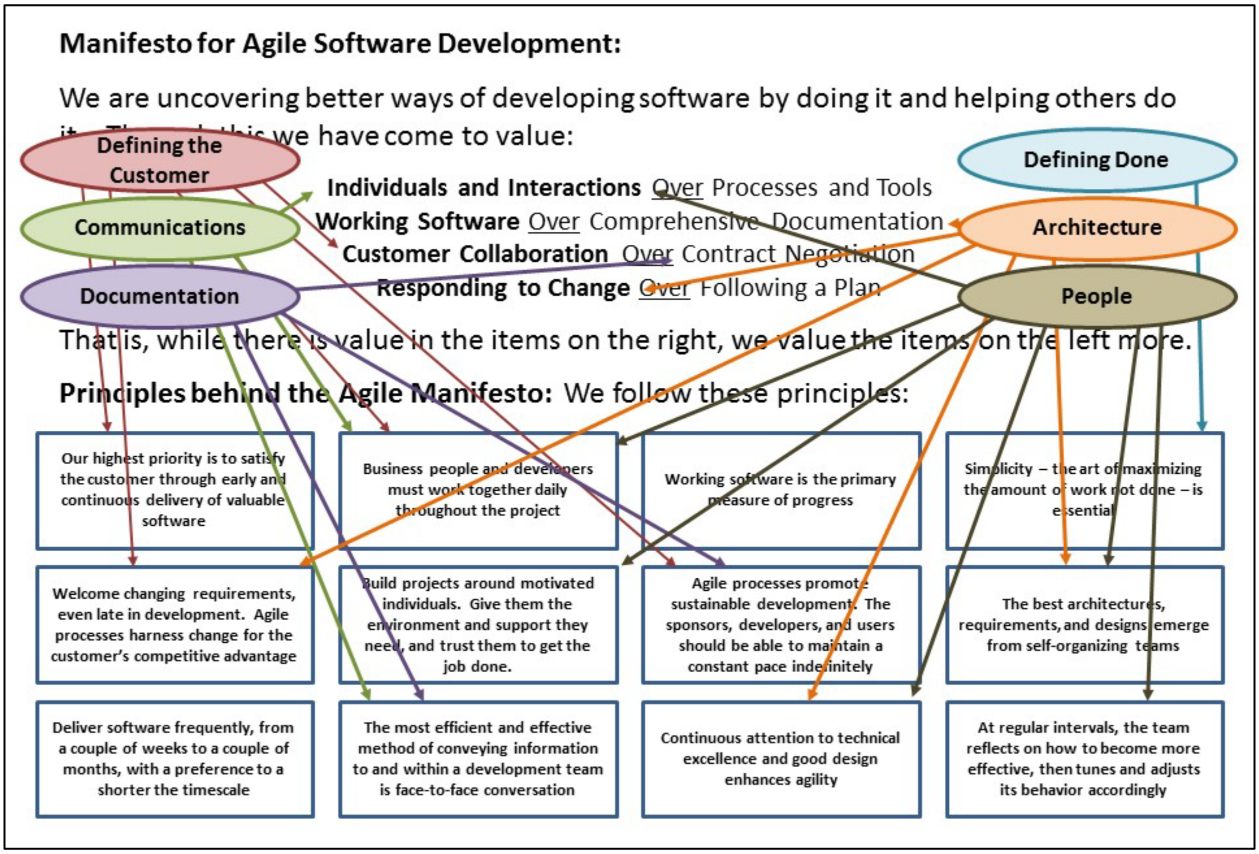

Figure 3: Mapping Discussion Topics to the Manifesto for Agile Software Development

DEFINING DONE

As previous stated, an agile team should concentrate their efforts on the most valuable stories, those that give the most return on investment and that 80% of the benefit comes from 20% of our stories, consequently there is a huge value in the work not done (Apke, 2015). Unfortunately, the principle of "Simplicity – the art of maximizing the work not done—is essential" is frequently interpreted as not needing to perform many routine activities, such as software version control, that ensure the integrity of the system throughout its life cycle. Figure 4 examines the concept of tailoring. The left diagram shows the increasing cost of executing all components of a risk-adverse, plan-driven development methodology. It is generally easy to quantify these costs and consequently they are generally well-known to the project's stakeholders and participants. The middle diagram portrays the risk of not performing one or more components of a methodology. The chart conceptually translates risk into a cost value should the risk be realized. For example, an agile team delivers a system that contains 100 software modules, but then in subsequent releases the team only baselines the subset of modules that changed during the release, thus the work and cost of deploying each individual release is small. Left attended, this deployment methodology could occur many times over many years. But then a disaster occurs in the data center and the system has to be completely rebuilt. This would require the team to go back to the initial release and then re-apply all subsequent releases to bring the system up-to-date. Not only is more time required to rebuild the system, but the organization experiences a longer outage time, which could affect near-term revenue streams as well as long-term organizational reputation. The cost of versioning a complete build release is well known. The risks and costs of not doing something are not easy to calculate but could have a tremendous impact on an organization if realized.

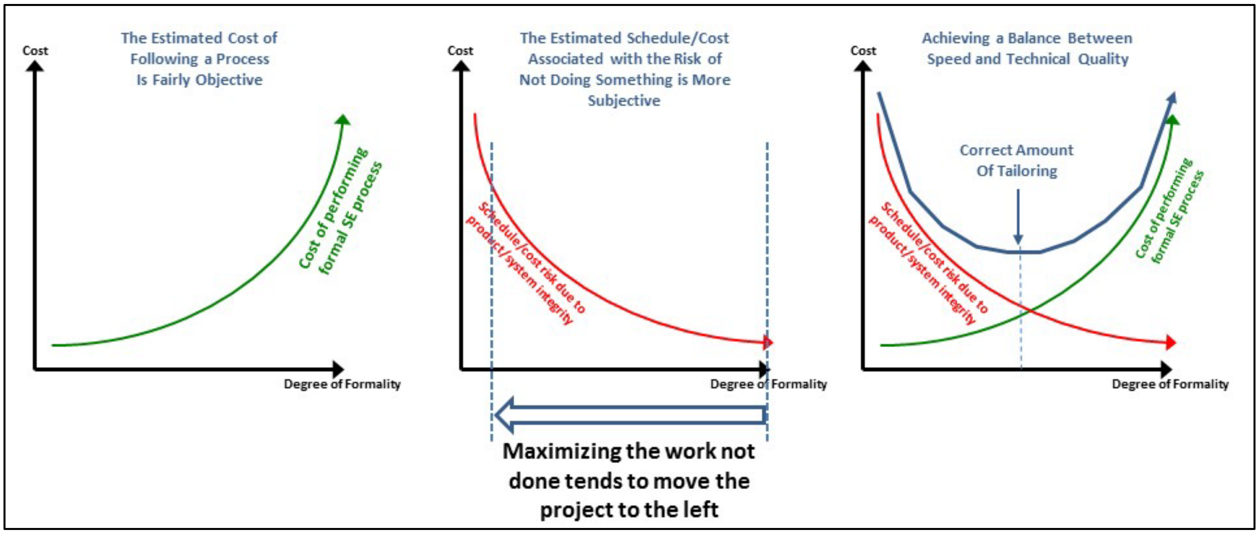

Figure 4: Tailoring Requires Balance Between Risk and Process (Walden, Roedler, Forsberg, Hamelin, & Shortwell, 2015)

The right diagram in Figure 4 identifies a mid-point between being "blind" to these risks and being "adverse" to these risks. This mid-point is defined through a process called tailoring and the mid-point is different for each project.

> "Factors that influence tailoring at the project level include:
>
> - Stakeholder and customers (e.g., number of stakeholders, quality of working relationship, etc.)
> - Project budget, schedule, and requirements
> - Risk tolerance
> - Complexity and precedence of the system
>
> …..Common traps in the tailoring process include, but are not limited to, the following:
>
> 1. Reuse of a tailored baseline from another system without repeating the tailoring process
> 2. Using all processes and activities "just to be safe"
> 3. Using a pre-established tailored baseline
> 4. Failure to include relevant stakeholders." (Walden et al., 2015)

By executing the tailoring process, it should accelerate the team's agreement and understanding on the definition of done.

> "As a recap, potentially shippable products are products that are completed from sprint cycles. In order to be truly completed though, everyone must agree on standard conditions on what completed work really means. One member may view completed work as something that just works whereas another member may view completed work as something that works, has proper documentation, and thorough testing. If team members don't have a unified idea on what completed tasks should be, the performance of the whole team will inevitably decline….Having a unified definition of completed work is especially important if multiple Scrum teams are working on one project….The idea on what's completed and what isn't is a hard one to standardize. People on the mediocre side tend to be more complacent, whereas people in the perfectionist side tend to be more strict and rigid. Their ideas on what 'completed' means will not always coincide, which is why the team needs to work together to have a unified definition of the concept. A unified idea of completion is not something that's achieved overnight, but as teams work on more projects together, soon enough, they'll have a better grasp on what completed tasks should really look like." (Dimes, 2014)

The definition of done can be different for a completed feature/story, for a completed iteration/sprint, and for a release into production.

> "For a user story, the definition may include code completion, the level and types of testing, and (just enough) documentation. For a release, the definition may include more rigorous testing, such as regression testing, certification, product owner approval and release build." (Modigliani & Chang, 2014)

DEFINING THE CUSTOMER

The manifesto includes one value statement and four principles that either specifically use the word "customer" or use similar terms such as "business people" and "sponsor." The manifesto infers that the overall goal is the continuous delivery of valuable software for the customer's competitive advantage. To appropriately define customers, then there needs to be some definition of who will either create or obtain value from the software. Table 1 provides an overview of the many entities that comprise this value stream.

The agile methodologies typically assign a person to represent the needs of the customer. The person, called the Product Owner is Scrum, manages the product backlog and defines and accepts completed features or user stories. In many situations, the Product Owner typically represents the customer and operators of the system and they are focused on the delivery of new functions or features of the system. They may have insight into how the timely delivery of specific functions and features will provide a competitive advantage in the market place. Unfortunately, very few Product Owners have the technical expertise to ensure that non-functional requirements, such as performance under-load, availability, disaster recovery, and information security are addressed to ensure business continuity and customer reputation are maintained in the market place.

Table 1: Entities That Create or Obtain Value from the Software

Type of Customer	Position in the Value Chain
Shareholders, Owners, Corporate Executives, Sponsors	Revenue and profit generation through reputation, business continuity and competitive position in the market place
Customers of the system	Willing to pay money to obtain the services provided by the company and its systems (e.g., travelers on an airline)
Operators of the system	Use the system to deliver value to paying customers (e.g., airline travel agents, gate clerks, baggage handlers, customer service representatives)
Maintainers of the system	Keep the system up and running such that value can be continuously delivered (computer support technicians)
Developers of the system	Develop new and updated capabilities that provide more value to the organization (future developers)

System maintainers are focused on functions and features that either prevent a system outage or minimize the duration of an outage. They are also interested in capabilities that minimize the manual effort required to keep a system operating at peak efficiency. As application software becomes more complex and hardware setup and operating system provisioning, especially in a cloud environment, are now being executed through software provisioning scripts, system maintainers are now becoming members of agile teams through a practice called DevOps.

Lastly, future developers of the system need to be considered in this definition of the customer. Agile methodologies embrace the notion that the system will be continuously changing over its life cycle and thus any system decisions must embrace the ability to make change. As Dave Thomas, one of the authors of the manifesto, states "A good design is easier to change in the future than a bad design….When faced with two more alternatives that deliver roughly the same value, take the path that makes future change easier." (Thomas, 2015)

ARCHITECTURE

The manifesto has one value statement and two principles that affect architecture. One states that "the best architectures, requirements, and designs emerge from self-organizing teams" while the other two state that the team should welcome and respond to change for the customer's competitive advantage. Implementing these elements without applying energy to architecture can have serious consequences. As Roger Sessions states:

> "Architectures naturally seek the maximum possible level of complexity all on their own. If it is a complex architecture you are after, you don't need architects. You might as well just fire them all and let developers work on their own. This observation that architectures are naturally attracted to complexity is actually predicted by physics—in particular, the law of entropy. This fundamental law of physics states that left to their own, all systems evolve into a state of maximal disorder (entropy). It takes a constant inflow of energy into a system to keep the disorder at bay. In this regard, enterprise architectures are just another natural

system, like gas molecules in a balloon. The law of entropy tells us that the battle for simplicity is never over. It requires a constant influx of energy to keep enterprise systems simple. It isn't enough to design them so that they are simple. It isn't enough to even build them so that they are simple. You must continue working to prevent an erosion of simplicity for the life of the system. In this sense, the work of the enterprise architect is never done." (Sessions, 2008)

Successfully incorporating architecture into agile projects is a difficult balancing act.

> "Companies where architectural practices are well developed often tend to see agile practices as amateurish, unproven, and limited to very small, Web-based sociotechnical systems. Conversely, proponents of agile approaches usually see little value for a system's customers in the upfront design and evaluation of architecture. They perceive architecture as something from that past, equating it with big design up-front (BDUF)—a bad thing—leading to massive documentation and implementation of YAGNI (you ain't gonna need it) features. They believe that architectural design has little value, that a metaphor should suffice in most cases, and that the architecture should emerge gradually sprint after sprint, as a result of successive small refactoring….The tension seems to lie on the axis of adaptation versus anticipation. Agile methods want to be resolutely adaptive: deciding at the 'last responsible moment' or when changes occur. Agile methods perceive software architecture as pushing too hard on the anticipation side: planning too much in advance." (Abrahamsson, Babar, & Kruchten, 2010)

Grady Booch provides insight into the birth and maturing of many systems and the need for architecture:

> There are many examples of notable systems that began with the code of one or two people and grew to become a dominant design: the packet-switched multiple-protocol router, first developed by Bill Yeager; a graphics editing system, first developed by Thomas and John Knoll; a social network, first popularized by Mark Zuckerberg. The list goes on. In each of these cases, architecture was not a primary concern. I'd be surprised if it was on their radar at all, save for the reality that each of these developers had the chops, the experience, and the intuition to deliver something Good Enough that could be grown….Quite often, the developers who did the internal exploration are not the most skilled at production. Furthermore, the risk profile changes, and the success of a system is less dependent on rapid innovation and much more dependent on quality and efficiency in manufacturing and delivery….it's also these times that intentional architecting becomes intensely important." (Booch, 2011)

The following discussion provides insight into the application architecture processes into an agile activity:

> "Do not dilute the meaning of the term architecture by applying it to everything in sight. Not all design decisions are architectural….(apply architecture) early enough because architecture encompasses the set of significant decisions about

> the structure and behavior of the system. These decisions prove to be the hardest to undo, change, and refactor, which means to not only focus on architecture, but also interleave architectural 'stories' and functional 'stories' in early iterations….User stories in agile development relate primarily to functional requirements; this means that nonfunctional requirements can sometimes be completely ignored. Unfulfilled nonfunctional requirements can make an otherwise functioning system useless or risky. A main objective of integrating architectural approaches in agile processes is to enable software development teams to pay attention to both functional and nonfunctional requirements." (Abrahamsson et al., 2010)

Richardo Valerdi identifies five reasons for why architectures matter:

> "First, they enable designers to document assumptions and understand the structure of their creation….Architects use architectural patterns that leverage reusable solutions to commonly recurring problems….Second, architectures provide the ability to establish design baselines and perform trade studies, also known as 'what-if' analyses….Third architectures help clarify details at the micro and macro level. End users might be interested in the detailed design as it affects efficiency, security and implementation. Owners might be interested in business requirements and environmental contexts of a system that may change over time, such as legal, social, financial, competitive, and technology concerns. Fourth, architecture allows reuse of components between projects….Fifth, architectures provide insight into the maintainability of a product. The architecture that is originally implemented might change over time as improvements are introduced. This change might cause an architectural drift between the planned and actual architecture of the product as realized in his implementation….The gap between the planned an actual architectures is sometimes understood in terms of technical debt." (Valerdi, 2014)

COMMUNICATIONS

In its simplest form, communication is the transfer for data, information, or knowledge from one entity to another entity, however it is an extremely difficult activity to perform:

> "Communications is never perfect and complete. Such a thing is not even possible. Even assuming for a moment that you, yourself, know what you intend, the receivers of the communication must jump across a gap at some point and must jump it all on their own. People with similar experience can jump a large gap, working even from mumblings and gestures. The more different another person is from you, the smaller the communication gap that he can jump. You have to back up, explain basic concepts, and then work forward until he builds his own bridge of experience and understands what you are saying. There is no end to this backing up. No matter how much you back up, there is always someone who will not understand." (Cockburn, 2007)

Multiple organizational knowledge theories recognize to major types of knowledge; explicit and tacit.

> "Explicit knowledge refers to the knowledge that can be translated into formal, systematic language. It is knowledge that can be written, documented and widely distributed. Tacit knowledge is considered to be that which you know, but have difficulty explaining. It is often called 'hidden knowledge' because it is difficult to explicate, such as explaining to someone how to ride a bicycle. Tacit knowledge has a personality quality that makes it hard to formalize. Therefore, it is deeply rooted in action and commitment to a very specific context….Explicit knowledge is easy to articulate and verbalize, systematic and objective, rational and logical, digital, sequential, comes from the past, and free of context. By contrast, tacit knowledge is difficult to articulate and verbalize, subjective, linked to experience and emotions, analogue, simultaneous, refers to the present and context dependent. Therefore tacit knowledge is deeply rooted in action, procedures, routines, commitments, ideals, values, and emotions. From this assertion, it follows that tacit knowledge includes technical-expert elements as well as cognitive ones. In other words, it involves the skills, experience and capabilities, mental models and precepts." (Salmador & Florín, 2013)

Table 2 provides a brief summary of the SECI model which describes various modes for the transfer and conversion of tacit and explicit knowledge.

Table 2: SECI Model for Knowledge Transfer (Annukka Jyrämä & Anne Äyväri, 2007)

Concept	Definition	Conversion Modes
S – Socialization	The process of converting new tacit knowledge through shared experiences	Tacit-to-Tacit Knowledge Conversion
E – Externalization	The process of articulating tacit knowledge into explicit knowledge	Tacit-to-Explicit Knowledge Conversion
C – Combination	The process of converting explicit knowledge into more complex and system sets of explicit knowledge	Explicit-to-Explicit Knowledge Conversion
I – Internalization	The process of embodying explicit knowledge into tacit knowledge	Explicit-to-Tacit Knowledge Conversion

It is argued that innovation is largely based upon the continuous exchange between tacit and explicit knowledge (Salmador & Florín, 2013).

In developing a framework for collaborative knowledge creation, Salisbury assesses the skill levels of various people within a team. As shown in Figure 5, novices rely more on explicit forms of knowledge, such as documentation and instructions, whereas experts use more tacit forms of knowledge, such as obtaining expert advice, to obtain the knowledge they require (Salisbury, 2008).

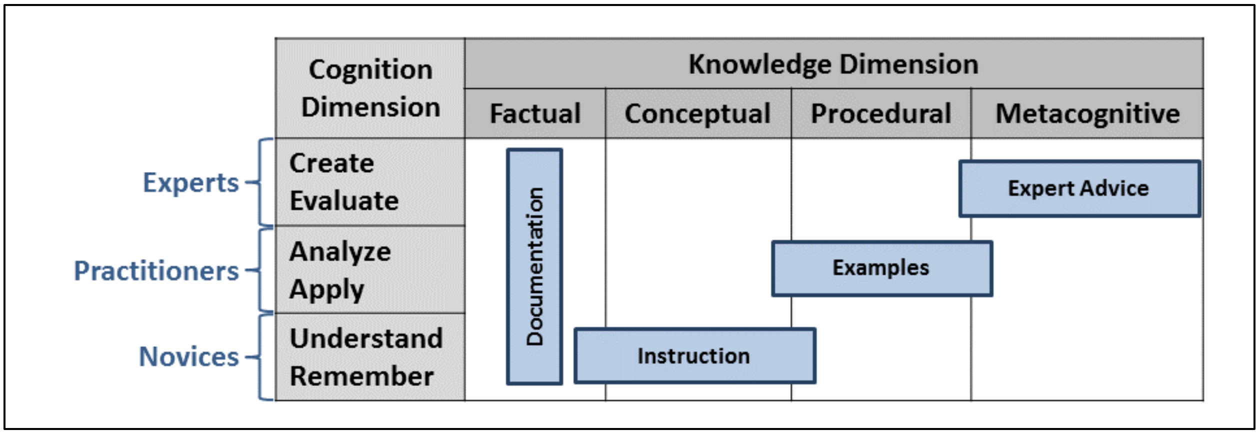

Figure 5: Differentiating Leaners and the Knowledge They Seek (Salisbury, 2008)

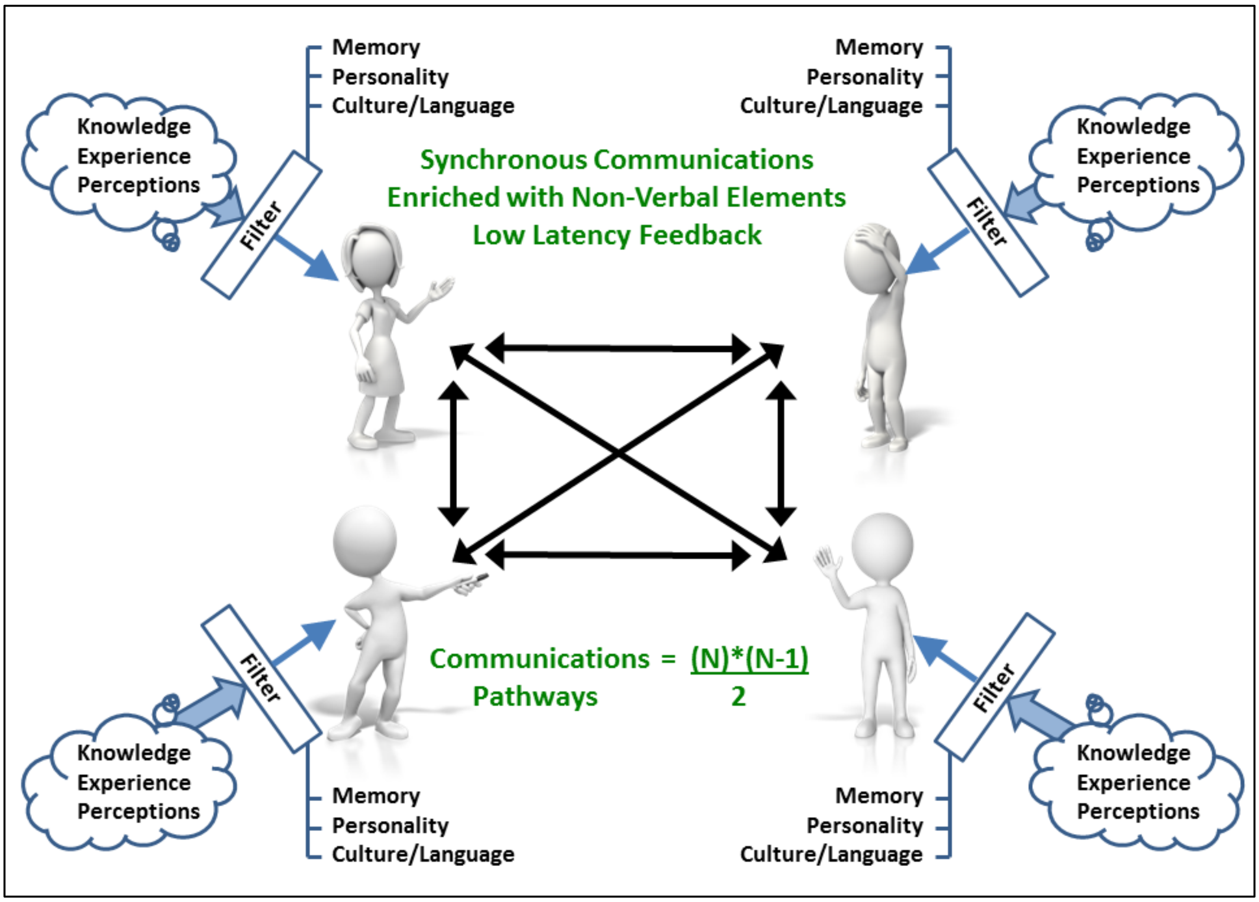

Figure 6: Face-to-Face Communications

The manifesto has one value statement and two principles related to communications, of which the strongest principle states "The most efficient and effective method of conveying information to and within a development team is face-to-face conversation." (Manifesto for agile software development, 2001) As shown in Figure 6, face-to-face communications has multiple advantages. First, the information and knowledge exchange is enriched with non-verbal clues which gives additional insight into the level and confidence of the information exchange. It also allows each participant to ask and respond to questions in a very interactive dialog. The conversation topic is generally restricted to the information required for a specific contest, thus the information exchange rate has low latency. However, there are also disadvantages. First, the communication pathways are synchronous, meaning both parties must be present at the same time for the exchange or information. Critical knowledge could quickly be lost if a critical team member leaves the project. Next, the number of possible communication pathways rapidly increases as more members are added to team. Thus, there is no guarantee that the same information will be consistently communicated to all team members. Face-to-face communications allows one team member to draw on the knowledge, experience, and perceptions of another team member, but access to that knowledge may be impeded or filter by many factors, such as a person's ability recall from memory, his personality to willingly share information, and/or his cultural background and language abilities to conduct a meaningful information exchange.

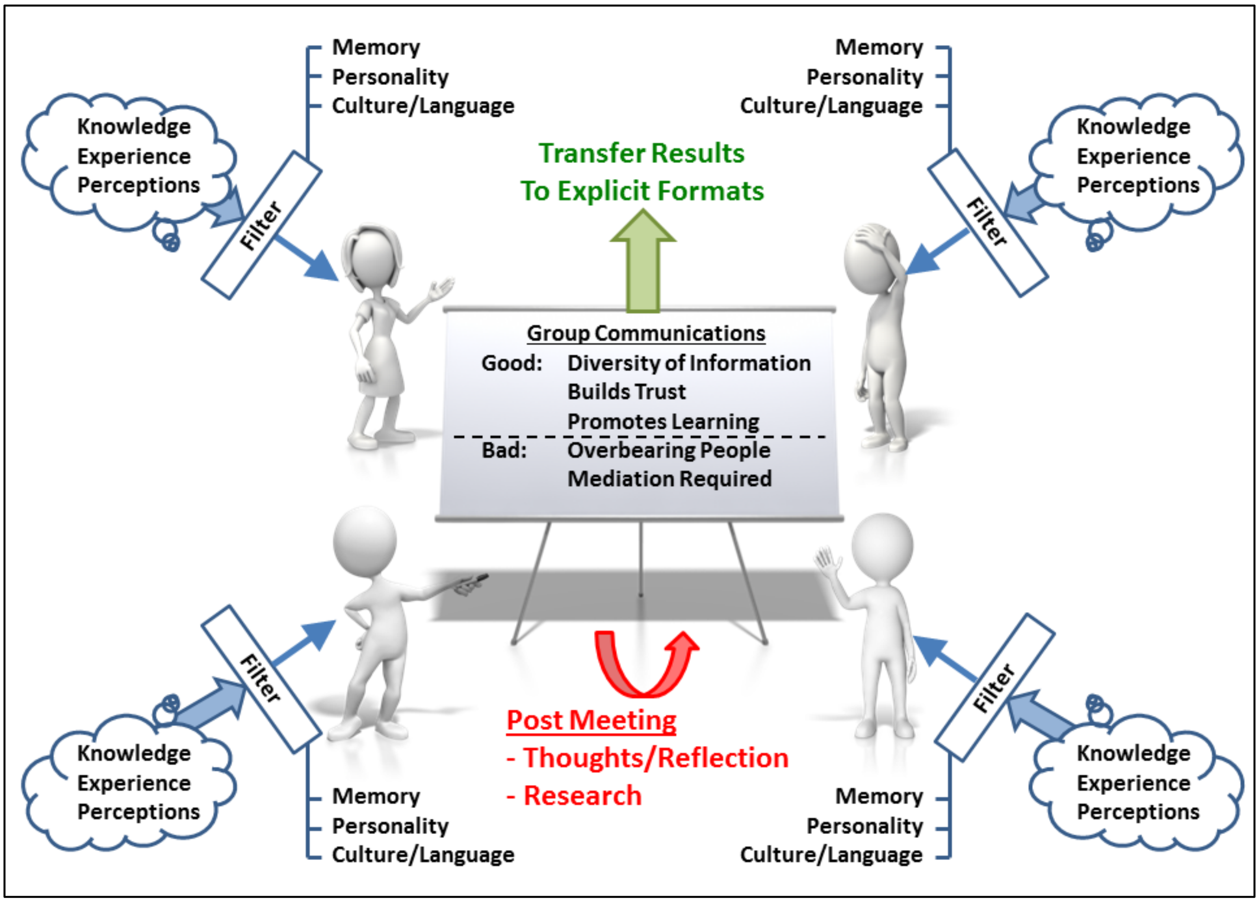

Figure 7: Face-To-Face Communications in a Group Setting

As shown in Figure 7, face-to-face communications in a group setting brings additional dynamics to the information exchange. A group setting allows for the greatest access to the entire diverse set of information within the team. If the group setting is conducted in a professional manner, it can build trust promote shared learning throughout the team. However, group meetings can be become very disruptive based on the personality of a single team member. Likewise, if multiple strong personalities are present and a meditating entity is not identified, then group direction moving forward may not be reach. Group settings allow new information to presented, or identify the need to research new information pathways. Consequently, it is quite possible that multiple group meetings may be required to successfully arrive at a conclusion. Building and documenting team consensus is not an easy process and tools are being developed to support this process. For example, MITRE has developed an Agile Capability Mashup Environment (ACME) that uses low cost tools, such as horizontal whiteboards, cut outs, and webcams, to quickly develop, communicate, and document in an explicit knowledge format, project level knowledge outcomes based on individual knowledge inputs (Hall & Weiss, 2016).

Needless to say, both tacit and explicit forms of communications are required for a project to be successful.

DOCUMENTATION

In reviewing the literature, the phrase "comprehensive documentation" is directly associated with the concept of big up-front design (BUFD) where all elements of a system's design are completely thought out and documented before any software coding begins. This massive amount of documentation then quickly falls out of sync soon after development starts (Erdogmus, 2009). As previous discussed, agile teams need to be concerned about the system's architecture but "what is architecture" versus "what is design" may not be obvious.

> "What does a particular project or organization mean by architecture? The concept has fuzzy boundaries. In particular, not all design is architecture. Agreeing on a definition is a useful exercise and a good starting point….Do not dilute the meaning of the term architecture by applying it to everything in sight. Not all design decisions are architectural. Few are, actually, and in many projects, they're already made on day one." (Abrahamsson et al., 2010)

Grady Booch offers these insights:

> "As I've often said, the code is the truth, but not the whole truth, meaning that there are certain architectural decisions that cannot easily be discerned in the code itself. This is so because such decisions are manifested as mechanisms that are either scattered or tangled throughout the code, their meaning and presence are in the heads of the code's creators and not easily evident by staring at it (the code)….It's these bits of architectural decisions that are best documented elsewhere, external to the code base. Such decisions often live in tribal memory, in the heads of people. This is fine when the team is small, but when the system grows to economic significance, tribal memory is a particularly noisy and inefficient repository of architecture.
>
> The architectural mechanisms that are not baked into the code and thus are in the heads are the things you want to (a) take time to document and, where possible, (b) create a domain-specific language that is baked into the code to implement it. My experience is that every reasonably software-intensive system will have a couple dozen such architectural mechanisms…..These are the kinds of decisions that can be documented in a static document of two or three dozen pages—any longer and no one will read it….this artifact becomes a vehicle for orienting new

> folks to the code based as well as attending to some degree of architectural governance, whose simple goal is getting people to continue to grow the system according to those architecture principles." (Booch, 2011)

Alistair Cockburn shares similar advice:

> "the designer's job is not pass along 'the design' but to pass along 'the theories' driving the design. The latter goal is more useful and more appropriate. It also highlights that knowledge of the theory is tacit in the owning, and so passing along the theory requires passing along both explicit and tacit knowledge."

Cockburn then promotes a Theory Building View of a system and then summarizes by providing these recommendations for what should be put into documentation:

> "*That which helps the next programmer build an adequate theory of a program.* This is enormously important. The purpose of the documentation is to jog memories in the reader, set up relevant pathways of thought about experiences and metaphors. This sort of documentation is more stable over the life of the program than just naming the pieces of system currently in place. The designers are allowed to use whatever forms of expression are necessary to set up those relevant pathways….Experienced designers often start their documentation with just:
>
> - The metaphors
> - Text describing the purpose of each major component
> - Drawings of the major interactions between the major components
>
> These three items alone take the next team a long way to constructing a useful theory of the design….Documentation cannot—and so need not—say everything. Its purpose is to help the next programmer build an accurate theory about the system." (Cockburn, 2007)

For a client who had incurred tremendous amounts of technical debt caused by the absence of credible explicit knowledge and about his technical systems, the author was asked to identify, in priority order, those items that need to be explicitly described and the following was recommended:

1. Any knowledge that defines to users, operators, and maintainers how to operate and maintain the system
2. Any knowledge that describes how to rebuild and redeploy all the system, should a disaster occur
3. Any knowledge that is used to verify that system that been successfully rebuilt and redeployed such that it can again support the business
4. Any knowledge that allows future personnel to modify the system over its life cycle

PEOPLE

The manifesto places tremendous reliance on the skills, qualities, and talents of the individuals that comprise an agile team. Team members must be motivated, trustworthy, interactive, reflective, able to work at a constant pace indefinitely, and collaboratively work within a self-organizing team. Boehm and Turner describe the:

> "critical factors for agile methods include amicability, talent, skill and communication… and that both (agile and plan-driven methods) operate best with a mix of developer skills and understanding, but agile methods tend to need a richer mix of higher-skilled people…The plan-driven methods of course do better with great people, but are generally able to plan the project and architect the software so that less-capable people can contribute with low risk." (Boehm & Turner, 2004)

Vidgen and Wang define that "self-organization is the ability of interconnected autonomous agents of a complex adaptive system to evolve into an organized form without external force." (Vidgen & Wang, 2009) Glenda Eoyang provides a variance on this definition by stating that it is a "process by which the internal dynamics of a system generates system-wide patterns" but also adds that the system must be pushed away from thermodynamic equilibrium into a significant nonequilibrium region to require change. She identifies the following three necessary conditions of self-organization:

- Container – a bounding condition that distinguishes a system from its environment
- Significant difference – a distinction within a system that establishes a potential generative tension, which represents the potential for change
- Transforming exchange – A transfer of information, resources, or energy among system agents that results in changes within the agents and/or changes in system-wide patterns (Eoyang, 2001).

It should be highlighted that self-organization may not always occur for goodness, but simply represents internal dynamics that generates system-wide patterns.

For agile teams, the container is the value-added capabilities which the customer is requesting. Significant difference is closely related to the motivations of people and Cockburn discusses the following three potential intrinsic motivators for agile team members:

- Pride-in-work
- Pride-in-accomplishment
- Pride-in-contribution (Cockburn, 2007).

In the realm of transforming exchange, Kristina Grumadaite identified multiple factors that affect knowledge sharing in a self-organized system. She groups these factors based on culture, personal, and organizational characteristics (Grumadaite, 2013). Takpuie and Tanner developed a theoretical model shown in Figure 8 that defines and links various characteristics needed by Scrum team members to successfully transfer tacit knowledge during an agile software project (Takpuie & Tanner, 2016).

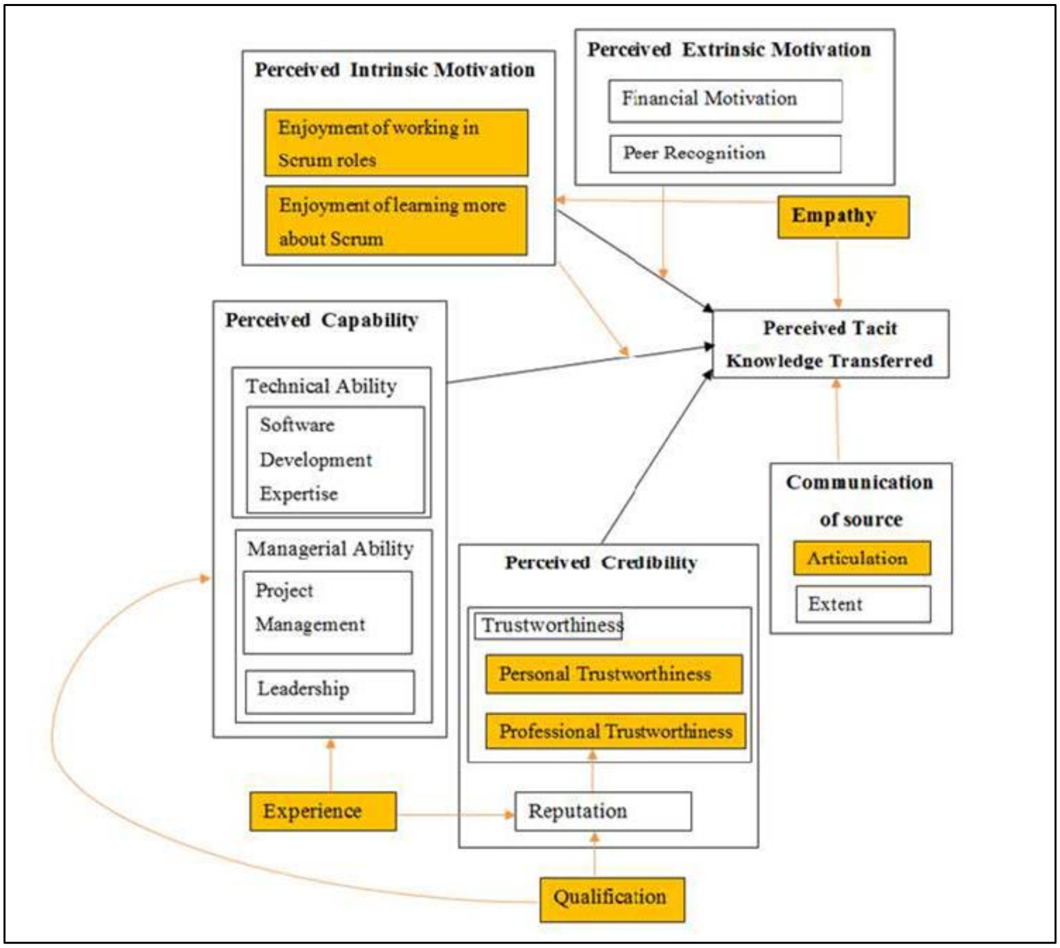

Figure 8: Theoretical Model for the Characteristics of a Scrum Team Member (Takpuie & Tanner, 2016)

CONCLUSIONS

The following conclusions can be obtained from this paper:

- Projects can experience a progressive set of warning signs indicating project stress
- Agile methods can address these warning signs by placing requirements prioritization at the beginning of project, and then only committing the team to deliver a release that is progressively constructed through daily tasking and demonstrated at the end of periodic iterations.
- Because agile methods assign time-boxes to the delivery of features, an inherent risk in agile methods is the introduction and accumulation of technical debt
- To ensure technical quality is not reduced the following recommendations are provided:
    - Provide a definition of done for features/stories, iterations/sprints, and releases.
    - Expand the definition customer to ensure that non-functional requirements and long term project life cycle concerns are addressed.
    - Incorporate architecture concerns into the project such that non-functional and future functional requirements can be anticipated.

- Communication mechanisms must incorporate both tacit and explicit knowledge mechanisms, realizing that innovative teams effectively implement both mechanisms.
- When developing documentation, focus on those artifacts that provide others with the architectural constructs of the system. The software code does not represent the theory of the system but future developers need this awareness as they continue to modify the system over its life cycle
- Agile methods place significant reliance on the skills, qualities, and talent of the individuals that comprise the team. A model for the characteristics of a successful agile team member is provided and should be used in the identification and selection of people for inclusion in agile projects.

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Big data in construction projects: Risk and opportunity management

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Abstract

Bid data in construction projects has become the trend as the construction industry is bridging the gap for productivity and embracing disruptive and innovative technologies that rely on large volume of data and information. This presentation will emphasize a value assessment of big data in construction projects. Within a project management framework and using the data information from Virtual Design Construction (VDC) models and project data compiled using Unmanned Aerial Systems or drones throughout construction projects, we will:

· define and discuss the risks associated with big data such as data security and privacy, and bad data or analytics in construction projects.
· identify the value of opportunities and benefits of big data for design and construction projects.

Introduction

The daily business and human activities in the 21st revolves around capturing, handling, sorting or analyzing petabytes (10^{15} bytes). On a daily basis, Google deals and processes about 24 petabytes or 24,000 terabytes. By analogy, that's about 17,500 Trillion full floppy disks. On the other hand Facebook gets more than 10 million photos per hour [1].
Big data is not just about the 4 V's volumes, variety, velocity and veracity. For business enterprise and full integration s it has to add value.
In big data, volume is what makes data "big". Over the past 5 to 6 years data storage has been increasing exponentially. Variety in data is a bit more complex because not all data is structured the same way. Unstructured data like pictures or videos is what makes big data analytics powerful Veracity such as accuracy or trustworthiness and the dynamic velocity, frequency of data are some key challenges and potential risks from a management viewpoint. The value of data capturing, processing and analysis will vary from one sector of application to another.
A good example of value added to big data, retail giants like Walmart or Amazon use data mining to identify, predict and react in real time to customers' expectations (2)
In the construction industry, as in all other sectors, big data refers to the huge quantities of information that have been stored in the past and that continue to be acquired today. However, the construction industry has been lagging behind on integration or implementation of innovation and other mechanisms for change. Although the volume of data may not be as "big" as that of retailers or financial institutions, construction companies get to deal with very heterogeneous quantities of information from drawings, material supply, work breakdown schedule to specs, As data gets bigger and bigger, the need to boil it down to the actionable essentials gets bigger too.

In a survey of construction companies conducted by a software vendor [5] it was found that:

- 57% want consistent, up-to-date financial and project information.
- 48% want to be warned when specific situations occur.
- 41% want forecasting, allowing them to better prepare for best and worst-case building events.
- 14% want online analytics to see for instance precisely which factors are affecting profitability and by how much.

In comparison to other industry sectors, one of the challenges that the construction industry has been facing is a low level of productivity. Many factors or causes have been identified by numerous research, reports and analyses (6). A PMI study from 2013 has also identified the risks for project failure due to poor communication. Hence, over 7% of projects cost is put at risk by ineffective communications, indicating a critical need for organizations to address communications deficiencies at the enterprise level. Whether the cause is related to human factors, or a technical issue it is ultimately a management issue on how to make the project successful on time, on budget with the same quality. Therefore, big data analytics can enable or offer opportunities to address or improve each of the aspects identified as a priority. The variety of inputs in big data allows better levels of certainty about status reports and forecasts. The analytics can provide more helpful indications of levels of risk before a threshold is exceeded and an alert generated. This paper offers an overview of some of the risks and challenges of big data with the integration of BIM and Unmanned Aerial Systems in the management of project on the basis of big data analytics.

This paper will offer a short insight on big data in construction, the challenges and opportunities [particularly when integrating large data input from the integration of Building Information Modeling and Unmanned aerial systems.

What is big data in construction?

Building information modeling (BIM) and virtual design construction (VDC) have disrupted the construction sector bringing information and communication technology (ICT) into the realm of construction project management. Building Information Modeling (BIM) can be defined as a reliable, digital, three dimensional, virtual representation of the project to be built for use in design decision-making, construction scheduling and planning, cost estimates and maintenance of construction projects

Building Information modelling also known as BIM and often also referred to as Virtual Design and Construction VDC, was introduced as a conceptual model with object based design, parametric manipulation and a relational database; which was developed much later into a visual display of conceptual design. Integration of BIM in construction has significantly grown over the last 10 to 15 years. BIM has firstly extended the traditional 2D (planar) technical drawings (plans, elevations, sections, etc.) to a 3D design and furthermore adding time to the three primary spatial dimensions (width, height and depth) to what is defined as a BIM fourth dimension (4D). With cost as the fifth dimension, BIM 5D thereby provides the key attributes of a construction project. Often BIM 4D is what allows for the visual animation of projects, but fundamentally it enables progress tracking of construction projects.

When drones are used in construction: a flight of 30 minutes over a 150 acres site can generate millions of data points in 3D models. Data analytics can deliver any distance or volume measurement in few minutes.

BIM and Unmanned Aerial Systems are some of the most innovative technologies that the construction is slowly adopting. However, big data in construction is not just limited to construction phase of a project. In fact with increasing demand and delivery of green and sustainable buildings constant monitoring of facilities for total building performances generates multiple layers of data and information.

What is the current state for big data in construction?

The construction sector has always been slow to adopt innovation at a larger scale because of the risks that can be associated with anything new that has not been well tested. Often associated with prohibitive costs of investment in innovation, the fact that the construction operates with multiple stakeholders who don't necessarily have the same stake in a project creates a barrier to adoption.

Current use of data analytics in construction can include various applications including but not limited to: identifying causes of construction delays, learning from post-project reviews (PPRs) decision support for construction litigation, detecting structural damages of buildings, identifying actions of workers and heavy equipment. Big data in construction is currently heavily used for: tracking construction equipment, various simulations before construction and after construction with construction time laps, and construction site organization. .

One type of project delivery system of contractual agreement for construction that subscribes ideally with the value principle of big data is the design-build-operate model where the lifecycle increasingly defines construction projects. Below are some examples of how data capturing and collection is used at the various level in a D-B-O type project.

1. <u>During the Design phase.</u> Big data, including building design and modeling itself, environmental data, stakeholder input and social media discussions during programming phases, can be used to determine not only what to build, but also where to build it. Brown University in Rhode Island, US, used big data analysis to decide where to build its new engineering facility for optimal student and university benefit (9). Drones are used to survey construction sites. Lessons learned from previous projects failures and successes are increasingly presented and brought forward at the bidding or tendering process to adjudicate for specific proposals or designs.
2. <u>During the Construction Phase:</u> Big data from weather, traffic, and community and business activity can be analyzed to determine optimal phasing of construction activities. These can also be used during the planning phase. Sensor input from machines used on sites to show active and idle time can be processed to draw conclusions about the best mix of buying and leasing such equipment, and how to use fuel most efficiently to lower costs and ecological impact. Geolocation of equipment also allows logistics to be improved, spare parts to be made available when needed, and downtime to be avoided. Dons used to capture and monitor construction progress, or check on site safety

3. <u>During the operation phase</u> Big data from sensors built into buildings, bridges and any other construction makes it possible to monitor each one at many levels of performance. Energy conservation in malls, office blocks and other buildings can be tracked to ensure it conforms to design goals. Traffic stress information and levels of flexing in bridges can be recorded to detect any out of bounds events. This data can also be fed back into building information modeling (BIM) systems to schedule maintenance activities as required.

Sustainable high performance building currently has the capacity to generate and create valuable information and data. Some of it is automated and "smartly 'processed to for example turn off lights or adjust and control temperatures. A big gap however remains on full data analytics to learn from the data captured not to simply react but build on it towards even other decision making processes.

Do the benefits outweigh the risks?

Most notably the integration of BIM with unmanned aerial systems provides the construction industry with a very powerful tool to make all construction projects not solely successful during the construction management but throughout the whole life cycle. The ability to timely identify issues of material supply chain to site or weather unforeseen conditions can be analyzed and interpreted to reduced risks making project management more effective.

The risks associated with big data are not unique to the construction sector and can directly relate to change in processes, methods, or management. Because of the newness of the technology and the fact that it relies on various skills may impede or limit strong enthusiasm for adoption until the innovation has demonstrated and showcased it can add value.

Risk averse adopters or reluctant to change managers and/or contractors and builders will use the followings against widespread use of tools that capture and then analyze information often available that could otherwise be wasted. Some of the risks are: data security, data privacy, costs, bad data, and finally bad analytics.

Big data analytics can enable opportunities to improve. BIM in construction has demonstrated the capacity to save project costs by up to 20%. Aside from reducing miscommunication between the various stakeholders, such as designers, engineers and contractors BIM reduces requests for information (RFIs) by making all the information viewable and accessible to all stakeholders. For the construction design of a facility in Portland Oregon, Portland state University and Oregon State University have save over $10 M in hourly wage and paper required to make drawings and all the building specifications (12). The data from the BIM model can then be used for construction progress and facility maintenance.

Big data is not a new concept by any stretch of the imagination. It has been around for quite some time but is only now beginning to make its way into the construction industry. This leap into construction has offered a few specific benefits such as: increase capacity to solve problems using information already available; value added ability to enable certainty and thereby reduce some risks; all these benefits however, imply well-organized processes and effective communication w construction projects or organizations.

The last few words

- Is big data a new concept? Definitely not
- Is Big Data Innovative? Absolutely
- Do the benefits outweigh the risks? Of course; Big data analytics is actually an enabler to risk prevention and immediate mitigation
- Is big data costly? Cost of big data will always be directly related to the volume of input data and information, the speed at which it is processed and analyzed to render it usable for other value added decision making or processes. However, larger amounts of data mean you can more accurately track your performance. This includes project profitability and efficiency.

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Circular Construction: Opportunities and Threats

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ABSTRACT

The construction industry is one of the largest consumers of raw materials. Very little of the wastes generated from its activities are recycled or reused constituting a major concern for the environment. Common construction processes in most developing countries follows a linear concept of “take-make-use-dispose”: a fragmented process resulting in inefficient use of resources. The circular economy (CE) concept of “take-make-use-regenerate” aims at zero waste of materials, and efficient use and reuse of resources. CE principles include reduce, reuse, and recycle and their adoption within the construction sector has been encouraged by researchers, policy makers, government and non-governmental organisations. Numerous opportunities accrue when the CE concept is applied to the construction industry. This paper introduces circular construction (CC) as the integration of CE into the construction industry. It identifies opportunities and threats for CC across the sector. Opportunities were categorised into economic, social, environmental and technological while threats were professionals, clients, government and industry. The study adopted a qualitative exploratory research design where data were derived from an analysis of secondary sources through a review of literature. In conclusion, the paper recommends the adoption of CC especially at the design phase, and deconstruction rather than demolition.

Keywords: circular construction, circular economy, opportunities, threats, wastes

INTRODUCTION

Infrastructural developments in many developing and developed countries continue to rise owing to economic growth, urbanisation, increased population and advanced technology. Deterioration of the environment and depletion of natural resources have been identified as major environmental consequences of these developments (Huang, 2012; Menikpura, Gheewala, Bonnet, & Chiemchaisri, 2013; Plagányi et al., 2013; Song, Li, & Zeng, 2015; Vieira & Pereira, 2015) due to the activities of various sectors including industrial, manufacturing, construction. Environmental issues across different sectors of the economy may vary. For instance, construction activities (such as carpentry, masonry and trenching) generate waste which leads to pollution. Although, some other issues arising from the industry negatively affect the environment (Abidin, 2010; Dania, Kehinde & Bala, 2007), waste generation has sparked the need for global consideration of its associated risk.

According to Eurostat (2014), the construction industry contributed 33.5% (871m tonnes) in waste generated by economic activities in the European Union in 2014. Wastes from the industry represent one-third of total wastes generated annually in the EU. In the same vein, a report by the UK Green Building Council indicates that the construction and demolition sector generates 120m tonnes of waste every year. This makes the industry the largest contributor of waste. Similarly, in the US, about 40% of solid waste comes from construction and demolition. In Finland, the construction industry is responsible for 18% of the 90m tonnes of waste generated annually (Sitra, 2015). According to Australia Bureau of Statistics (2013), out of the total 53.7million tonnes of waste generated in 2009 and 2010, construction waste accounts for 16.5million tonnes. Despite the high generation rate of wastes across the construction industry globally, less than one-third is recovered, reused or recycled (World Economic Forum, 2016). The European Commission (2001) however identified the potential for re-using and recycling construction and demolition wastes but the reality is that a considerable portion of it is landfilled. About 44% of construction waste in Australia and the UK ends up in landfill, 29% in the US, 54% in Finland and 35% across the globe (DEFRA, 2013; Oyedele, Kadiri and Ajayi, 2014; Solis-Guzman et al., 2009; Sitra, 2015).

The traditional methods and fragmented construction processes commonly practiced across the industry could be responsible for high waste generation. These methods and processes could be equated to a linear economy model ("take-make-use-dispose"), where raw materials are extracted (i.e. Take), manufactured into products (i.e. Make), used by consumers (i.e. Use) and disposed of after use (i.e. Dispose). Traditional construction methods use materials made from natural resources some of which are disposed of during construction and deconstruction or demolition. This model is unsustainable, resource inefficient, wasteful, problematic, uses large amounts of energy and poses serious threats to the environment. It is also uneconomical as increases in demand for natural resources will inevitably make them more expensive and scarce (Bastein et al., 2013). If this trend continues, increased demand for natural resources (European Commission, 2011) could triple by 2050 (UNEP, 2011). It is obvious that our planet is becoming stressed and may not be able to cope with demand for natural resources soon. Therefore, it is crucial that the industry shifts to alternative methods and processes to improve resource and energy utilisation and facilitate sustainable construction. Although the industry has been described as conservative and slow to change (James et al. 2006), a swing to modern construction methods and processes (such as disruptive transformation, analytics, BIM etc.) is evident around the globe.

The circular economy (CE) has been described by several authors (Andrews, 2015; Dorn, Nelles, & Flamme, 2010; Murray, Skene, & Haynes, 2015; Qian & Wang, 2016; Si-yuan & Yuan, 2012; B. Su, Heshmati, Geng, & Yu, 2013) as a sustainable development concept that is restorative and regenerative by intention and design and could be applied to any sector of the economy. It eliminates waste of materials, ensures resource efficiency and low energy use. Guohui and Yunfeng (2012) described it as a "resource-product-waste-regenerate resource" model which utilizes resources and protects the environment effectively. With CE, products at the end of their useful lives are regenerated either by recycling or reusing them. This contrasts with the linear economy where products are disposed of after use. In practice, it hinges on economic development through reduction in resource consumption and pollutant emission, waste re-use and material recycling (Shi et al., 2006). A strong link exists between CE principles (reducing, reusing and recycling), environment and economics (Heshmati, 2015). The CE has been adopted particularly in the manufacturing, steel and agricultural sectors in some countries whilst others are in the process of adopting it. Although some countries have advocated its integration into construction, its adoption is still limited. It presents a huge opportunity for the construction industry to reduce material wastage, limit extraction of finite raw materials and reduce global emissions thereby achieving environmental sustainability. Its integration into the construction industry is referred to as "circular construction". Circular construction (CC) ensures products (i.e. buildings) are regenerative at the end of their lives through recovery, reuse and recycling of their components. Bastein et al (2013 p. 5) argues that "in the transition to a circular economy the focus is no longer solely decoupling environmental pressures from economic growth, but also on the opportunities created if these things remain coupled" (Bastein et al., 2013 p.5). This study aims to answer the following questions:

i. What opportunities are available with the adoption of CC?

ii. What threats inhibit the adoption of CC?

THE CONCEPT OF THE CIRCULAR ECONOMY

Over the last two decades, literature has emerged on the CE covering its origin, founding principles, characteristics, approaches, framework, and implementation. Murray et al. (2015) asserted that its origin is debatable. Damen (2012) supports the assertion that CE's origin cannot be traced to a particular author(s), publication or year. It is mainly rooted in ecological, environmental economics and industrial ecology (Ghisellini et al., 2015; Murray et al., 2015; Preston, 2012). It originates from eco-industrial development (EID) theory and thought (Geng, Fu, Sarkis, & Xue, 2012) and general systems theory developed by Von Bertalanffy (1950; 1968). Qian and Wang (2016) claimed that CE can be traced to environmentalism due to its concern for the environment. It also has roots in some schools of thoughts and theories that disapprove of the linear economy (Allwood, 2014; Ellen MacArthur Foundation, 2013; Preston, 2012). One such theory is the spaceship theory postulated by Professor Kenneth E. Boulding (an American economist) who has been acclaimed by several researchers (George, Lin, & Chen, 2015; Ghisellini et al., 2015; Greyson, 2007; Persson, 2015; Rizos, Behrens, Kafyeke, Hirschnitz-Garbera, & Ioannou, 2015) as the originator of the idea of the CE concept.

Boulding described the earth in his article ("*The Economics of the Space Ship Earth*") as a single spaceship on a journey with a pre-loaded stock of resources. As the journey progresses, the resources are depleted, unless they are recycled. This implies that resources are consumed without an option of recycling. His idea was to evoke a shift from an "*open system*" to a "*closed system*". Stahel and Reday-Mulvey further developed the idea of a closed system in 1976 into a "closed-loop economy" which dwells on improved durability (Murray et al., 2015). Matthew and Tan (2011) however referred to CE as closed-loop economy. The term CE was coined by two British environmental economists, David Pearce and R. Kerry Turner in 1990 in their book titled: Economics of Natural Resources and the Environment (Qian & Wang, 2016; B. Su et al., 2013).

Several definitions of CE exist indicating the lack of a common definition (Bechtel et al., 2013, Damen, 2012; Yuan et al., 2006). Most are based on individual's perceptions. Some selected definitions are presented in Table 1. Liu (2012, p. 256) gave a detailed definition of CE as "*an economy system which is characterised by principle of sustainable growth and depends less on depletion of natural resources than traditional economies through mechanism of recycling the waste output of its system*". Similarly, Ellen MacArthur Foundation (2012, p. 22) described it as "*an industrial economy that is restorative by intention; aims to rely on renewable energy; minimises, tracks and eliminates the use of toxic chemicals; and eradicates waste through careful design*".

Table 1: Definitions of the CE

Author(s) and year	Definition
Andrews (2015)	CE mirrors natural life cycles where dead organic material decomposes to become a nutrient for the next generation of living organisms.
Dorn et al. (2010)	CE as an economic development system that is focused on environmental protection, avoidance of emissions, and on sustainable development in order to prevent waste and emissions at source, and reduce the formation of such at each production unit.
Guohui and Yunfeng (2012)	CE is in nature an ecological economy which uses ecological principle to direct economic activities in human society. It is an economy focusing on highly

	efficient utilization and reutilization of resources based on the principle of decrement, recycle and resource extending.
Iung and Levrat (2014)	CE is a generic term materializing an economic concept that fits in the context of sustainable development and based on the concepts of green economy, usage (functionality) economy and industrial ecology.
Preston (2012)	CE is an approach that would transform the function of resources in the economy.
Van den Berg and Bakker (2015)	CE describes a model of closing material loops in an economically attractive way to decouple wealth from resource usage.
Wilson (2015)	CE is a generic term for an economy that is regenerative by design.

The central theme of these definitions is environmental protection, waste prevention, resource reuse and material recycling. Although these definitions differ, the purpose and objectives of CE remain unchanged. Therefore, for the purposes of this paper CE is defined as a sustainable concept that ensures zero waste of materials, low pressure on resource consumption and energy through reuse and recycling principles. The philosophy of CE has been explained by several authors. Ellen MacArthur Foundation (2015, p. 5-7) described its principles to include the following:

i. "*Preserve and enhance natural capital by controlling finite stocks and balancing renewable resource flows*" (p. 5)
ii. "*Optimise resource yields by circulating products, components, and materials at the highest utility at all times in both technical and biological cycles*" (p. 7)
iii. "*Foster system effectiveness by revealing and designing out negative externalities*" (p. 7)

Some authors (Preston, 2012; Sakai et al., 2011; B. Su et al., 2013; Zhijun & Nailing, 2007; Ren, 2007; Reh, 2013; Lett, 2014) described the basic principles of CE as the 3R's - Reduce, Reuse and Recycle. Ghisellini et al. (2015) claimed that the 3R principles can be integrated by the principles developed by the Ellen MacArthur Foundation in 2012. Their claim received a boost when Pan et al. (2015) added two more R's to make it 5R (Reduction, Reuse, Recycling, Recovery and Reclamation). However, most literature refers to the 3R principles of CE.

Liu (2012) asserted that reduction is an efficient method where input of materials is reduced so that efficiency can be increased while energy consumption is reduced. Su et al. (2013) agreed, arguing that reduction is aimed at minimising the input of primary energy, raw materials and waste to achieve efficiency in production and consumption processes. The European Commission (2008) described reuse as any operation where products or components used before are used again for the same purpose they were initially used for. Materials are reused to avoid waste, and reduce resource extraction and energy. This benefits the environment since it requires less energy, fewer resources and less labour (Castellani, Sala, & Mirabella, 2015; James, 2011). Recycling is the third principle of CE and the last option to recover the value of a material at its end-of-life (Van den Berg and Bakker, 2015). It involves reprocessing which could be referred to as a recovery operation for materials assumed as waste. These materials can be used either for their original purpose or other purposes (Ghisellini et al., 2015). Recycling is fundamental to CE because of its proven sustainable character over years (Van den Berg and Bakker, 2015) and its help in reducing the consumption of virgin materials (Shi et al., 2006; Su et al., 2013).

The CE is widely practiced in China while similar concepts have been implemented in other countries (Japan, USA, UK and the EU). According to Ghisellini et al. (2015), CE practice in China resulted from a top-down approach. This is a system of command and control from the government to the people. It was implemented on a three-layer approach (micro, meso and macro) with four practice areas (design, production, consumption and waste management) as shown in Table 2. At the micro (enterprise) level, emphasis is on cleaner production involving resource reuse and recycling of by-products to achieve dual environmental and economic performance goals (Ren, 2007; Wang & Li, 2006; Zhu et al., 2010). At the meso (inter-firm) level, implementation of CE hinges on reuse and recycling of resources within industrial parks and clustered industries (Wang and Li, 2006). The macro level considers products, collection, processing, storage and distribution systems at the regional, municipal, provincial or city level (Wang and Li, 2006).

China has successfully implemented the CE concept in some industries including iron and steel, paper making, process and manufacturing, tourism, construction, agricultural and electric power. The adoption of CE across the globe is generally sparse but is being considered by the European Union and some other countries. Its adoption in the construction industry has been advocated in some countries (Netherlands, Sweden, UK, Austria, Australia and US) while its implementation is a work in progress. Several authors have identified possible threats and opportunities associated with the CE. For example, Moreno et al. (2015) ranked threats to CE as high, medium and low. The high ranked threats are "*cost restraints, consumer perception and behaviour, producers and consumers locked into the current economic/market system*" (p. 7). The medium ranked barriers include: "*cultural expectations for new models, closed loop supply chains and reverse loop supply chain could increase cost of logistics, transportation and energy*" (p. 7). They identified "*cost restraints (lack of operational capital, lack of investment capital to develop and build new facilities), time constraints, lack of knowledge, lack of certification procedures for alternative practices, complex supply chains and complex information flows within the supply flow and unknown take back process*" as the low ranked challenges. Geng et al. (2012) identified the opportunities of CE to include improved public awareness of environmental issues and improved relationships between local societies and industrial sectors. In the same vein, Andrews (2015) emphasised that CE will create employment opportunities from recycling business.

Table 2: Implementation structure of CE in China

Areas	**Micro (Enterprise)**	**Meso (Inter firms)**	**Macro (Provinces, Region, State and Cities)**
Design	Eco-design	Environmentally friendly design	Environmentally friendly design
Production	Cleaner production	Eco-industrial park	Eco-city Eco-municipality Eco-province
Consumption	Green purchase and consumption	Environmentally friendly park	Renting service
Waste management	Product reuse and recycle system	Waste trade market Industrial symbiosis	Urban symbiosis

Source: Adapted from Su et al. (2013)

The aforementioned literature identified CE as a sustainable concept that could be adopted in the construction industry. Its application to construction activities is referred to as circular construction (a sustainable concept that ensures efficient and effective reuse and recycling of all materials throughout construction and demolition phases). Opportunities and threats of the CE require careful consideration before its adoption in the construction industry.

METHODOLOGY

This study adopted a qualitative exploratory research design. Babbie (2012), Neuman (2006) and Zikmund (2003) described exploratory research as that which investigates a new phenomenon to develop propositions for future research. It utilises literature searches, focus groups, surveys, interviews, observations, experiments, case studies and / or archival analysis as strategies (Saunders et al., 2007). Exploratory research seeks to create hypotheses, answer 'what' questions (Neuman, 2006) and produces qualitative data. Since this study seeks to answer 'what' questions, a review of literature provides a clear focus for the research questions.

Data were derived from secondary sources through a systematic review of literature. Electronic searches of the following databases were conducted; Scopus, Elsevier, Science direct and Google Scholar. Keywords and terms used for search strategies include: "circular economy", "opportunities", "threats", "sustainable construction", "resource efficiency" and "construction wastes". The searches produced an extremely large number of results. These were refined using the following criteria:

i. Time period was limited from 1996 to 2017
ii. Only peer reviewed articles were selected
iii. Abstracts were screened to determine inclusion

From the foregoing, 172 publications including journal articles, conference papers, book reviews, technical notes and theses were downloaded into Endnote. A search was conducted to locate additional publications and bibliographies of articles for diverse terminologies. Of all the publications downloaded, refereed journal articles were prioritized. Overall, 75 articles were selected for review. These yielded opportunities and threats associated with circular construction which were analysed in the study.

FINDINGS AND DISCUSSION

Opportunities. Circular Construction has been argued by several authors as a sustainable approach. The studies reviewed indicate that its opportunities comprised social, economic, technological and environmental opportunities.

Social opportunities. The social opportunities of CC justify its sustainable development potential of meeting present and future social needs. In the construction industry, CC can create opportunities for collaboration between clients and construction teams, which will prolong the commercial relationship between them (Yuan et al., 2006). It can improve relationships between local societies and industrial sectors leading to the socioeconomic development of the nation (Geng et al., 2012). It also has the potential to reduce unethical practices and corruption in the industry (Andrews, 2015). More likely, it is expected to facilitate the selection of non-corrupt suppliers as a result of changes in value chains while encouraging others to change. Su et al. (2013) assert that it can strengthen national security due to increased sustainable energy supply while Zhijun and Nailing (2007) affirm that it can integrate population, close income gaps and promote social justice.

Economic opportunities. Several economic opportunities are linked to the CC. Ghisellini et al. (2015), Persson (2015), Jun and Xiang (2011) and Zhu et al. (2010) claim that it can achieve economic growth without extracting more resources. Resource productivity, material cost reduction, and increased revenue from waste sales (Yuan et al., 2006; Moreno et al., 2015; Geng et al., 2012) are some of its potential economic opportunities. More so, it can allay demand-driven price volatility of raw materials and supply risks (Crowther and Gilman, 2014) as well as create new business models thereby increasing profits (Moreno et al., 2015). It can also create employment opportunities for design graduates and professionals with related expertise (Andrews, 2015). Benton, Hazell, and Hill (2014) posits that it can bring direct cost savings to businesses, offer reputational advantages and become a market differentiator without placing undue pressure on resources.

Environmental opportunities. The potential environmental opportunities of CC are numerous as they may be seen as a possible alternative to traditional methods of construction. They include: "*conservation of natural resources (especially non-renewable resources such as water, fossil, fuels and minerals), reduced environmental impacts through efficient energy and material and less water discharge, avoidance of toxic materials, extended life cycle of landfill sites, and recovery of local ecosystem*" (Geng et al., 2012, p. 221). It can reform environmental management (Yuan et al., 2006) thereby improving public awareness of environmental issues as it relates to their health (Geng et al., 2012). As a sustainable approach, CC will result in positive environmental outcomes through efficient waste and resource minimisation (Andersen, 2007). It is also expected to mitigate environmental pollution (Wang, 2009), improve eco-efficiency (Yuan et al., 2006), prevent environmental poverty (Zhijun and Nailing, 2007) and reduce unsustainable pressure on natural resources, thereby reducing environmental challenges (Preston, 2012; Zhu et al., 2010).

Technological opportunities. Within the CC, technological initiatives are expected to serve as a support in achieving social, economic and environmental characteristics. The construction industry is faced with several challenges ranging from management to methodologies. It is imperative that modern technologies are explored as possible solutions. The CC can provide technological opportunities such as increased innovation and adoption of cleaner technologies (Andersen, 2007) to ensure resource efficiency and waste minimisation. It could also assist in industrialisation (Preston, 2012) through industrial symbiosis (i.e. the exchange of waste materials between two or more companies). Kalundborg (in Denmark) is a good example of industrial symbiosis in practice (Damen, 2012).

Threats. Threats to successful acceptance, adoption, transition, and implementation of the CC are categorised as professionals, clients, government and industry related threats.

Clients threats. Threats posed by clients play crucial roles in the adoption and successful implementation of CC. Several authors (Xue et al., 2010; Guohui and Yunfeng, 2012; Rizos et al., 2015; Su et al., 2013; Li and Li, 2011, European Commission, 2014) have reported lack of awareness, knowledge and understanding of environmental protection and benefits of CC. Many clients do not consider the environmental impacts of their projects, they concentrate more on the cost and aesthetics (Hayles, 2015). This could be attributed to their lack of awareness and attitudes to environmental threats posed by their actions. More so, Preston (2012) identified lack of enthusiasm, life style and fashion of clients as possible threats to the adoption of CC. Clients' taste, fashion and life style at times determine their preference.

Professional threats. Similar to clients' threats, professionals in the industry also lack awareness, knowledge and understanding of the CC. Several authors (Meqdadi, Johnsen, and Joh, 2012; Wooi and Zailani, 2010; Xue et al., 2010; Rizos et al., 2015; Li and Li, 2011) attributed this to their attitude and resistance to change. According to Andrews (2015), most products (i.e. buildings) are not designed for disassembly. This is a result of design professionals' inability to adopt new technologies, systems and methods of designing (such as designing out waste, designing for resource efficiency and designing for deconstruction and disassembly). Lack of motivation to reuse or recycle materials (Löfgren and Enocson, 2014; EC, 2014) is another threat. Some professionals are not motivated because of the common belief that recycled materials are inferior (Andrews, 2015).

Industry threats. Threats posed by the industry are enormous due to their fragmented nature. The industry has been criticised for its poor leadership and management (Su et al., 2013) which is a major threat to the adoption of CC. Lack of reliable information systems and shortage of advanced technologies (Su et al., 2013; EC, 2014; Liu et al., 2009; Xue et al., 2010) experienced in the industry also pose serious threats. Similarly, changes in industrial practices and patterns as well as lack of independent organisations to certify CC (Preston, 2012) often discourages their adoption. Innovation challenge, lack of appropriate quantitative tools for design, and lack of standardization for performance and structures (Su et al., 2013; Preston, 2012; Greyson, 2007; Zhu, 2000) are potential threats.

Government threats. Government agencies and institutions are key to the success of CC. For example, the role of the Chinese government was critical in the adoption and implementation of the CE concept. Policies, regulations and legislation are a government's instruments in developing a sector or a nation. These instruments could also serve as threats. Lack of policy coherence (Xue et al., 2010), lack of legal system on CC (Geng et al., 2012) and difficulties in enforcing environmental laws have been identified as potential threats to the adoption of CC. More so, lack of financial support was widely reported as a major threat to its adoption and implementation. It therefore seems possible that the private sector may be co-opted to relieve the burden on the government. Lack of enforcement of legislation (Su et al., 2013; Xue et al., 2010; Liu et al., 2009) is also a threat especially in some developing countries. Other threats include: lack of support and encouragement (Calogirou et al., 2010; Struder et al.,2010); weak economic incentives (Su et al., 2013; EC, 2014) and high cost of green investment for firms (Preston, 2012; Andrews, 2015; Rizos et al., 2015).

CONCLUSION

This study has described the CE concept as a viable alternative to the linear economy and identified reduction, reuse and recycling of materials as basic principles of CE. It discussed current CE practice in China and identified design, production, consumption and waste management as areas of practice. It highlighted CE as a sustainable concept that could achieve sustainable construction when adopted in the construction industry. This study has proposed the adoption of the CE concept in the construction industry as circular construction. Resource efficiency, low energy use and waste minimisation could be achieved in the construction industry. The research revealed that the adoption and practice of CC could be difficult to implement due to the fragmented nature of the industry. However, it is achievable. Several opportunities of CC were identified and categorised into social, economic, environmental and technological opportunities. More so, the study identified threats to adopting CC and categorised them into clients, professionals, industry and government-posed threats. The implementation of CC would require the industry to review its opportunities and threats. CC provides significant benefits, especially at the design and deconstruction phases. The former could involve design for disassembly while the latter could adopt pre-demolition audits. The adoption would require a framework involving all stakeholders in the industry. Possible areas of improvement of the CE could be explored and country specific implementation processes developed. These are recommendations for future investigations.

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Integrated Project Delivery: Complicated Collaboration or Improbable Panacea

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Abstract

Integrated Project Delivery (IPD) is different from traditional construction project delivery methods. IPD requires early involvement of key parties with sharing of decision-making, control and project risks. Removing the associated liability encourages the parties to focus on producing the best, economical design while executing the construction efficiently and effectively. In IPD, the facility owner pays for direct costs and overhead, theoretically striped of profit. The risk of losing money is minimal with the opportunity to share in net budget savings. IPD seems like a panacea; however, skeptics remain. The typical designer and constructor, both pragmatic by nature, are distrustful of unproven methods. IPD seems complicated to those not attuned to creative problem solving. IPD participants must be trusting and trustworthy, able to collaborate and cooperate, and, communicate ethically and sincerely – not common traits of the construction industry. The paper compares and contrasts these positive and negative aspects of IPD.

Introduction

Integrated Project Delivery (IPD) has been touted with both raves and reservation as a construction project delivery method. IPD boasts better buildings thanks to multiparty contracting with trustworthy partners. However, detractors warn that IPD remains as complicated as it is collaborative.

In IPD, project risks are shared equally among the multiparty contract entities and offers subsequent profit sharing from any positive budget balances. Removing the associated liability encourages the parties to focus on producing an economical design and executing the construction activity efficiently and effectively. The IPD project is organized like a business with early involvement of key players with shared team decision-making and control. Orientation [onboarding] is critical because IPD's approach, process and vocabulary are different from the normal project delivery methods. In IPD, the facility owner pays all contract signatories' direct costs and overhead, theoretically striped of profit. The team of designers and contractors contribute to a profit pool, based on a target price. The risk of losing money is minimal with the opportunity to share in the net budget savings (i.e., profit). Moreover, IPD offers opportunities for repeat business with trusted partners.

However, skeptics remain. The typical designer and constructor, both pragmatic by nature, has honed their business skills from the school of hard knocks. IPD seems complicated to those not attuned to team-based, creative problem solving. IPD participants must be technically knowledgeable with the requisite business savvy, be good at 'playing well' with others, and exhibit good communication skills; not the typical tool-kit of the A/E designer and construction manager.

The paper reviews the background of IPD including requirements, compares and contrasts the positive and negative aspects of IPD, and, suggests recommended practices to ensure the best brick for the buck from IPD.

Background – Constructed Facility Project Delivery

The methods and means by which the Constructor delivers the completed facility [the "how"] based on the design of the Architect / Engineer [the "what"] is important.

Construction Contractual Arrangements

In construction, the contract type will vary over the project life cycle. Typically, reimbursable contracts are used for the conceptual and design work at the beginning of the project, and fixed-price contacts are preferred for the construction work. The following factors affect the selection of the contract type for a specific work package: level of detail available, urgency of the procurement, level of competition desired, level of competition available, and, organization's risk utility or tolerance.

The major types of construction contracts (PMI, 2008) are as follows:

Fixed-price or lump-sum contracts. The contractor performs the work for a fixed, lump-sum price according to the contract bid package.

Unit-rate contracts. The contractor performs the work for specified unit rates.

Cost-reimbursable contracts. The contractor performs the work on a reimbursable cost basis plus a professional fee. The fee can be a fixed amount, a percentage of the costs up to a target amount, an incentive amount, or, other variations.

Time and materials contracts. The contractor is reimbursed for the time spent and resources expended on the work performed.

Facility Project Delivery Approaches

In construction, a project delivery method refers to selecting the best strategy for project execution, including the project procurement activities. The strategic decisions made at this point determine which portions of the project are best suited for a particular execution approach depending upon a number of factors such as degree of definition, schedule, and cost requirements and uniqueness of requirement.

Alternative project delivery methods (PMI, 2008) include the following:

Design-bid-build (traditional method). The design and the construction functions are performed by separate organizations. This is the traditional construction method where the construction is solicited by way of competitive bidding after the design is essentially complete.

Design-build. The responsibility for both design and construction is obtained from a single source.

Turn-key. The contractor has overall responsibility for delivering the project to an owner, providing all services for initial concept, design, purchasing, construction, commissioning, and start-up.

Construction management. The construction management (CM) entity manages the overall functions of the project including design, bidding, purchasing, and construction. The CM can execute the construction on an agency or on an at-risk basis. During construction, the at-risk CM functions much like a general contractor with their subcontractors; whereas, the agency CM manages the work of prime contractors and their subcontractors.

Single-source, non-competitive. In cases where the construction requirements are unique or where there is only one source for the desired result, a negotiated contract with the source is the usual way of accomplishing this.

Design-build-operate-maintain-transfer (DBOM). This method encompasses the design-build method with the added feature of time scaled functions for operating and maintaining the product after construction is completed. After the DBOM contract is completed, the product is transferred to the buyer, and/or another contract is procured for continuation of the operating and maintaining functions.

The next section reviews the requirements of IPD, a new constructed facility delivery approach that requires the facility owner, designer, and constructors all to change from their traditional roles into a new arrangement of cohesive collaboration.

IPD – A New Delivery Approach of Collaboration and Trust

Simply put, Integrated Project Delivery [IPD] throws out the traditional rules of the construction game. In an ENR cover story (June 10, 2015), the title tells the story - “Raves and Reservations: Integrated project delivery zealots boast better buildings thanks to multiparty contracting but warn the IPD remains as complicated as it is collaborative.” The IPD discussion/debate note several game-changing points. First, IPD requires sharing project risks as a team among the multiparty contract entities. Removing liability encourages the parties to focus on producing an economical design and executing efficiently and effectively as possible. Second, each project organized much like a business with early involvement of key players, and, team decision making and control. For newcomers, orientation [called onboarding] is critical because IPD’s approach, process and vocabulary are vastly different from the normal project delivery methods [Design-Bid-Build, CM at Risk, Design-Build]. And thirdly, in IPD, the facility owner pay signatories' direct costs and overhead, theoretically striped of profit. Designers and contractors contribute to a profit pool, based on a target price. The risk of losing money is minimal (ENR). The sharing of project risks, especially the "waiver of liability" associated costs, offers significant rewards for the team partners. The brave new world of IPD beckons.

Working Definition of IPD

According to the AIA California Council (2007/2010), Integrated Project Delivery (IPD) in working environments is described as a project delivery strategy that integrates people, systems, business structures, and disciplines into a manner that collaboratively manages the expertise of all participants in the project in order to reduce waste and optimize efficiency. Integrated Project Delivery principles can be implemented into a variety of contractual forms, and the Integrated Project Delivery team usually includes members outside of the basic triad of owner, designer, and contractor. Responsibilities are usually on the most qualified member of the IPD team with decisions being made on a "best for project" basis (NSBA, 2010).

AIA's working definition of IPD has three main steps: First, the integrated practice is defined. Using the computer aided design (CAD) technologies such as the Building Information Modeling (BIM) is recommended in the stage to allow efficiency in the workflow. Second, the Essential Principles are and collaboration policies should be set as necessary and the compliance should be enforced with in the IPD team. Finally, project workflow should be cleared and started by the Integrated Team and concluding with Integrated Closeout (AIA/CC, 2010).

IPD Methodology

According to the *Integrated Project Delivery For Public and Private Owner's Manual* (2010), IPD offers a tiered approach to collaboration based on three levels. The three levels show the usual spectrum through which owners move. Authoritative constraints, policy limitations, and cultural barriers, are some of the factors that affect where on this collaboration spectrum the owner will be.

The three Collaboration Levels are: (a) *Collaboration Level One*: Typical collaboration, contracts are not required; (b) *Collaboration Level Two*: Enhanced, some contractual collaboration requirements; (c) *Collaboration Level Three*: Required, requires a multi-party contract.

Conventional design development has workflow boundaries that do not align with a collaborative process. In general, integrated project delivery will result in greater intensity with enhanced of the team involvement in the early phases of design. In the integrated project, design will flow from a) determining the project goals, to b) what will be built, then to c) how the design will be realized, as shown in Figure 1 in the Appendix (AIA/CC, 2010).

IPD Phases. IPD is a cradle-to-grave methodology, involving all parties inclusively and exclusively for the complete length of the project from the initial inclination for facility expansion by the owner into facilities management. The IPD eight-phase process is: (1) Conceptualization phase [expanded programming], (2) Criteria design phase [expanded schematic design], (3) Detailed design phase [expanded design development], (4) Implementation documents phase [construction documents], (5) Agency review phase, (6) Buyout phase, (7) Construction phase, and (8) Closeout phase. (AIA, 2007). IPD is similar to the design/build delivery approach, with the caveat of the involvement of all key parties working together from the onset at the conceptualization phase.

IPD Essential Principals. The foundation of IPD is built on collaboration. Successful IPD endeavors require the following essential principals in order to live well and prosper: (a) mutual respect, (b) mutual benefit, (c) early goal definition, (d) enhanced communication, (e) clearly defined open standards, (f) appropriate technology, (g) high performance, and, (h) leadership (AIA, 2007). These principals are not easily acquired and require significant investments in time and effort to initiate, develop and then sustain.

The IPD method is based on the team principles of trust, shared risk and creative collaboration. The next section will review the benefits of the IPD process.

IPD Benefits

The benefits of IPD are evident in improved project execution – improvements in budget performance [cost], time efficiency [schedule], and facility serviceability [quality]. In addition, the integrated team approach will benefit the participants as to a more satisfying project experience based on trusting relationships and a lean approach [less waste] to the construction of the facility.

Improved Project Execution

Improved project execution comes from improvements in better cost budget performance, improved time efficiency, and overall facility quality.

Cost Budget Performance. In the IPD approach, the cost structure is developed earlier and in greater detail than a conventional project. Costs may be linked to Building Information Model [BIM] to allow rapid assessment of design decisions. Cost structure is accessible to parties to evaluate areas where greatest improvements are possible.

IPD promises significant cost savings over traditional delivery methods, like Design-Bid-Build [DBB]. With IPD, value is added and continuous improvement is achieved by the teamwork approach and participation by all core team members, including the contractor, from the inception of the project. Savings of up to 30% in the cost of construction can be achieved where integrated teams promoted continuous improvement over a series of construction projects (RJO, 2015)

Execution Time Efficiency. Taking an integrated approach can speed up project delivery. Better communication and shared risks can help reduce the amount of time wasted normally wasted on senseless bickering over non-essential items, allowing teams to deliver projects on time if not ahead of schedule. However, until IPD becomes a mainstream delivery method with a widely recognized organizational and legal structure, the extra time required to assemble the appropriate team upfront could be considered a detraction.

Overall Quality of the Facility. By owning both the design intent as well as budget and schedule performance, the entire team is compelled to focus on the overall quality of the completed facility instead of making conflicting changes for the individual company's best interest. The integrated approach leverages the entire brain trust of the team partners to produce the optimal facility in balanced terms of serviceability [function] and aesthetics [form].

Trusting Partnerships

The leadership traits of trust, integrity, and people-orientation are critical to success in the construction industry (James, 2002). IPD builds on the trust among the partners, which is essential in any design-construction endeavor.

For the IPD approach to truly succeed, the individual tea m members must believe that they are working for the project instead of their respective companies. Individuals must be ready, willing and able to accept all project responsibilities jointly. Trusting partnerships leads to improved team relations with less waste in effort and minimal aggravation.

Improved Team Relations. The symbiotic relationship that exists between IPD and trust is axiomatic. Trusting relationships are a requirement for IPD to function [system-based trust], and, IPD communication augmented with trusting behavioral principles [cognition-based trust] (Pishdad-Bozogi & Beliveau, 2016).

IPD allows for creative problem solving and subsequent profit sharing. Long term, successful IPD endeavors offer future opportunities for repeat business with trusted partners. Trusting partnerships require open/honest communications among the team partners. The esprit décor tone of the team allows for collaborative instead of combative relationships. IPD is complicated to the new comers; participants must be technically knowledgeable with business savvy, be good at 'playing well' with others, exhibit good oral & written communication skills.

Less Waste. Utilizing the IPD process engages heartily the principles of *lean construction*, which offer two main advantages over the traditional design-bid and design-build processes. The IPD approach reduces waste. The IPD project will have reduced waste in the design and construction processes as much as twenty percent over the traditional approach. Further, IPD increases the reliability of the planning process. The IPD project eliminates the inability to plan work reliably and effectively by removing the unpredictability of the workflow (LC, 2014).

Challenges Using the IPD approach

The IPD approach challenges the facility owner, the designer and the constructors alike. Overall, it is critical that all three entities; i.e., the Facility Owner, Designer and Constructor, equally agree on the contract as well as believe in the process. The IPD differences in contractual obligations and consensus teaming versus the traditional adversary approach, gives rise to fundamental cultural shifts and non-conventional project experience that must be addressed, or at least admitted by the project participants (NASFA, 2014). IPD is a brave new world.

Facility Owners

The Construction Owners Association of America [COAA] note their members high interest in the cost savings and improved facility quality offered by IPD, but are reluctant in complete endorsement. The facility owner must lead the paradigm shift, including exhibit of willingness to change, take risks, and develop a culture of trust. (COAA, 2016)

As the farmer opined about a talking mule – everything is fine as long as the mule remembers who owns the farm. Is the facility owner willing to take this leap to share their “farm” [project control] with the “livestock” [designers, constructors and the construction trades]? The large, sophisticated facility owner with a significant facilities portfolio will very likely enjoy the benefits of IPD. Conversely, the casual developer without the significant investment in fixed assets will not consider IPD worth the effort.

Designers

In IPD, all participants are working together in the early stages of the project where goals are set. Information is shared, efficiency is optimized, and team members are project-focused instead of profession-focused, all in an effort to reduce risk and build harmony. However, the IPD approach changes the perceptions of the team members concerning joint responsibility of risks for the design and the construction work. The construction contractors now assume design responsibility, and, the designer deals with the means and methods used during construction. These unfamiliar risks must be considered when using IPD (PSU, 2016).

For the designer, the IPD process requires a higher level of effort early in the project as compared to their traditional modus operandi. The design firm, accepting expanded up-front responsibilities, needs to balance the elevated level of effort with suitable fee structure. Moreover, the designer’s responsibilities do not end with providing suitable documents for construction (PSU, 2016). The Architect/Engineer has a roles and responsibilities overlap with the construction firms and trades throughout the complete project life cycle.

Construction Firm

The Construction Association of Michigan [CAM], the oldest construction builders and traders association in the USA, identified four areas of concern with IPD for construction firms: funding, contract language, lack of collaboration, and, workforce. The same four issues can be said of the traditional project approaches, which are inefficient, adversarial and expensive. How can the constructor win?

First, the construction management firm and key trade contractors are involved at the onset with the facility owner and the designer, and, are selected based on their qualifications rather than lowest price. The integration of the team can be increased by co-location of all key members of different disciplines in one location, and, the use of Building Information Modeling [BIM]. The use of BIM requires significant investment in set-up time and upfront training, which the tradition contractor is not interested in expending (Kelly & Ilozor, 2016). Hence, the benefits of IPD / BIM do not accrue easily [no pain / no gain].

Although intuitively, the aspects of early involvement, co-location and teaming all seem very beneficial for all involved; the constructor is leery, at best, and likely highly skeptical of unproven methods without a means for recourse if things do not work out (CMAA, 2015).

Conclusions

In conclusion, the relational contracting approach of IPD offers the benefits of improved project performance [better quality, faster completion time and lower overall cost] and trusting partnership [improved team relations and less waste]. These benefits outweigh the costs of early involvement with detailed planning, team development [onboarding], investment in BIM [technology], and, shared risks [waiver of liability].

The true test of IPD will be the improvements in long term relationships amongst the partners that leads to repeat business. Trusting partnerships, endemic to IPD, fosters the ethical relations that leads to long-term profitability. The IPD "integrity chain" (James, 2002) links integrity in the process, trust amongst the members, and repeat business based on satisfactory performance and quality, and, a profitable relationship for each of the parties. Keeping strong egos in check will continue to a challenge, be it the overtly controlling facility owner, creative architect, or independent minded contractor. People are people. IPD will be a continuing study of creating possibilities for improved constructed facilities through collaborative cooperation. IPD is both the complicated collaboration and improbable panacea.

Unlike the design–build project delivery method which typically places the contractor in the leading role on a building project, IPD represents a collaboration concept where the entire building team including the owner, architect, general contractor, building engineers, fabricators, and subcontractors work collaboratively throughout the construction process. This collaborative approach allows informed decision making early in the project where the most value can be created. IPD combines ideas from integrated practice and lean construction to solve several problems in contemporary construction such as low productivity and waste, time overruns, quality issues, and conflicts during construction among the key stakeholders of owner, architect and contractor. The close collaboration eliminates a great deal of waste in the design, and allows data sharing directly between the design and construction team eliminating a large barrier to increased productivity in construction.

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Appendix

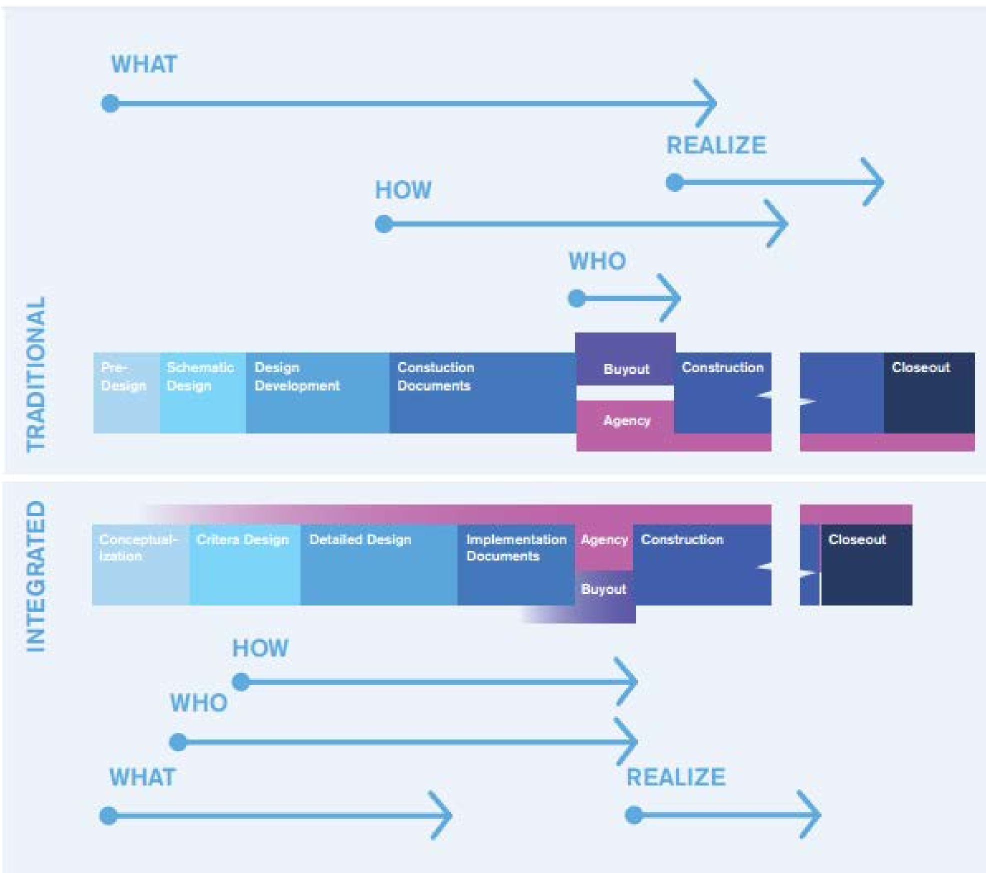

Figure 1: Comparison between the traditional design and Integrated Project Delivery (AIA, 2010)

CONTEXTUAL INSIGHTS INTO LAND- BASED MUNICIPAL INFRASTRUCTURE FINANCE MECHANISMS

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The generally deplorable conditions of public infrastructure and services in developing nations have continued to be a major subject of discourse in academia, industry and policy debates. A major cause of this problem is inappropriate finance mechanisms. Land based financing mechanisms remain sustainable tools for solving infrastructure deficits in the region but are perhaps the most under-utilized methods of infrastructure finance. The bases for adopting land based financing approaches are primarily founded on the responsiveness of land and real estate values to the level and quality of public infrastructure provided. This is because of the positive relationship that exists between public infrastructure and real estate values. However not all land based financing mechanisms fit well in various circumstances. This study makes a nouvelle attempt at carrying out an investigation from literature, on the supporting operational elements under which each mechanism will thrive. As such the research approach is largely based on documentary evidence. It discusses the factors that support the performance of each mechanism under the specific situation of Lagos, Nigeria. As such better insights will be provided for decision making at policy level as a panacea for sustainable growth in the public infrastructure development sector.

1.1 Introduction

The adequate provision and delivery of public infrastructure remains high on the agenda of most countries. In developing economies, public authorities appear to be grappling and 'finding their feet' with appropriate and sustainable finance mechanisms in the delivery of infrastructure projects.

Land based finance mechanisms represent internally valuable tools in the funding of specific infrastructure projects. In Balachander and Sahasranaman (2013), where large-scale borrowings are hard to come by, land-based financing presents an important option for finance. By leveraging the sensitivity of land values to public infrastructure development, and on the principle that benefits of infrastructure are capitalized into land values, land-based financing mechanisms have come to play a key role in the area of infrastructure finance.

Unfortunately, in developing nations, the challenge in this regard is particularly acute, as the issues of inadequate land tools impinge on tapping onto land as a means for achieving sustainable outcomes. (Global Land Tool Network, 2014).

The specific focus on it in this study is hinged on the fact that that land values typically increase by more than the cost of infrastructure investments. Land based financing techniques are therefore *arguably* the most veritable and sustainable means of infrastructure finance. The purpose of this study is to provide contextual insights into land based finance strategies for public infrastructure projects under the current circumstances in Lagos, Nigeria. In this regard, it sets out to elucidate the constraints present in adopting the use of land based financing mechanisms.

2. Land Based Finance Mechanisms

The unearned increment resulting from the rise in land values, resulting from change in use of land from public investments or decisions, or due to the general growth of the community must be subject to appropriate recapture by public bodies.

United Nations (1976) in Walters (2012)

The workings of Land Based Finance (LBF) mechanisms is anchored on a range of approaches by which governments can generate revenue that will help them realize their service delivery, infrastructure development and maintenance goals though land assets. E.g. taxation of the unearned increments that property owners enjoy, as a result of the increase in the values of their properties from municipal infrastructure projects. The rationale for employing most land based finance techniques is based on the theory that "growth should pay for itself", and not be a burden on existing tax payers. (Bird, 2005). According to Paulais (2012), in African Centre for Cities (2015), given the current rate of urbanisation and the scale of investment needed, it is important that governments consider using these mechanisms.
This section focuses mainly on the various approaches and associated practices of capturing the value of public infrastructure in land and real estate developments.
The main object of this study, which is to provide operational elements under which each mechanism operates, is provided in this section of this paper. The mitigating factors, from documentary evidence are highlighted accordingly. According to the UNHabitat (2015), Strategic public investments must go hand in hand with strategic supporting governance systems.
Iacono, Levinson and Zhao (2009) identify different approaches that may be classified as LBF methods.

2.1 Property (Ad Valorem) Taxes

These are general property taxes. 'Property taxes' as they are more commonly known are annual levies imposed on non- exempt properties within a municipality or taxing district as a form of payment charge for local infrastructure and services. In property tax literature it is argued that tax burdens need to be apportioned according to the benefits that individuals gain from government expenditures, which are funded by the tax (Kayuza, 2006; Slemrod & Bakija, 2001; James & Nobes, 2000). This implies that levies must be equitably scaled with the value of infrastructure provided. According to Bahl (2009), there are transparency issues with property tax in the case of developing countries. While property owners are aware of the amount of tax that they pay, it is doubtful that they can equate this burden with the benefits from services financed by the property tax. This has been identified as a major cause of below-potential revenues in the property tax sector. The underlying cause responsible for low resource mobilization of property taxes is the poor link between the equitable concept of tax payment and provision of communal services. (Babawale and Nubi, 2011). However, the assessment systems used, in ultimately determining tax rates is a key factor to the validity of equating levies with public infrastructure provided. According to Mayor, Lyons and Toll (2010), ad valorem (value-based) property taxes are more equitable than flat (area based) rate taxes.
In Lagos, Nigeria, under the policy on property taxes, (Land Use Charge Law of 2001), assessments are carried through an area appraisal model for which a statutory formula - as opposed to the conventional valuation methods or one based on virtual objectivity – is used. . Ogbuefi (2004) explains that taxes in these regions are usually levied without regard to the municipal benefits that the tax payer receives. This potentially creates scepticism on the part of the tax liable and consequently adversely affects the revenue stream. According to Aderibigbe (2009), under the Land Use Charge Law, 2001 there is an increasing number of people who have complaints to make. This elongates –avoidably-, the eventual payment time, as complaints lodged, statutorily halt the process

of action of non-payment against the tax liable. The area-based system is usually only used in situations where a land market is technically non-existent amongst other factors. Essentially, the operations of the enabling law on property taxes mitigate the successful and viable use of value based systems.

2.2 Tax Increment Finance (TIF)

TIF is a targeted development finance tool that captures the future value of an improved property to pay for the current costs of those improvements. This mechanism can be used to finance costs typically pertaining to public infrastructure, land acquisition, demolition, utilities, planning, and more. TIF funds have also been used to help support community amenities such as parks, recreational facilities, schools, and network infrastructure. (Rittner, undated). It places focus on a challenging area, for development that addresses both the economic needs of a community and the quality-of-life advancements that will improve the locality.

TIF Workings as Rittner expatiates begins when the community identifies the TIF district's geographic boundaries, then establishing the initial value of all land within the district. Next, property tax revenues are established. As development advances and revenue from taxes rise, the income is used to pay debt service for the developments. By so doing, local authorities are able to build infrastructure and incentivize development, thereby increasing tax rates. Only the tax revenue generated by the development is used to finance the infrastructure, thereby creating a sustainable revenue stream for the project. The advantages of this model have made TIF a popular development finance tool.

Benchmarking against best practices helps to identify areas for reform and intervention. In Rittner, the first area of TIF best practices is related to public policy and statutes. For example, a TIF project should be clearly eligible according to the state's authorizing statute. However, according to Fjeldstad et al. (2014), in African Centre for Cities (2015) in Sub-Saharan Africa generally (with the exception of South Africa), using TIF to finance urban infrastructure has limited applicability. For example, there are no known institutional or policy agendas in Lagos specifically towards the attainment of the use of this Land based Financing tool. There is no specific national legal/statutory framework to this end. The closest policy in this regard is Public-Private Partnership (PPP) oriented, which can reasonably suffice for the same purpose. The main infrastructure law in Lagos State is the Lagos State Public Private Partnership (LSPPP), Law which was enacted and signed into law on the 24 June 2011. The LSPPP Law, in the main, encompasses in one document the framework for PPPs (Soyeju, 2013). The second and third areas outlined for best practices involve stakeholder/ community involvement in the project. It is explained that in assessing the financial viability of the project, consideration should be given to whether the development or redevelopment has a high likelihood of maintaining an enduring presence in the community. Similarly, the identification of the project's broader stakeholders (which include neighborhood groups, business leaders, school districts, and elected officials) and a plan for communicating the importance of the project, as well as information on how the project will be financed, should be developed and executed is recommended. In Lagos, government authorities usually adopt a paternalistic command approach to infrastructure provision which confirms the view that infrastructure in developing countries has been characterized by strict command and control arrangement. (Kessides, 1997 in Otegbulu, 2010). These are issues which need to addressed in Lagos if TIF as a Land Based Finance tool is to be a viable option.

2.3 Special Assessments

They are described as public fees or compulsory levies imposed upon the owners of properties for the specific purpose of defraying the cost of *additional* public improvements that are likely to additionally enhance the value of a property within the operative framework of that public development (Famuyiwa, ongoing). Special assessment taxes care particularly used for projects that involve repairs or improvement to adjacent property. E.g sewer and water system improvements, improvements to roads and sidewalks, installation of public utilities, cleaning, landscaping etc. The charges are limited to the recovery of actual costs incurred.

The size of the charge is based on a specific capital expenditure in a particular year, but the costs may be spread over a number of years. It is more common with high-scale infrastructure like construction of highways, sewers, and irrigation projects etc. Its roots can be traced to the Great Fire of London (1666). Special assessments only affect only those properties that benefit from these public improvements. They are also levied based on benefits received.

The special assessment district would be a well-defined geographical area within an already existing region. It is utilized by the region to define the area which has benefited from specific public improvements. Each lot in the area is assessed commensurately with the benefit which it derives from the improvement.

In Iacono et al (2009), special assessments may be levied if the direct special benefits for properties can be clearly identified and measured within a special assessment district. One basic requirement for imposing a special assessment is that the municipality must first have the statutory authority to make the improvement or provide the service for which the assessment will be imposed. Second, the municipality must have the statutory authority to assess for that type of improvement or service. (Michigan Municipal League, 2006). In addition, there must be a "finding" (a legally proper determination) that a project to be specially assessed is "necessary" as defined by the appropriate law. (Michican Property Consultants, undated). Thirdly, the cost of the improvement must reasonably relate to the increase in value.

Regarding the second requirement, in Lagos, most municipal or local governments are not backed by any laws relating to special assessments or land based financing generally (as explained under the tax increment financing discussions above). Because the valuation of environmental amenities is a relatively new endeavour and largely confined to academic discourses, its use and application is very limited beyond the ‘boundaries’ of academia. They are more commonly applied in the valuation for compensation, as opposed to man-made public amenities such as municipal infrastructure.

2.4 Development Impact Fees: This is also known as development charges or Impact taxes, and are one-time charges to raise revenue against new infrastructure, necessitated by new developments. This is imposed on developers – at a fixed rate per plot – in order to finance the off-site capital costs of new and or additional developments. This form of land based tax is often applied to the initial costs of infrastructure delivery, and under other circumstances, it may be applicable to additional capital costs required to service re-development. According to Kitchen (2003), under the benefits received principle, a development impact fee is fairest when it is easy to identify beneficiaries of the services provided by the physical infrastructure. In other words, when one can determine the cost of the eligible infrastructure for each plot/property and the benefits from the infrastructure are confined to the properties in question. Examples are water mains, and sewers. An efficient development charge must include the full cost of delivering the service. Where the services are to be allocated most efficiently, the rates charged per property should vary according to distance from the infrastructure development.

In implementing development Impact fee programs, Brown and Lyons (2003) explain that the power to exact such fees arises from the local authority’s police power to protect public health, safety and welfare. It allows a city to act in the interest of its citizenry and to enact and enforce ordinances and regulations that are not in conflict with state law. Further, it is not a tax or special assessment; by its definition, a fee is voluntary and must be reasonably related to the cost of the service provided by the local agency.

In setting up a *development impact fee program*, it is recommended that (a) trend of growth of a city should be determined through the regional plan - this helps plan for specific infrastructure that may be needed in several respects (b) at the beginning of the process to enact fees, it is important that the nexus requirement is understood between community growth and infrastructure requirements. This nexus requirement answers the questions (i) Is the impact of new development linked to the need for public infrastructure? (ii) Does the fee equate with value of the infrastructure? (iii) Is there a reasonable connection between the use of the fees and the benefits produced for the new development? In *Lagos, Nigeria*, these fundamental pre-requisites are not 'feats' which cannot be attained, but not in the current state of hazy data. According to Opoko and Oluwatayo (2014) controversies continue to trail Lagos population figures. However there is a general consensus that population growth of Lagos has been very rapid. Similarly, community infrastructure needs are usually not well articulated. Whittington et al in Fox (1994) report that for two decades hundreds of boreholes were drilled in Nigeria in order to meet the water needs of rural residents during the dry season. However, these boreholes are inoperative today. This failure was traced to the fact that the boreholes were drilled without careful consideration of local water demands. This is a fundamental condition for the use of development impact fees. Zegras (2003) further elucidates other conditions necessary for its use especially in developing countries.

(a) Administrative Capacity and growth management controls. As such, projects should be limited to the authority's geographical sphere of control and management.
(b) Efficiency and fairness, where the financing system is viable and equitable
(c) Justification for public finance, in this regard, and in the interest of transparency and clarity for all stakeholders.

2.4 Negotiated Exactions

Negotiated exactions are functionally similar to Development Impact Fees, except that they are not determined through a formal, formulaic process and are not necessarily/typically applied to off-site infrastructure provision. It emanates from a provision in the development approval process that requires a developer to give or provide something to a local government. Negotiated exactions can take the form of 'in kind' and not 'cash' contributions to local roads, parks, or other public goods as a condition of development approval or can be requested in the form of in-lieu fees. Negotiated exactions could for example require developers to forfeit part of their land in exchange for off-site infrastructure benefits (Iacono et al, 2009). It may not strictly be a 'cash' payment levy. They allocate the costs of development (through a one-time fixed charge) to those who generate them. Provides benefits to contributors. The distribution of the burden of costs across income groups is likely to depend on the incomes of the new residents of developments.

Factors encouraging negotiated exactions include helping to hold property taxes down by utilizing an alternative revenue source to pay for infrastructure improvements, acting as an effective growth management tool, diversifying the local approach for providing infrastructure, providing an opportunity for planners to negotiate with developers over the provision of infrastructure etc. Negotiated exactions are similar to development impact fees, but negotiated on a case-by-case basis rather than set as a policy and determined through a formula. (Transit Wiki, 2017). In Bauman and Ethier (1987) the typical legal issues underlying development exactions and impact fees are basically the same. Essentially, fees must be authorized by the state law and must be constitutional, which is encapsulated in previously discussed land-based finance mechanisms above. The nexus requirement is equally necessary with negotiated exactions.

2.5 Joint Development This involves collaboration with the public sector to simultaneously improve infrastructure while developing land. According to the National Council for Urban Economic Development (1989) in Zhao et al (2012), joint developments are public-private partnerships designed to decrease the costs of constructing or operating public investments/ infrastructure improvements through creative public-private financing arrangements. Further, Landis et al (1991) describe it as any formal agreement between a public transit agency and a private individual or organization that involves either the private sector paying to the public sector or the private sector sharing the capital costs with the public sector - in mutual recognition of the enhanced real-estate development potential created by using a public transit facility. Most examples in literature however pertain to transportation

infrastructure e.g. public transit, or high speed rail. In some instances, private developments are carried out using publicly owned lands, land banking.
In Lagos, this strategy appears to be the most promising in terms of workability - as several public private partnerships have been successfully implemented.
2.6 In all it can be seen that the regulatory framework in this area needs further concretization, which supports Salleh and Okinono's (2016) assertion that a major weakness expressed by majority of the developers is difficulty to promote private sector involvement in local infrastructure development due to unregulated-procedures.

3.0 Methodology and Empirical Data

Generally, the operational framework for land-based financing systems can be used within the context of Lagos, from documentary findings above. In the African Centre for Cities (2003) report, land-based financing is directly related to the property development process as the funding is raised from property developers or property owners. This section of the paper therefore ultimately attempts to investigate the extent to which land based financing techniques may have been adapted for use by private developers. According to Salleh and Okinono (2016) there is a heavy burden on the government in taking responsibility, and therefore the involvement of the private sector. A survey of 27 randomly selected developers along the Lekki corridor were selected in order to further investigate the inhibiting or encouraging factors towards the use of land-based financing mechanisms particularly. This area was used as a case study due to the astronomical rate of developments in the axis vis a vis the attendant problem of infrastructure delivery. The indicators so used were derived from literature, and respondents were given the opportunity to include other factors that they considered significant. A relative importance index was utilized as to the importance attached to the significance of these factors.
In Table 1 below, the mean response for each of the performance elements was to be able to measure the degree of importance for each factor, the following categorisations were used:

- If the mean response is below 1.49, then the respondents 'Strongly Disagree '.
- If the mean response is between 1.50 and 2.49, then the respondents are 'Disagree'.
- If the mean response is between 2.50 and 3.49, then the respondents are 'Neutral'
- If the mean response is between 3.50 and 4.49, then the respondents are 'Agree'
- If the mean response is between 4.50 and 5, then the respondents are 'Strongly Disagree'

Table 1. Significant factors constraining the use of Land Based Financing techniques in Lagos

Factors	S.A.	A	N	D.	S.D.	Mean	Ranking
Have no clear guideline of negotiation practice	5	10	12	-	-	3.741	2
No proper guidelines on the requirements of infrastructure.	-	9	11	7	-	3.074	3
Inadequacy of legal framework	14	7	6	-	-	4.296	1
Knowledgeability of Land Based financing			2	16	9	1.741	5
Other factors	1	2	14	4	6	2.556	4

Unsurprisingly, 'Inadequacy of legal framework' had the highest mean score of 4.296. 'Other factors' which was not garnered from documentary evidence within the context of the study area scored 4th on the mean score ranking of 2.556, and included factors like 'willingness to adopt its use' and 'uncertainty'. 'Knowledgeability of land based financing' weighed least on the scale with a mean score of 1.741. In Salleh and Okinono (2016), the selection of developers and local authority is based on diverse views on their professional expertise and knowledge. This section essentially was included to support documentary evidence.

4.0 Conclusion and Recommendations

This study set out to provide contextual insights on the best land based finance strategies for various public infrastructure projects under varying circumstances in Lagos, Nigeria. A particularly resonating observation from documentary evidence on various land based financing strategies is the policy gap in Lagos, Nigeria. The legal framework for use is lacking and therefore must be established. From evidence above, it can be seen that virtually all the land based mechanisms require legal backing and policies guiding their use, which appears absent. This was also found to be the strongest factor from empirical data.

This paper recommends that if land based financing systems are to be employed in Lagos, Nigeria, the relationship between the various land based financing systems must be clarified and well defined in order to avoid an overlap in usage which could arise due to their intense similarities. The benefits that can be harnessed from land based finance mechanisms remain veritable sources of infrastructure finance, as is seen from the example of Chile where it has been utilized, formalized and expanded with regulations such as the Urban Impact Study Requirements and 'Road Way and Urban Transport System Impact Studies (Zegras, 2003). Also, associations like the Real Estate Developers Association of Nigeria (REDAN) are encouraged to enlighten members on land based finance concepts, negotiation strategies, risks and immense benefits from the use of Land Based Finance methods.

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Case Study: Creative Risk Identification Techniques

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Disclaimer: This paper represents the authors' personal experience with project management challenges. The views expressed are those of the authors and not necessarily those of the U.S. Census Bureau.

ABSTRACT

As risk identification should occur early in a project life cycle, it is an ideal opportunity for an activity designed to push a forming project team into storming. When the project team has little project management experience and/or low risk tolerance, it is even more important to gather risks in a facilitated group environment.

In the last year, we have piloted risk gathering sessions that encourage creativity, get team members collaborating in small diverse teams, help novices understand risk management, and produce very robust risk registers. Below are examples of some of our sessions:

- Understand Risk Statements. In an example session, teams review and compose risk statements in different categories using pop culture references (i.e., "If recruiting materials are not translated into Klingon, then the Star Trek Enterprise…").
- Identifying Risks with Creative Brainstorming. In an example session, participants used an Etch-a-Sketch to illustrate risks, assuming teams need to brainstorm several risks before identifying one that can be effectively drawn.
- Risk Identification Challenge. In an example session, teams competed to be the first team to create a risk for every category in the risk breakdown structure, and a prize was awarded for the best risk.

Creativity is not highlighted as an essential skill for risk identification, despite the necessity for the team to imagine myriad potential obstacles and outcomes. In this paper we describe the techniques we have attempted and discuss lessons learned, to encourage more project managers to attempt fun and creative risk identification activities in their organizations.

Keywords: risk identification, creativity, brainstorming, risk management.

Problem

In the 1986 John Hughes film, *"Ferris Bueller,"* a teacher taking roll call is met with total silence when asking whether the title character is present in class. This cinematic moment gave birth to the classic line, "Bueller? Bueller?" (Hughes, 1986) which has since become indelibly synonymous to hearing no response from a full room. It is also often the experience of a project manager asking a new project team to identify risks. This is unfortunate as the engaged involvement of all members of a diverse project team is essential to identifying risks that could either derail or provide opportunities for the project.

When we were selected as co-project managers for a large project in the summer of 2016, we recruited project team members with the skillsets necessary for successful completion of the project. While these team members were experts in communications, web design, contracting, operations, translation, etc., many had little to no project management experience. When we attempted to discuss and baseline the project schedule, we quickly realized that a primer on work breakdown structures, predecessors, successors, and other schedule components was necessary for some team members to interpret the schedule we were proposing. Eventually, the project team was able to understand the straightforward importance of our artifacts and processes, such as a detailed project schedule and comprehensive plan, and the process of explaining each artifact and process, though slow, was effective, until we reached risk identification.

Risk identification presents an additional challenge in that team members can find it difficult to think about all of the things that might go wrong, or to identify a risk no one else has mentioned (much like the child who points out that the emperor is not wearing any clothes). As such, when we began our risk management processes, we were met with silence and the proverbial blank stare. There was some acknowledgement that risk management was important, but identifying risks and constructing informative risk statements was beyond the team's current abilities.

Analysis of Alternatives

Recent research explains the "Bueller?" level science we were encountering, and gave us an idea to combat it. (We are making the assertion that risk identification, creativity and innovation are similar, as all require thinking outside of the box.) An October 2016 *Harvard Business Review* article summarized a 2014 review of analyses by Silvia da Costa, from the University of the Basque Country, which found that "People's innovation output doesn't simply increase as the challenge increases. Instead, the relationship looks like an inverted U shape. Just as the Yerkes-Dodson law indicates that both very low and very high levels of stress decrease performance on complex tasks, when people are faced with a challenge so big that they feel they don't have the skills or resources to tackle it, innovation performance also declines." (Imber, 2016). Perhaps our team members were so overwhelmed by the task of identifying risks that their ability to think of risks also declined. Could breaking the task into more manageable pieces engage the team?

There is also an emerging management philosophy that focuses less on teaching creative staff a discipline and asking them to refine the process, and more on encouraging creative staff to redefine the process. An article in the October 2008 issue of *Harvard Business Review* cited research that focus on processes can ultimately hinder important innovation in each industry (Amabile, 2008). Furthermore, the article quoted Franz Johansson's finding, from interviews with people doing highly creative work in many fields, "that innovation is more likely when people of different disciplines, backgrounds, and areas of expertise share their thinking. Sometimes the complexity of a problem demands diversity." We needed everyone on the team to participate in risk identification, and we needed to find a technique that fit their style rather than training them to do it our way.

Creativity is not highlighted as an essential skill for risk identification, despite the necessity for the team to imagine myriad potential obstacles and outcomes, and when and how to use creativity in project management is an evolving concept. A conference paper from Paul Warner advises, "If you go overboard with creativity, the result is no longer recognizable as project management. This is my blanket warning that there can be too much of a good thing when it comes to applying creativity to the field of project management" (Warner, 2012). However, Warner later clarifies that project issues and risks are "an area where creativity can really set a project manager apart from others and lead to greater project success" (Ibid.).

This led us to look for an accepted risk identification technique that would enable us to break the task into smaller pieces, be appropriate for our diverse group and encourage creativity. The fifth edition of the PMBOK guide lists many different techniques for identifying and refining risks, including brainstorming, Delphi Technique, interviewing, root cause analysis, checklists, assumptions analysis, SWOT analysis, expert judgment and various diagramming techniques (PMI, 2013). Each of these techniques is not enough on its own, but employing each of them does not guarantee an exhaustive risk register either. For example, in the PMBOK's discussion of checklists, it explains, "While a checklist may be quick and simple, it is impossible to build an exhaustive one, and care should be taken to ensure the checklist is not used to avoid the effort of proper risk identification" (PMI, 2013). Most techniques also require an extended period of time, with several cycles of review that may not always be available.

An additional wrinkle in our situation was the newness of the team. Our team was a collection of individuals and needed a team-building activity to push them into collaborating on project work. We focused primarily on those risk identification techniques that required group cooperation, challenging the team to enter the storming phase.

Recommended Approach

Returning to the basics, as Srinviasan noted, "The main goal of risk management is to avoid unpleasant surprises" (2010, p. 10). We could accomplish risk identification for this particular group in their stage of group development, by focusing on designing a facilitated brainstorming session that taught classic risk identification concepts, in small short sessions, while also providing an opportunity to engage our team members' creative side.

Implementation

Attempt One: May the Risks Be with You

"Help me, Obi Wan. You're my only hope!" ("Star Wars Episode IV: A New Hope," Lucas, 1977).

Obi Wan Kenobi, a popular character from the original Star Wars film, was obviously not on hand to assist. However, our first challenge was to make "the process of determining which risks may affect the project," easier for our team members to approach (PMI, 2013). Our challenge was to help the team feel less overwhelmed by presenting the identification of risk in a manner that would not only be more comfortable, but also fun.

We chose examples from film and other popular culture references, especially examples from fantasy and science fiction, and inserted them into the standard "If ________, Then, _________," risk format to introduce the risk statement concept to the team. For example, "IF Princess Leia is unable to use R2D2 to save and transmit the Death Star design plans to Obi Wan Kenobi, THEN the flaw within the design of the Death Star would remain unknown and the Rebellion would be crushed." When the risks were imaginary, they struck a creative nerve within the team, allowing them to more openly share their thoughts on the real-life projects. And when the subject matter involved situations and conflicts that most people recognized, identifying the causes and effects was easier.

Results

While our project was definitely not important to the safety of the galaxy, using these types of pop culture references made it easier for the project team to understand the format, concept, and process, and then transfer that understanding to identifying real risks that might affect their subject areas. After reviewing eight examples of pop culture risks, the project team was able to identify over forty actual project risks ranging from budgetary constraints to language barriers (no C3PO to translate!) that were then incorporated into our project risk register.

Attempt Two: Smells like Team Spirit

"But I get nowhere unless the team wins." ("The Untouchables," De Palma, 1987).

We also worried that the forming project team was engaged with us but not engaging with each other. Risk identification presents a crucial opportunity for collaboration, as an event in one sub-team will have effects in other sub-teams that may only be known by those team members. To force communication, and encourage a bit of storming, we split the project team into four smaller groups, where they could brainstorm potential risks. They were then challenged to select one of their identified risks and draw it in twenty minutes. However, there was a twist; they must use an Etch-A-Sketch, a popular childhood toy that sketches by turning knobs associated with vertical and horizontal planes, to illustrate the depiction of the risk.

Results

Team spirit kicked in immediately as each group huddled together to share their thoughts and select an artist. Positive competition has long been identified as a motivator for employees. A 2013 article from Bright Hub Project Management asserts, "positive competition promotes an 'everybody wins' attitude where team members work collectively toward a common goal" (Plowman, 2013). When the challenge was to identify many risks in the hopes that one could be depicted, and ultimately win the selection as the best drawn risk, the stigma of suggesting risks disappeared.

There was laughter, good-natured ribbing of the artists, and real collaboration. At the conclusion of the event, teams felt empowered by their increased knowledge of risk identification, the number of risks that had been identified, and the fun they had experienced with their team members.

Attempt Three: And Your Little Risks Too

"And my head, I'd be scratchin' while my thoughts were busy hatchin', if I only had a brain." (E.Y. Harburg).

After the team had some experience with risk identification, most members joined a new project team for a follow-on project. Though members were now familiar and comfortable with the risk identification process, an expectation had been set for a fun risk identification session. Pleased with the team's energy and excitement, we developed a fun challenge to introduce the risk breakdown structure and identify as many risks as possible during one hour-long team meeting. We transformed our meeting room into the 1939 film, *"The Wizard of Oz"* (Fleming, 1939). We taped images of characters from the film around the perimeter of the meeting room, with each character representing a risk category we wanted to develop in our risk breakdown structure. For example, Glinda the Good Witch represented opportunities, The Wicked Witch of the East represented weather and environmental risks, and the Wicked Witch of the West represented reputation risks. To illustrate each risk area, we again developed an example risk statement for each area. Notional examples are as follows:

- IF Glinda creates a viral social media campaign THEN public engagement might be better than expected.
- IF the cowardly lion is unprepared to pitch interviews to the media THEN opportunities to increase awareness may be missed.
- IF Dorothy drops a house on her sister THEN the witch may organize a campaign to boycott Munchkin Land.

Team members were challenged to venture through our version of the land of Oz, and identify one real risk in each risk area displayed. The first team to identify at least one risk in each risk area within the risk breakdown structure won a prize.

Results

Project team members divided into small sub-teams and travelled around the room. We also moved around the room facilitating conversation and answering questions. For example, many team members had become proficient at identifying negative risks, but were stumped when asked to identify a potential opportunity. We explained the concept of opportunities in the risk context, and ended up compiling a very interesting list of opportunities within the risk register.

It was also entertaining to see the norming project team react to each other's risks. Choruses of "Ooh yeah, that's a good one!" could be heard when each sub-team read what they had identified as their best risks, and teams devoted real energy to constructing through risk statements. Following the session, we read all of the risks aloud, and the team awarded a small prize (a *"Wizard of Oz"* inspired Scarecrow bobble head) to the best risk.

Recommendations

We would field each of these techniques and strategies again, as we have developed a good routine and facilitation technique. Though the risk registers produced by these activities have been robust, causing heart palpitations for some risk averse PMs, we have been able to avoid a large proportion of the risks identified by ensuring that we were aware of their potential during the planning process.

There are small enhancements that could be made to perfect these techniques in the future.

- In several activities we collected the handwritten risks on colorful post-it notes. Due to the space limitations of a post-it note, we had challenges reading compressed handwriting, and experienced some ill-advised ink and post-it color combinations (i.e., silver Sharpie on dark blue post-it was very difficult to read).
- Some team members provided a well-developed risk, and then provided several additional risks that were slight variations on the original. Ideally, team members could focus on identifying many different risks during the session and then continue to further develop each risk after the session.
- We recognized that these sessions were not as conducive to those attending the session remotely (phone, etc.). With that in mind, we attempted to create an online brainstorming room for those participating virtually. This initial prototype was met with mixed results from a collaborative perspective and relatively low participation overall.

Summary

Though it may have looked like we were taking a Bueller-esque day off from project management, we did construct a robust risk register that prepared us to respond to the risks that ultimately became issues. We introduced the members of our project team to risk management in a positive and engaging way that may have positive effects for future projects, and we don't have nightmares about Ben Stein anymore. Though customized risk identification sessions may be very different in other organizations, the concept of designing a risk identification process to meet the needs, strengths, and comfort level of the group is one that can ultimately transfer across the project management discipline.

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Evaluating the Impact of Buildability Assessment and Value Management on Construction Project Delivery

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ABSTRACT

The economies of the countries of the world are constantly changing and the need for more efficient and effective delivery of construction projects is forcing stakeholders to seek ways of improving the productivity of construction projects to better meet the key performance indicators of time, quality and cost of a project. This research focuses on highlighting the importance of buildability assessment and value management on the performance of construction projects. A survey research was conducted on industry practitioners within the Nigerian construction industry to obtain primary data on the knowledge and implementation of buildability assessment and value management and a SWOT analysis was carried out based on findings from the survey which revealed the lack of knowledge and implementation of buildability assessment and value management in a formal context within the Nigerian construction sector. A framework was then developed showing how buildability assessment and value management can be integrated and implementation steps was provided. The implementation of buildability assessment and value management would enable the construction industries compete with other industries such as manufacturing in terms of productivity improvement and position it to become an integral part of the nation's economy in terms of its contribution to the gross domestic product (GDP).

Keywords: Buildability, value management, construction, project.

INTRODUCTION

The economies of the countries of the world are constantly changing and the need for more efficient and effective delivery of construction projects is forcing stakeholders to seek ways of improving the productivity of construction projects to better meet the key performance indicators of time, quality and time of a project. These three indicators provide the definition for a successful project as a project is said to be successful when a sort of equilibrium is realised between them. However, achieving this equilibrium is difficult as there are multitude of factors responsible for the success of projects. Typically, a delay in the anticipated project delivery date nearly always leads to an increase in the overall estimated cost of executing the project.

On the other hand, minimising duration without compromising quality is critical to success in any construction project and this has in turn led to buildability increasingly becoming a major requirement in building practice. Over the years, there has been an increase in the cost overrun and schedule slippage associated with construction projects in both developed and developing countries and the reasons for failure are similar across the regions and countries of the world. Yet, the issue of schedule slippage and cost overrun is still a recurring decimal in the construction industry leaving lots of clients dissatisfied. Walker (2007:101) posits that it is important to define and implement client requirements in a project due to the high level of influence they have on the success of projects. It therefore becomes important for organisations to adopt a broader range of procedures and greater flexibility in seeking ways to meet the expectations of the clients.

Leeuw (2001) reveals the importance of maximising the function to cost ratio of a project by scrutinizing all decisions from conception to completion against a value system determined by the client/owner in order to improve the possibility of providing value for money for the client. Research has shown that change orders resulting from design variation or change of scope as one of the causes of low productivity in construction (Hanna and Gunduz 2004; Moselhi et al. 1991, 2005) with the cumulative effect of client dissatisfaction. Design variation can usually result from a lack of buildability assessment before the commencement of the project or due of changing client requirements which can be indicative of the absence of a value management workshop before the commencement of the execution phase of the project. It then becomes imperative to ensure that design variations and changes in client's requirements are reduced and this is where buildability assessment and value management studies become invaluable.

LITERATURE REVIEW

Buildability and constructability are two words that cannot be found in most conventional dictionaries. However, the idea behind both concepts have been in practice in the construction sector for a long time. Buildability aims at enhancing the efficiency of the building process through the development of construction-sensitive designs. The construction industry research and information association (CIRIA 1983) defines buildability as the extent to which the design of a building facilitates the ease of its construction. All the definitions proposed by various researchers (Bamisile 2004; Chen and McGeorge 1994; Ferguson 1989; Griffith and Sidwell 1997; Jergeas and Put 2001; Moore 1996) have the same central theme "ease of construction".

Takim and Akintoye (2002) assert that the development of any nation is usually first assessed by the development of its physical structures. It therefore follows that the importance of buildability is directly linked to the importance a nation attaches to the development of its physical structures. Construction processes are becoming more demanding due to design complexities resulting from more innovative designs. Therefore, the implementation of buildability assessment becomes increasingly important to ensure that projects can satisfy time, cost and quality constraints.

The implementation of buildability starts at the design stage (Aina and Wahab 2011; Eldin 1999; Hiley and Yagci 2001; Mbamali et al. 2005) although Anderson et al. (2000) contends that it is best applied during the project definition stage where the project objectives, characteristics and scope are defined and went further to provide four basic steps which must be followed in developing a buildability plan. One important consideration for implementing buildability assessment is that it is done proactively and not reactively. Some important factors that should be considered to improve buildability includes: well defined specifications, site investigation/access to site, the use of prefabricated elements (modular construction), standardization and repetition, design for buildability using 3D, use of 4D for buildability reviews consisting of spatiotemporal clash detection and site safety considerations.

According to Koo and Fischer (2000), a 4D model defined as a 3D model linked to the construction schedule presents an excellent opportunity to enhance buildability as it provides a basis for analyzing time-space conflicts, safety issues,, and site workspace management. This is possible because the 4D model shows the logical, temporal and spatial information of the construction process.

Regardless however of the perceived importance of carrying out buildability assessment on projects, there are some barriers mitigating against its successful implementation. The Construction Industry Institute (CII 2016a) reveal that the biggest obstacle to the practice and implementation of buildability is the “review” syndrome and this situation arises when construction personnel are only invited to review completed or partially completed products from designs. Song and Chua (2006) claim that the difficulty inherent in measuring the benefit of buildability to the construction industry poses a barrier to its successful implementation. Other barriers include lack of practical construction knowledge by designers (Wong et al. 2004), lack of a systematic method of integrating the knowledge and experience gained in the industry overtime into the project development phase (Anderson et al. 2000), rigidity of clients and consultants in accepting alternative construction methods (Pheng and Abeyegoonasekera 2001). CII (2016b) broadly categorized the barriers to the implementation of buildability into four general areas; cultural, procedural, awareness and incentive barriers. The top five common barriers were also identified and this consists of; complacency with status quo, reluctance to invest additional money and effort in early project stages, limitations of lump-sum competitive contracting, lack of construction experience in design organisation and designers perception of “we can do it alone”.

One way to remove the barriers mitigating the successful implementation of buildability assessment is through the implementation of value management workshops/studies. A summary of the value management concept is shown in **Figure 1** .

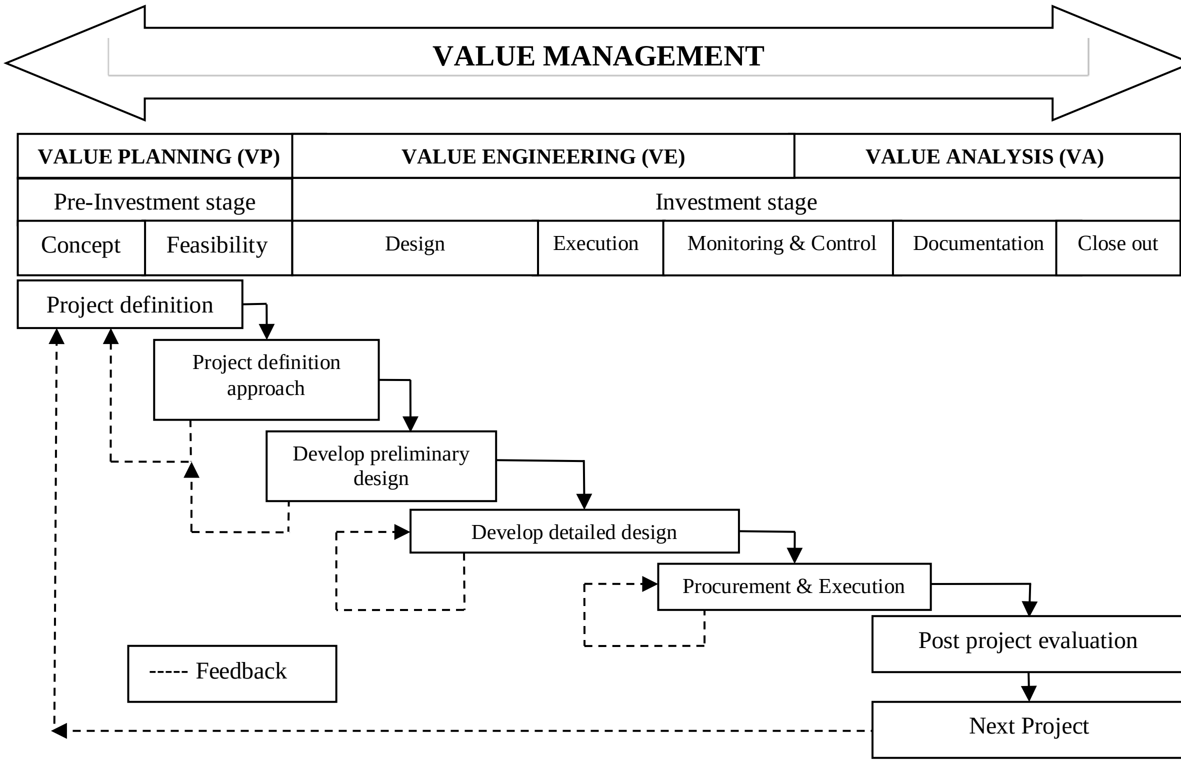

Figure 1:Value management concept (Adapted from Merna and Al-Thani 2008)

There are three techniques typically adopted in conducting a value management study namely; value planning (VP), value engineering (VE) and value analysis (VA). Value planning is the first step in the value management process and its focus is on identifying project objectives and developing general approaches to meet the project objectives. The VE phase commences after the VP and focuses on identifying and eliminating unwanted costs with the aim of increasing the value of the project by considering the availability of materials and their alternatives in respect to cost and adherence to the project specification.

Chen et al. (2010) asserted that value engineering is a systematic process which combines technical knowledge and common sense to identify and eliminate unimportant projects costs. Several research (Blyth and Worthington 2010; Kelly and Male 2003; Lin and Shen 2007; Norton and McElligott 1995; TAM 2004) provided different definitions for value management consistent with the concept of improving cost, schedule and buildability of a construction project.

From **Figure 1** , it can be observed that the value planning phase provides an excellent opportunity for the clients to make their requirements known to the design team. There is also the possibility of implementing buildability assessment within the value engineering phase of the value management process.

Value management studies involve the completion of three phases (pre-study, workshop and post study). According to Kelly et.al. (2014), the workshop stage is the most important phase of the value management exercise encapsulated by the job plan. ***Table 1*** shows the three major different steps adopted in the job plan as proposed by Kelly and Male (1993).

Table 1: Job Plan Procedure (Adapted from Kelly and Male 1993)

Pre-study Phase
• Gathering and blending of information, agenda production and presentation, team building.
Workshop/Study Phase
Information sub-phase
• Gathering, blending and sharing of information, task and process analysis.
Creativity sub-phase
• Brainstorming by team members to generate a host of ideas.
Evaluation sub-phase
• Sorting and refining of ideas for further development, function analysis, cost/worth analysis.
Development sub-phase
• Development of implantation of selected ideas.
Post-study Phase
• Presentation of sketch drawings and cost calculations to project sponsor.
• Feedback which involves giving the opportunity to test the designs and cost predictions.
• Comments and/or criticisms about the study from all project stakeholders.

Kelly et al. (2004) provided ten critical success factors (CSF) necessary for the success of value engineering workshops. The factors help to differentiate value management studies from other group decision making processes while focusing on key issues surrounding the conduct of a value management study. Fifteen CSF were identified by Shen and Liu (2003) with the focus of success being the composition of the value management team. However, their research failed to highlight the significance of the implementation of the job plan.

DEVELOPMENT OF INTEGRATED CONCEPTUAL FRAMEWORK FOR THE IMPLEMENTATION OF BUILDABILITY ASSESSMENT AND VALUE MANAGEMENT

The conceptual framework was developed from extensive study of existing literature and the model implementation steps were from the outcome of interviews conducted with project managers within nine construction companies in Nigeria with an average work experience of 9.5 years. The participants were chosen mainly based on their work experience and their decision-making capabilities within their organisations and their knowledge of buildability assessment and value management. The conceptual framework is shown in **Figure 2**.

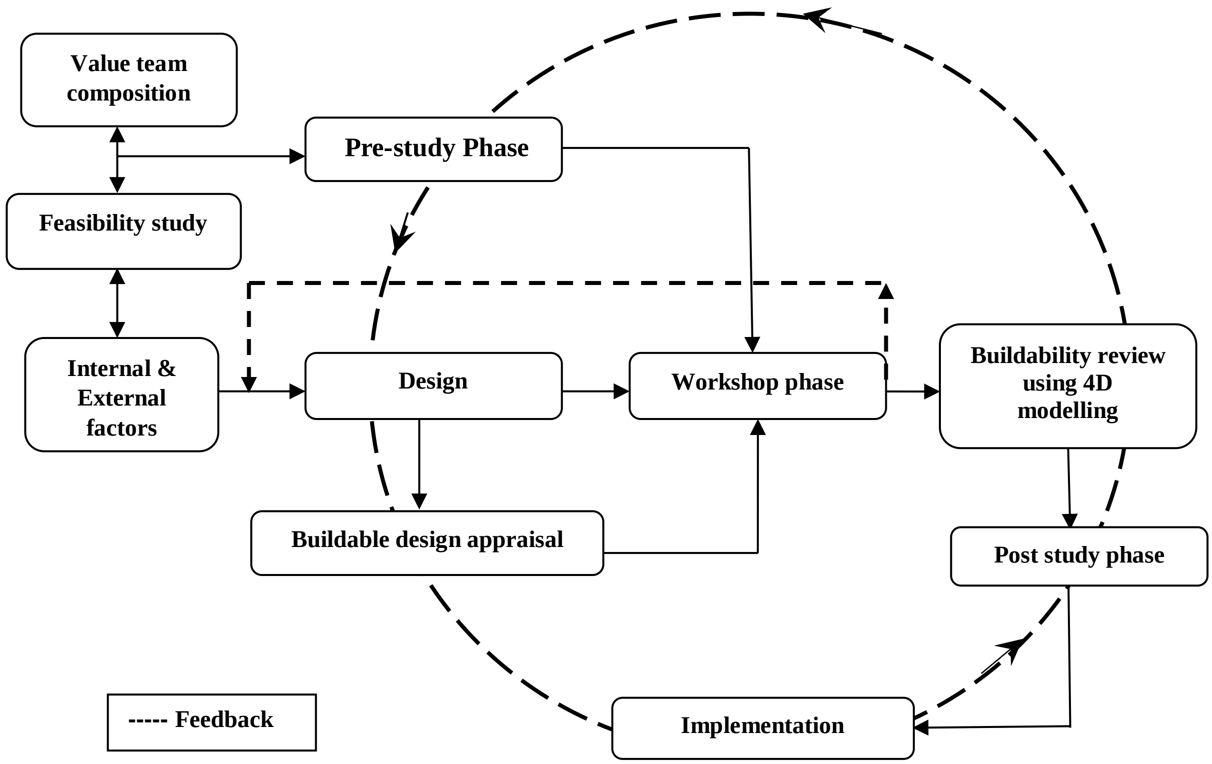

Figure 2:Integrated VM and BA framework

The proposed framework seeks to integrate buildability assessment into the value management workshop. It is a simple model which can easily be applied to the construction industry. The pre-study phase, the design phase and the buildable design appraisal process all cumulate to the workshop phase. The workshop phase seeks to propose better ways (more innovative) of approaching the construction process. This is done with the view of providing added value to the client and to the project.

The buildability review is an output of the workshop phase and it is best achieved using 4D modelling. The buildability review should lead to the production of a report documenting the findings, observation and/or recommendation of the value management team to the project sponsor.

Approval of the recommendation/ report from the post study phase leads to the implementation phase which is the commencement of the construction process. There is continuous room for improvement during the entire process. The steps for implementing the framework in **Figure 2** is listed below:

1. Select value management team composition.
2. As part of the feasibility study phase, carry out site visitation/investigation, identify factors that may potentially affect the project (risk identification), access the risk and prepare a risk plan.
3. Proceed with the design.
4. Carry out a buildable design appraisal with inputs from the major project stakeholders (including design and construction personnel).

5. Conduct function analysis to analyse the functions of the constituent parts of the project.
6. Carry out a buildability review of the design drawing using building information modelling (BIM) and 4D BIM.
7. Generate, sort and refine ideas for the construction process as well as construction materials.
8. Make corrections to the design drawings if the need arises and present sketch drawings, recommendations and project cost implication to project sponsor.
9. Commence the construction process.
10. Document lessons learn for use in future projects.

CASE STUDY

To evaluate the impact of buildability assessment and value management on the delivery of construction project, a case study approach was adopted using the Nigerian construction industry. Amade (2016) reveals that the state of the Nigerian construction industry does not suggest the deployment and use of buildability practices by professionals within the industry and this could in part be responsible for the poor performance of construction projects in the country. Akpan et al. (2014) further assert that the cases of project delays, abandonment, cost overrun and failures can be blamed on the lack of adequate knowledge and non-implementation of constructability principles in the project delivery process.

A survey methodology was adopted using a questionnaire administered to practitioners within the Nigerian construction industry. A total of 310 copies of the questionnaire were distributed via email and the sample size included project managers, architects, engineers, consulting engineers, building contractors and quantity surveyors. 94 valid responses were received representing a total response rate of 30.3%. **Figure 3** shows a breakdown of the valid responses received based on the respondent type.

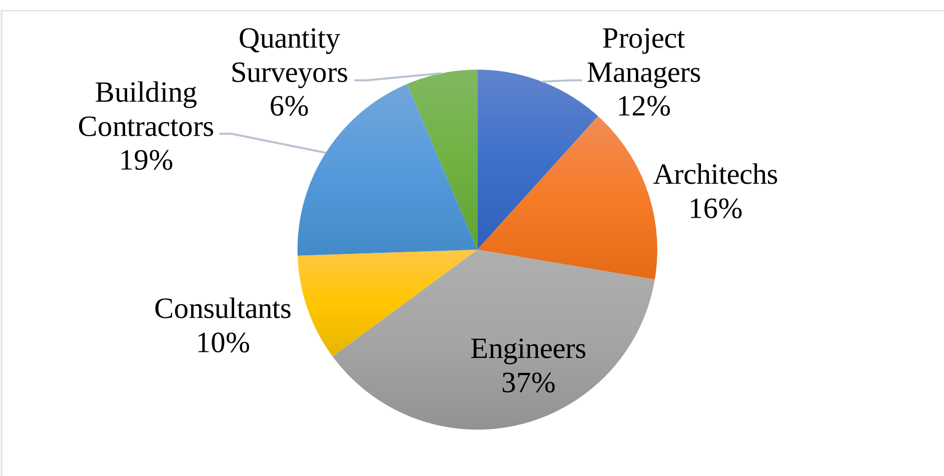

Figure 3: Breakdown of valid questionnaire responses

The questionnaire was structured into two parts, the first part was used to conduct an industry strength, weakness, opportunity and threat (SWOT) analysis of the Nigerian construction sector. The SWOT analysis is presented in **Table 2**.

Table 2: SWOT Analysis of Nigerian Construction Sector

STRENGHTS	WEAKNESS
• Availability of cheap and affordable labour. • Large labour force. • Large number of foreign graduates. • Availability of local raw materials.	• Poor credit facilities and access to finance. • Lack of suitably experienced and motivated professionals. • Poor integration of people with construction knowledge in the design process. • Poor documentation of lessons learnt from previous projects. • Poor implementation of health and safety policies. • Lack of research and development aimed at developing innovative construction approach. • Low quality standards and poor enforcement of construction specifications. • Poor inspection and control • Poor remuneration of indigenous staffs in comparison to expatriates.
OPPORTUNUTY	**THREATS**
• Large construction market. • Adoption of lean thinking. • Collaboration with foreign construction companies presents opportunities for technology transfer.	• Harsh and unpredictable business environment. • High level of extortion by local communities. • Lack of social security. • Over reliance on foreign expatriates. • High inflation levels.

The second part of the questionnaire sought to provide answers regarding the knowledge and implementation of buildability assessment and value engineering within the respondent's organisation. The findings of the survey revealed that 95% and 90% of the respondents were familiar with the concepts of buildability assessment and value management respectively. However, only 20% of the respondents claim the use of value management workshops on projects they have been involved in within the last 5 years while 45% reveal carrying out buildability assessment on designs prior to commencing construction.

The research findings revealed a lack of implementation of buildability assessment and value management on construction projects within the Nigerian construction sector, hence a framework was developed showing how to integrate both concepts to enhance the knowledge and facilitate the implementation.

DISCUSSION

The construction industry is often criticised for its poor performance in quality, cost, safety and speed of delivery. One of the main reasons for this criticism is the degree of fragmentation that exists in the construction sector. This "bridge" can be mended using value management workshops which seeks to bring together all the major stakeholders typically involved in a project early in the project. The ease of implementation of the value management workshop is facilitated by choosing a project delivery method that promotes early interaction of the project stakeholders such as the integrated project delivery method (IPD). However, Ghassemi and Becerik-Gerber (2011) contends that this delivery method is beset with legal, financial, cultural and technologies barriers while Azari et al. (2014) revealed that the IPD is best suited for complex, dynamic and fast projects.

The reviewed literature highlighted the importance and role of buildability assessment and value management in improving a projects performance indicators as both practices are structured towards providing value to clients in terms of better and more buildable designs, speed of delivery, improved quality and helping to identify cost saving potentials in a project regardless of the project delivery method adopted. Through value management workshops, more innovative ways can be discovered which would seek to add more value to the project. Some schools of thought however view value management as a cost saving exercise because it seeks to provide the best value for clients at the most affordable cost and the argument following this line of observation is that quality will be sacrificed at the alter of cost. It therefore becomes imperative to ensure that the outcome of the value management workshop is not a trade off with the quality requirements of the project.

A major observation from literature was the revelation that although there is a consensus of the benefits to be gained from implementing value management and buildability assessments on projects, both concepts are carried out differently using different personnel and this has the potential of leading to time and resource wasting as opposed to when there is an integrated team involved in both processes.

CONCLUSION

Integrating buildability assessment and value management would help in reducing cost overruns while enhancing the satisfaction of the project stakeholders as it seeks to discover alternative cost-effective ways of carrying out construction processes while ensuring that the project still conforms to the expected quality standards. The implementation of an integrated conceptual framework within the Nigerian construction sector will serve as a vital step towards improving productivity, increasing profitability while increasing collaboration.

The use of building information modelling (BIM) plays an important role in answering the question of buildability to some extent. It however does not take the place of a formal buildability assessment exercise with input from construction practitioners nor does replace the ideas and innovations that a value management workshop would generate. Better designs facilitating ease of construction can be produced when the input of construction personnel are sought during the design process. Also, the potential for cost savings are at the highest during the early stages of the projects and this presents an excellent opportunity to exploit the advantages of conducting a value management workshop.

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Kansas City Hyatt Regency Hotel Walkway Collapse

What caused the worst structural engineering disaster in the United States?

The hotel was designed and built with an atrium lobby with walkways above the lobby floor. The critical walkways were the 4th floor walkway, which was directly above the 2nd floor walkway. On July 17, 1981 at 7:05 PM the 4th floor walkway failed and collapsed onto the 2nd floor walkway. At the time there were 1,600 people in the atrium attending a tea dance completion. The collapse caused the death to 114 people.

The original design called for the 4th floor walkway and 2nd floor walkway to be hung from the atrium roof by single continuous steel rods that served as the hangers for the walkway supports to the beams under the walkway.

During the structural design review process, the single continuous steel rods got changed to steel rods, going from the atrium roof to the 4th floor beams, and then a second set of rods going from the 4th floor beams to the 2nd floor beams. This structural change effectively doubled the load on the connection at the 4th floor box beam holding up the 4th floor walkway. The 4th floor walkway collapsed over the 2nd floor walkway and they both continued to fall to the atrium floor.

Who is to blame for this engineering tragedy? The courts determined that the structural design engineers were liable for neglecting to properly review the structural shop drawings and allowing changes to occur.

Lean or Agile:
Lessons Learned from a Tech Startup

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Abstract: "Lean or Agile" provides a model of how any businesses can discover, develop, and deploy innovative solutions under extreme uncertainty. This paper evaluates project management techniques by using a technology startup case study to explore the extreme conditions which clarify when Lean and Agile management are most successful at achieving the organization's goals. The paper presents insights on the indicators of when and where it is most appropriate to use Lean or Agile project management techniques, and how to transition between the two. The case study uses real-world examples of success and failure in applying these techniques to enrich its proposed theory on Lean and Agile. The paper's subject is a startup, Second Nature Software LLC, that began with neither a product nor a target market and that, within one year, developed a cutting edge application piloted by five large research institutes, including two institutes at the National Institutes of Health (NIH).

Influences and project management theories referenced include: Lean Startup, Customer Development, Product Development, Design Thinking, Theory of Constraints, Scrum, Disciplined Agile Delivery, Kanban, and Total Quality Management.

Introduction

Which method is the best for managing uncertainty in startup-like environments - Lean or Agile?

This is the question that Second Nature Software LLC faced when beginning with one goal in mind: start, develop and build a successful product company. The three co-founders had over twenty years of software development experience, and about ten years' experience using Agile. However, they had no market, no product, and no identified customers - and only a small amount of savings. By the end of their first year, Second Nature Software had built a data science product that was in trial at the largest medical research organizations in the world; including three institutes at NIH (NCI, NIAID, and NCATS), Johns Hopkins University, and the University of Maryland School of Medicine.

There are many competing perspectives on what works best for success in organizations discovering and building new technology to sell in the marketplace. Startups, especially technology startups, work in such extreme conditions that they have only a 10% chance of succeeding [1]. With so much uncertainty, traditional business plans, schedules, resource matrixes, and requirements specs do not last long enough to write them down. Teams must be willing to change fast and leverage management processes that can ensure order in a chaotic environment.

In the case study of Second Nature Software LLC, both Lean, Agile, and Hybrid methods were used at different stages in the company's development. The case study offers details of the how the methods were employed, the tools used, the success of employing the techniques, and lessons learned for how to do it better. The Conclusion then judges which method is better for most startup and extremely uncertain project environments, based on these real-world experiences.

Lean vs. Agile - What's the Difference?

Most project managers today study Lean for process improvement and Agile for delivering projects. This general classification makes sense given the history of the techniques. Lean was invented for manufacturing cars, and agile was conceived for coding software. The goal of lean was to manage capacity and have the requirements for production "pulled" from the customer with *varying demand over time but defined orders* (e.g. scope and price) [3]. The goal for agile was to manage changes in what the customer asked for during development with *varying orders but defined demand over time* (e.g. schedule and price) [4]. If we map these concepts, as well as the traditional approach of varying price with fixed scope and schedule, we form what is known as the triple cost constraint:

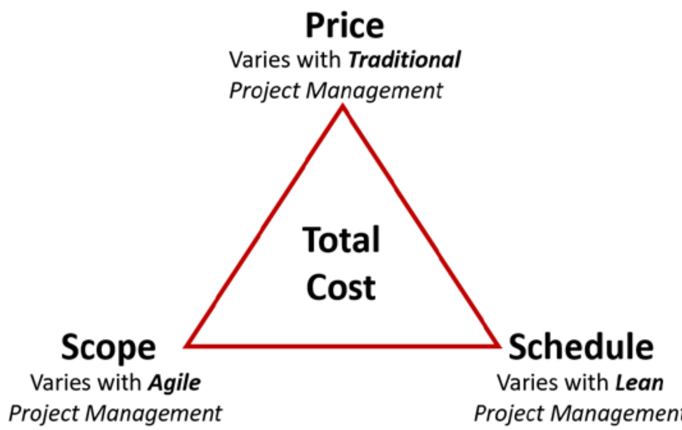

Figure 1: Triple Cost Constraint Alignment to PM Methodologies

In practice, however, it is difficult to understand the true differences between the Lean and Agile methods that are often considered variants of each other. Both methodologies "eliminate waste" and "vary output." The history of two methods show a strong connection between Lean and Agile, which both have roots in Total Quality Management and its emphasis on continuous improvement.

The difference between Agile and Lean in a project management environment is the type of *uncertainty* they address.

For Agile, one should have a certain customer and team fully capable of doing the work, but uncertainty which business needs will achieve the customer's business goal. Agile manages uncertainty by varying the scope of the project and maintaining a singular focus on the customer and their ability to express business needs. Therefore, Agile fits when the customer is not changing and the business needs are able to be prioritized at least for a set period of time. Agile's goal is to ensure that only the truly necessary business needs are satisfied to reduce the price and time to delivery.

In other words, Agile asks the question: *"What are the business needs that must be satisfied?"* Agile focuses on *business needs uncertainty.*

Lean, on the other hand, is best fit when one has a fixed set of resources and clear scope, but uncertainty in what the time and effort ("technical needs") really are to achieve that scope. Lean manages the uncertainty by prototyping, "learning by doing," and iteratively elaborating the technical needs to reduce time to delivery. Therefore, Lean fits when the business needs are certain but the technical needs are unknown. The goal is to learn what technical needs are required and achieve them as efficiently as possible.

In other words, Lean asks the question: *"How can the business needs be satisfied efficiently?"* Lean focuses on *technical needs uncertainty.*

However, it should also be said that every method will in fact manage change in scope, schedule, and price throughout a project. Lean often leads to changes in scope driven by learning what is needed to deliver. Agile leads to changes in schedule by learning what not to deliver. And every Traditional project manager will use systems engineering to reduce overlapping scope and hasten delivery to be on time and budget. But it is the emphasis of either varying price, schedule, or scope that differentiates project management methods and the approach to managing uncertainty.

Case Study Background and Overview

Second Nature Software LLC was founded by three former IBM employees: Matthew Garlan, John Johnson, and Michael Pato. At IBM, the team delivered an award-winning project for the National Archives, where Michael and John served as the two Agile Project Managers for the 50 team members, and Matthew Garlan served as Development Lead and Architect. The project called ERA 2.0 implemented a cutting-edge, cloud-based platform for the National Archives to process and store petabytes of government records; and was awarded Project of the Year in Project Management for all IBM projects (the company employees over 400,000 people).

After completing the ERA 2.0 Pilot, the startup co-founders decided that they wanted a change from services to build products that could sustain them financially and do good in their communities. At first, the startup was named “One Year LLC” because the team gave itself one year to be successful. However, this name was quickly changed to “Second Nature Software” as the startup did not want any customers thinking the company was unstable. The team had no product or market, but managed to navigate its way to becoming a data science products company for the medical research community.

Second Nature Software’s primary product, “Rocketfish,” is a data management automation tool that is faster than Excel, while being more traceable than scripting languages like Python or R. This case study covers the first year of the startup’s history and its first three phases of selecting, building, and distributing the Rocketfish to the DC-Baltimore medical research community:

- ***Phase 1 - Going Lean on Product Selection***. This phase covers the process of selecting product, Rocketfish, by evaluating team strengths and market needs. The team used Lean project management to execute this phase of startup.
- ***Phase 2 - Build the MVP with Disciplined Agile***. Here the founders work to build the Alpha version of Rocketfish to get a minimum viable product (MVP) in the hands of medical researchers. The team used Agile for this phase.
- **Phase 3 - Distributing Rocketfish with a Hybrid Model**. With the Alpha built and in use, the co-founders worked using Lean and Agile methods to both respond to feedback and build new features needed to attract major institutes into product trials.

Second Nature Software LLC is still operating today and has almost medical researchers in trial with Rocketfish across institutes at NIH and major medical research universities globally.

Phase 1 - Going Lean on Product Selection

Second Nature Software started with a small team and a simple goal: discover, develop, and distribute a product for sale within one year. The team had experience starting companies before, but never without a predefined service or product. Therefore, a few of the initial steps were already known but mostly the plan for Phase 1 existed just as high-level objectives:

1) Establish the Company Formally (charter, bank accounts, operating agreement, etc.),
2) Set up Business Systems (Email, Website, Business Cards),
3) Determine Process to Discover Product Options,
4) Execute Process to Discovery Product Options, and
5) Select a Product.

The first two objectives were quickly achieved in the first week. The third, determining a process to discover product options, drew heavily on Customer Development by Steve Blank [6] and the Opportunity Canvas by Dr. James Green [5]. Using these blueprints the Second Nature team could map out a scope of how to identify a product that best fit the team:

1) Evaluate Team Strengths (Experience, Expertise, and Social Capital)
2) Evaluate Markets that align to Team Strengths
3) Select a Target Market
4) Interview 30 Decision Makers in the Target Market
5) Map Business Process, Archetypes, and Customer Needs (Pain Points and Gain Points)
6) Generate Product Lists
7) Evaluate Products against Team Strengths and Market Needs
8) Select a Product

No one on the Second Nature team was truly qualified to execute any of these tasks as an expert. However, the team had systems engineering and management backgrounds, so they felt they could figure it out with “learning by doing.” At this point, the team decided to formally use Lean management to execute the plan efficiently and quickly get to building software products.

Lean Planning and Mechanics

Lean project management is actually very simple in terms of planning and mechanics. First a charter is written detailing goals and a plan that includes clear a set of milestones. Then the first major milestone is broken down into component work elements, or “stories.” These stories are written to ensure the business need is clearly understood in terms of what the work is and what they expect output should be. The stories are designed to take no less than one day and no longer than one week. Stories are then put on a simple board showing progress called a “Kanban,” which means “billboard” in Japanese. There are five positions for each story:

- New - these stories are written as potential work, but not yet possible to deliver
- Ready - these stories are ready to be executed, but not yet being worked on
- In-Progress - these stories are currently being worked on by the team
- Ready for Review - stories are complete and ready for team verification
- Done - stories are verified complete by the team

Each story carries its entire information, updates, and attachments for documentation posterity and reference. Every story is assigned to one team member as the owner, but can be worked on by any team member. Every team member can see every story on the Kanban. This creates a fully transparent Lean Plan for accomplishing the scope for the first major milestone.

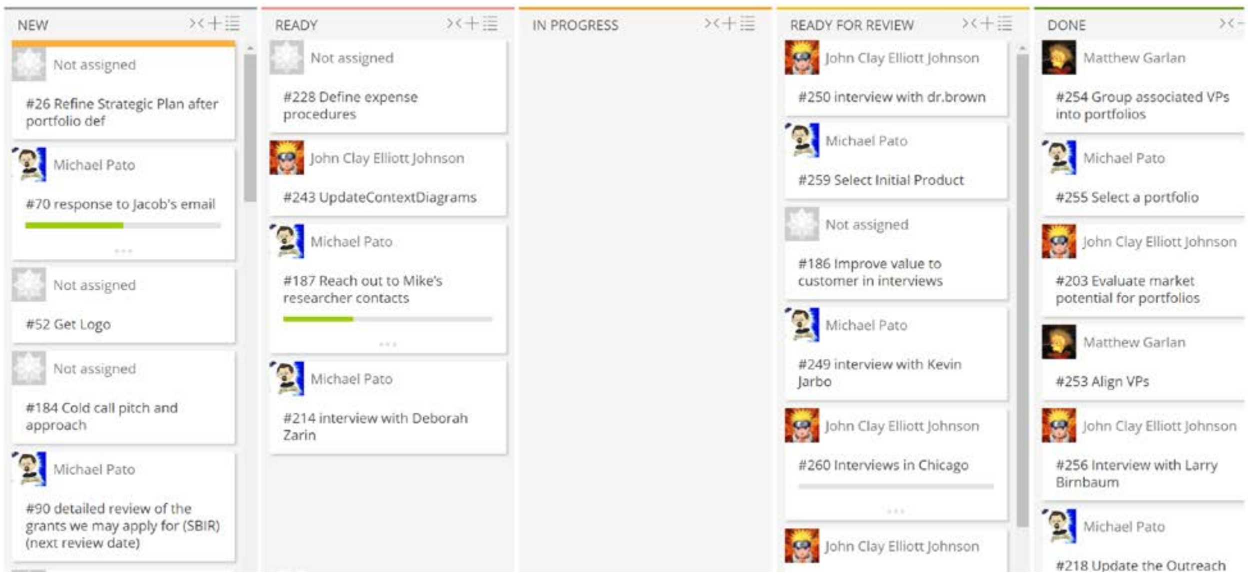

Figure 2: Example Kanban Board from Second Nature Software

The mechanics for operating a Lean team are also simple. Every morning there is a standup meeting where the team reviewed the board together and said what they planned to do. Team members can ask for help or offer it. Team members then continue work on the story they already “opened,” or if they have no story then the team member selects a new story to begin.

If there are enough stories waiting for Review (usually three to five) or a critical lesson learned, then the team sets up a Review meeting. During the Review meeting the team conducts story verification and planning to adjust, add, or delete New and Ready stories. This enables feedback to adjust the work and processes to become a more efficient team and meet the milestone as quickly as possible. Once it is determined that the milestone is complete, then a Milestone Review and Planning session begins the process again.

Results of Phase 1

The Second Nature Software team quickly took stock of its strengths, including experience, skills, and social capital. These strengths were then aligned to markets using government NAICS codes and Census Bureau datasets. The final markets chosen as best alignments to the team were:

- **Medical Research** - highest on social capital and a large market at $70B annually
- **IT Consulting** - highest on skills and experience, but a very crowded market
- **Home Improvement** - highest on favorability to entrepreneurs with good skills alignment

The team ultimately decided to bank on social capital to open doors for interviews of decision makers. Here the team began to stumble as interviews initially took multiple weeks to set up, prepare for, and evaluate. The team also brought in stories of mapping business processes, archetypes, and customer needs to update and iterate in-between interviews. This saved down-time from waiting for appointments and responses from interviewees.

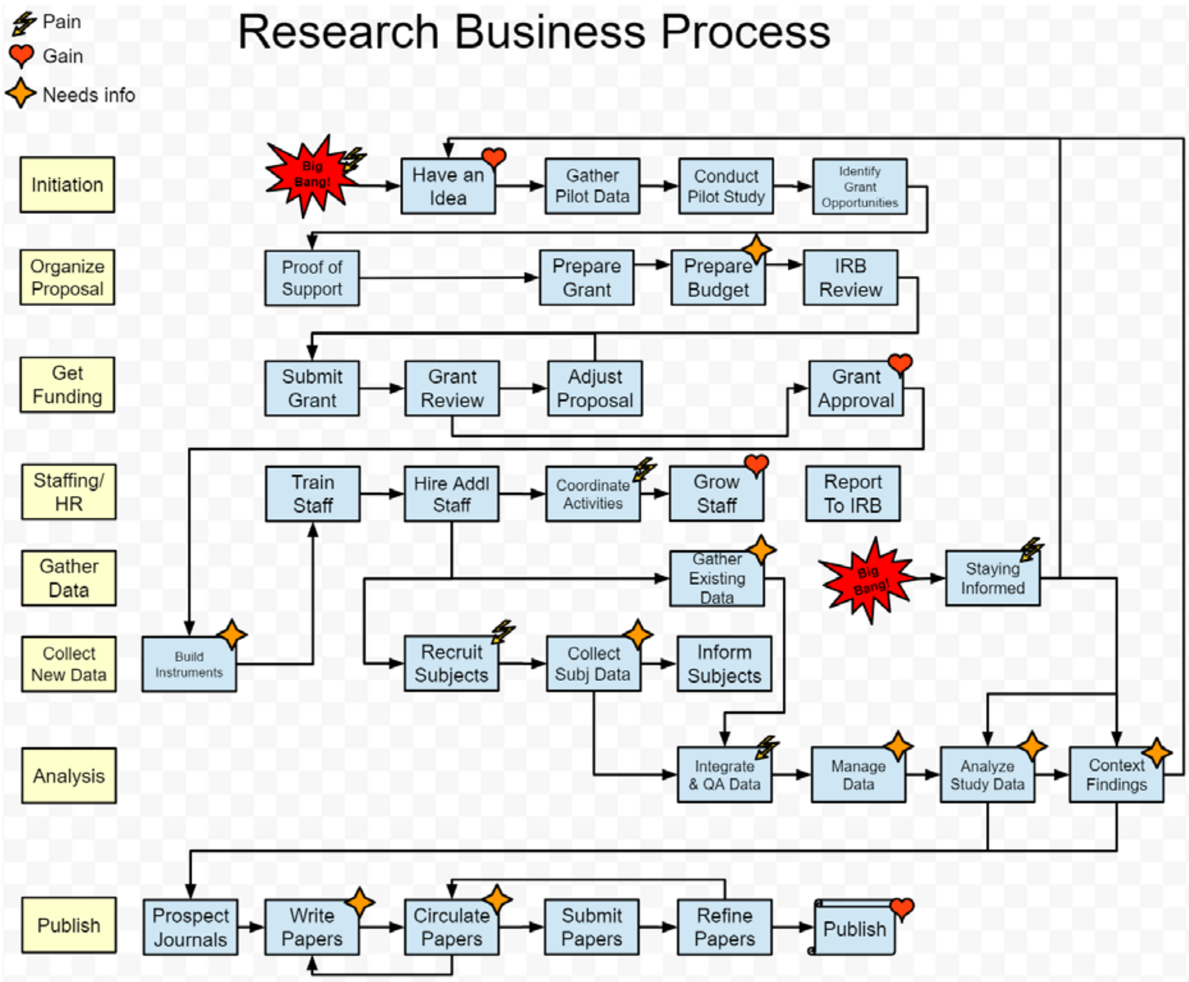

Figure 3: Business Process Map of Medical Research

Once interviews were complete, a quick decision making tool was developed to compare and prioritize customer needs. The top priority needs were then used as the basis for brainstorming product ideas that could fulfill one or more needs. The list was then systematically scored and reduced by the team to three potential products:

1) **Clinical Trials Recruitment App** - because 50% of clinical trials fail due to recruitment.
2) **Literature Review App** - staying informed is critical and time-intensive for researchers.
3) **Data Integration and Quality App** - researchers waste time working manually in Excel.

In the end, the team choose the Data integration and Quality Assurance App, which would become the tool now known as “Rocketfish.” This standalone tool would provide simple data processing, integration, and quality assurance to medical researchers who were spending large amounts of time doing manual work in spreadsheets.

Analysis of Phase 1

Phase 1 took a total of about four months to complete, and required much more work than anyone anticipated. About half the time was spent on interviewing decision makers, which turned out to be much longer than other startups usually take. Although the Second Nature processes improved for sourcing and conducting interviews, the methods were clearly flawed since on average the team performed at best 5 interviews per week and teams at Stanford in Steve Blank's startup class had interviewed almost five to ten times that number with similar resources [7]. However, the team largely attests the slow interviewing process to the nature of the medical researchers who are typically overworked and hard to schedule meetings with.

Lean management was extremely efficient for assigning and executing work, which enabled the team to quickly assign tasks to meet the objectives. Stories could and often were adjusted or updated based on lessons learned. The key was having a vigilant team always looking for ways to improve repeated processes, such as setting up and performing interviews. For example. standard emails for introductions and follow-ups reduced originally page-long emails to just a few key sentences. It was learned that most researchers only respond to the second or third email you send, so follow-ups increased success rates with getting interviews; and shorter emails with questions also got better reply rates. The interviews initially took an average of three to four weeks, but that time was cut in half by the last batch of interviewees.

This type of learning didn't require any time to pass between members because everyone was sharing lessons learned and observing each other's work daily. The transparency and all-hands-on-deck approach led to fast organizational learning and improvement in how the team worked through the planned scope.

Phase 1 Lessons Learned

Despite the learning, Phase 1 was likely twice as long as it needed to be because of the lack of experience on the team. The team lacked the skills or realistic expectations to know if progress was moving quickly or slowly. Many lessons learned were hard-earned instead of studied and incorporated from the beginning. The two major lessons learned were:

1) **Use Comparable Benchmarks** - leveraging previous, similar projects to understand what would be reasonable to expect in terms of pace and performance. When working in a Lean environment with uncertainty o\in how the scope can or should be performed, benchmarks offer a means of validating production efficiency.
2) **Seek Expert Advice** - If the team does not have expertise in the work, then the team will waste enormous time in Lean project environments. Lean offers a way to incrementally improve production, but teams without expertise will repeat many beginner mistakes that can be avoided with expert oversight. This is why many startups benefit most at early company stages by working in incubators and programs where experts offer advice from multiple startup successes.

Given this experience, it's recommended that only teams with significant expertise use lean management techniques; and in all cases Lean teams should seek outside expert consultation for benchmarks and validation of task performance.

Phase 2 - Building the MVP with Disciplined Agile

Selecting a product provided the Second Nature team with a clear vision to execute against. The team began by exploring potential technology architectures that could speed up MVP development and fit the technical constraints of the medical research community. It was quickly identified that a small, standalone application would be best instead of developing a website or server-based tool. A standalone application is like Microsoft Word or Excel, where it runs on a user's personal computer (PC). Standalone tools are simple to build and add the benefit of inheriting security of the user's PC, which was the main technical constraint of medical researchers who work with personal identifying information.

With a technology stack identified, Second Nature began investigating reference architectures and developing first round requirements. Tools built for cloud environments and used on large financial datasets, such as *Trifacta* and *Paxata* offered a service paradigm called "data preparation," which was exactly what the research community needed. Using these tools as reference, further prototyping and interviews of researchers helped to finalize technical designs and business requirements.

Second Nature was now able to finalize its first set of features for the Alpha release of Rocketfish. The target early adopters were lab-based researchers who needed to process data collected using assays (test tubes arrays). The features included:

- **Link** - ability to merge datasets with appends (add records) and joins (add variables)
- **Derive** - ability to calculate new variables with existing variables and constants
- **Format** - ability to summarize, filter, and export datasets for analysis

With the direction set, the team leveraged Agile planning and mechanics to quickly deliver a working Alpha in less than two months, from product idea to product pilot.

Agile Planning and Mechanics

Agile planning and mechanics follow simple general practices that are found in every Agile approach. These practices adhere to the Agile Manifesto of emphasizes people, change, collaboration with customers, and delivering working software:

- **User Stories** - like with lean, every work feature component is described from the perspective of the primary user, what the user wants to do, and why they want to do it.
- **Timeboxes** - in Agile there is not task-level schedule, work is listed as a backlog and performed within a set period of time, or "timebox." Timeboxes enable Agile teams to innovate how to accomplish tasks while avoiding the stress of deadlines or the procrastination of start dates.

- **Colocated Teams** - Teams work colocated to ensure everyone can communicate efficiently face-to-face. This also improves team unity and opportunity for inspiration from working near people who are thinking and dealing with similar work challenges.
- **Whole Teams** - the team also works through the whole lifecycle of a work item together, including design, development, and testing. This ensure adequate breakdown of work and the whole team's ownership of getting the work done.

There are many types of Agile, but the team was well versed in using Disciplined Agile Delivery to design and implement new software products, so that Agile paradigm was used. Disciplined Agile Delivery recommends two stages to agile projects to ensure a shared vision and prioritized set of business needs before development begins. The goal is to exit the second stage with a Minimum Viable Product (MVP) ready for market:

1) *Solution Definition* - define the requirements of the MVP and explore technical solutions
2) *Solution Development* - teams select and implement the planned and designed MVP

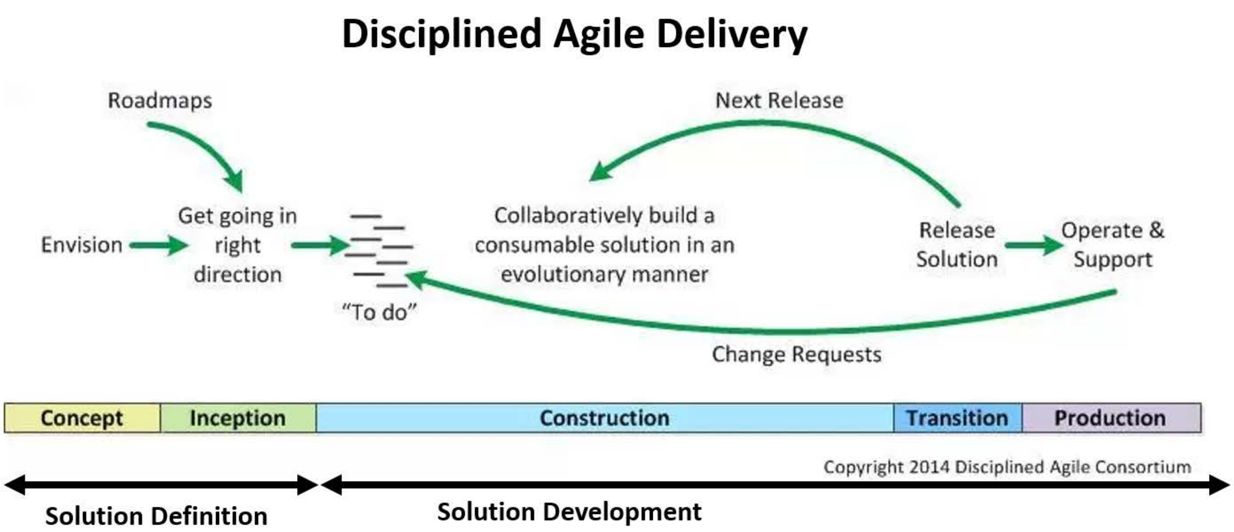

Figure 4: Disciplined Agile Delivery Stages [8]

Solution Definition

Solution Definition is a chance for the team to perform Agile planning for essential features. Agile planning starts by identifying a feature-driven breakdown of the business needs and alignment of those needs to a business process. Everything in Agile planning is based on the business, not the technical requirements (except when technology skills are lacking or solutions uncertain). The first release is determined to be the minimum set of features that will provide a "shippable product" that can be used by the business. This is called the Minimum Viable Product or "MVP."

Once the MVP is determined for the release, then stories are generated by whole teams of business and technology experts. These stories are then planned to be accomplished in fixed periods of time called “timeboxes” or “sprints” that are usually two to four weeks long. The stories are ordered based on testing dependency, risk, and priority. The resulting is a Story Plan forms a backlog of work that is testable by the team and users who support development.

With the initial planning complete, the team is ready to progress from Solution Definition to Solution Delivery.

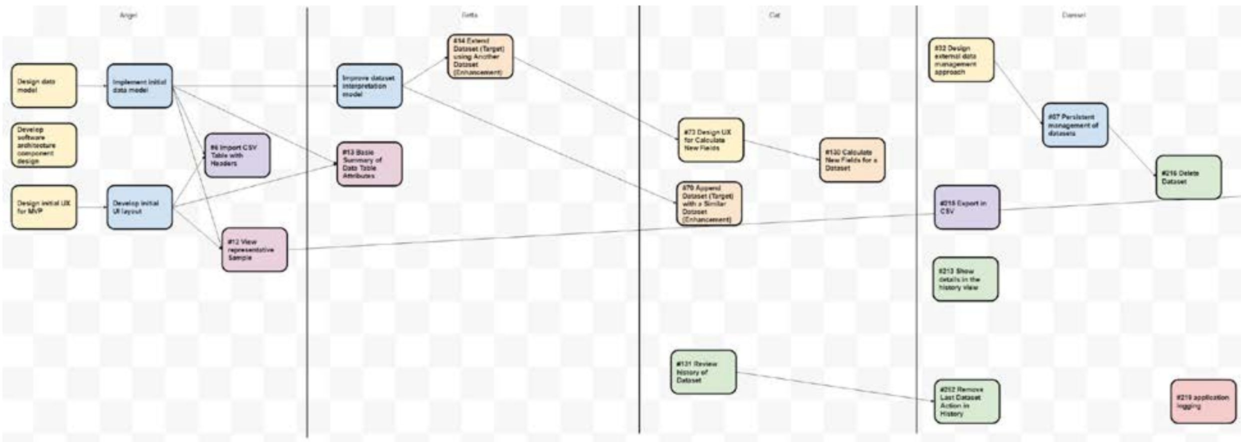

Figure 5: Sample of Rocketfish Alpha Story Plan

Solution Delivery

Solution Delivery begins with “Spring Planning” event where the whole team, product and customer team members, collaboratively selects stories for elaboration. Each story is first clarified in terms of the user, what the user wants to do in the app, and the business need satisfied by the story. The team then deconstructs these stories into tasks that include requirements, development, and testing of the solution. Once the story is fully understood, the team votes on the size of the story. This process continues until all stories are fully sized in detail.

Once all stories are sized, the team re-evaluates and selects the stories for the sprint. The team then commits to accomplishing these stories within the sprint timebox (usually two to four weeks) with no plans to change the stories.

After Sprint Planning the team begins working on the stories with each team member choosing the story and task to begin working on. Every day a standup meeting is held where team members say what they did, what they are planning to do, and if they need any support. Tasks are managed either as checklists or on a Kanban board; and when the final testing task is closed and approved by the whole team the story is complete.

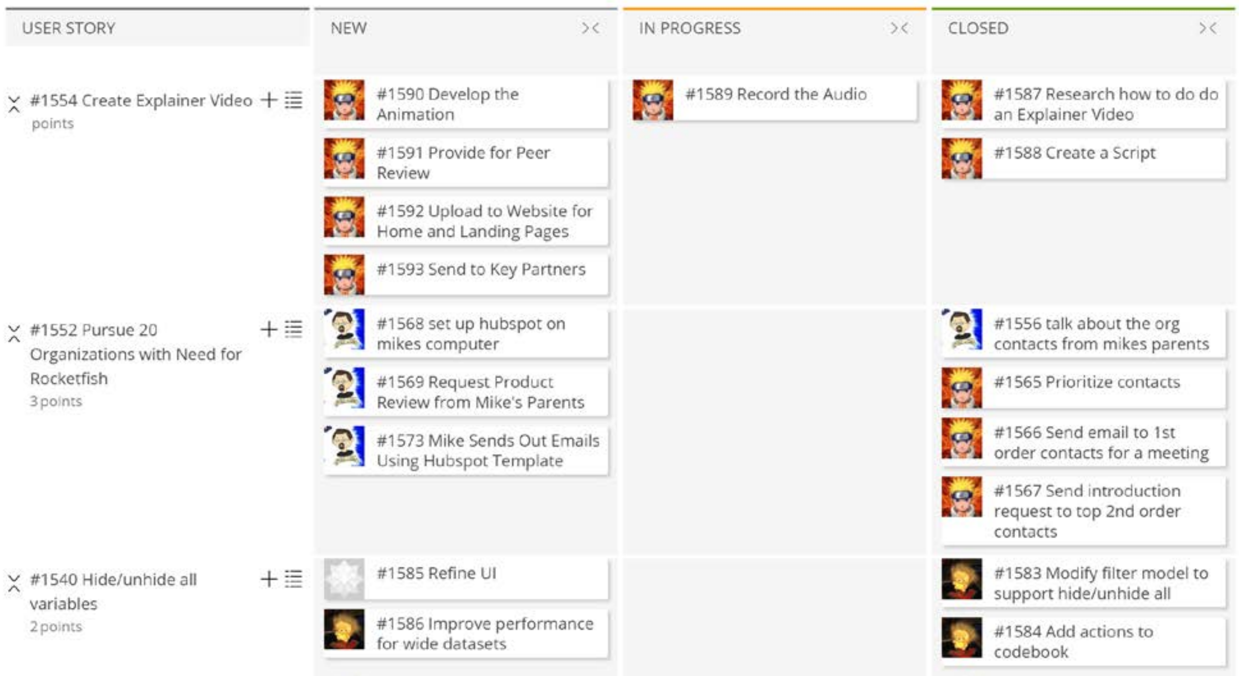

Figure 6: Sprint Execution Board

At the end of the sprint if the team was not able to complete the stories, any remaining stories are moved to the next sprint. The team then holds a Sprint Review to see what work was completed and provide feedback. Following the Sprint Review, is a Sprint Retrospective where the team discusses what went well, went poorly, and actions to be taken to make the next sprint better. This review process offers a means to continuously improve the team and hone in on a sustainable pace for development or “burn rate” (see Burndown Chart below in Figure 7).

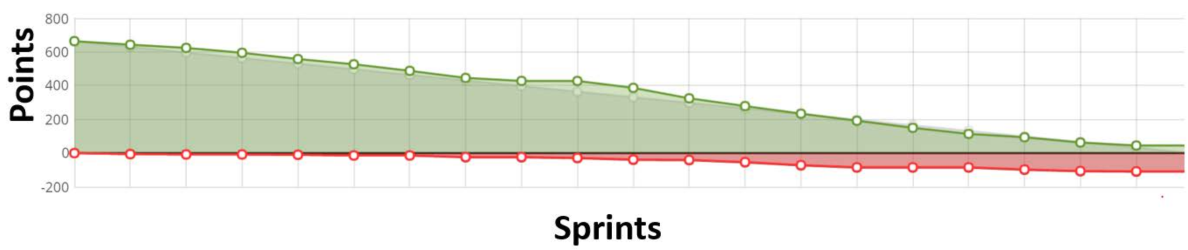

Figure 7: Sprint Burndown Chart

The next Sprint then begins again with a Sprint Planning session and the cycle continues until the Release date. In each sprint the team re-evaluates stories, prioritizes the stories, and builds the features and enhancements determined by the whole team. At Release the team performs a Release retrospective, and then depending on the backlog will either go into another Release in Sprint Development or back to Solution Definition.

Results of Phase 2

The Second Nature team finished the Alpha as designed on-time and with additional features that added data management and process history for each data set. The final product was release to 15 early evaluators of the tool that offered feedback on its design and use. The first release was such a success that one evaluator used it to complete her work that normally took days in just a few hours.

The Alpha Release was not without its hiccups. The user experience was generally overlooked in terms of installation, which required users to download the latest version of Java along with the tool. This flaw added barriers to getting started with Rocketfish and prevented some evaluators from being able to use to tool all together. However, in general reviews were very positive.

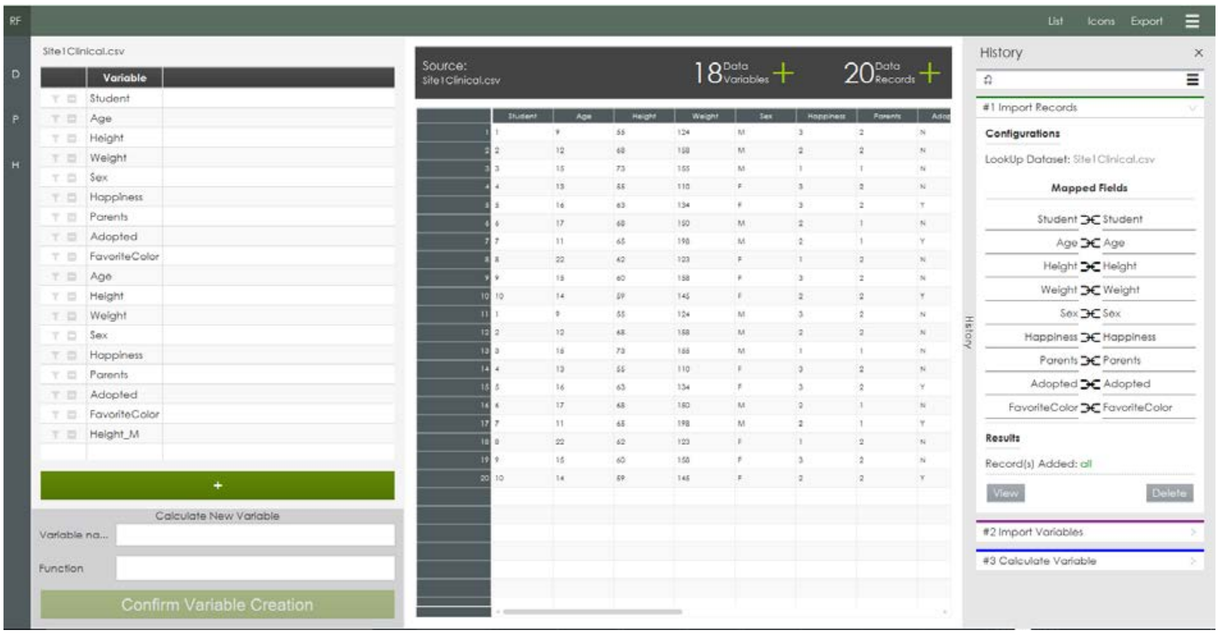

Figure 8: Rocketfish Alpha Screenshot

A major oversight for adoption was requiring data to be pre-formatted and cleaned before being used in the tool. It was expected that users would clear their data first in spreadsheets; but most early users did not follow instructions and quickly gave up because using two tools for cleaning and integration was too cumbersome. Data cleaning had been delayed in being added to the tool, and the result was that the Alpha was burdensome to prepare for as a data prep tool.

Lastly, to ensure on-time delivery the level of innovation in the design was limited, especially on the aesthetics and user experience. This was because achieving functionality on-time was prioritized over delighting the customers with a visually appealing and high-quality experience. The final design felt like what some called an “Excel-Light” user interface, which hurt branding the tool as something truly transformational.

Analysis of Phase 2

Phase 2 was efficient and productive, with a working product that truly added value to its users. There were many issues to be overcome before a true Beta could be released and sold, but the primary functionality was built and in the hands of users. The feedback was very positive and delivered recommendations from the decision makers in the National Institutes of Health (NIH) for Rocketfish to piloted institute-wide at both the National Cancer Institute (NCI) and National Institute of Allergy and Infectious Diseases (NIAID).

There were some issues with implementing Agile according to best practices. Although the key planning documents were developed and the researcher process understood, the team chose poorly in defining the MVP. Cleaning was an essential first step that was needed much more than integration or calculation (as the team would find out), and came first in the user's workflow. Without cleaning within the tool, the burden to the user was too great to get started. This could have been avoided by features into the tool in the order the features would be used in the researcher's workflow.

The detriment of using Agile was a miss on aesthetics and user experience because the push to deliver functionality within the timebox de-prioritizes polishing features. In some cases, this is not just acceptable, but preferable. However, when selling new data tools there was clearly a need for ease of use and tool attractiveness to gain first-time users that believed Rocketfish could be transformational.

Phase 2 Lessons Learned

Agile is focused on delivering features fast, and while that can be a great strength, it's easy to get caught up in what is known in startups as "featuritis." This occurs when features and capabilities overcome the true customer needs and selling potential of the tool. Users must be considered not just as part of a business process, but as psychologically-driven and incentivized people who must *want* to use the tool. Therefore, the key lessons learned were:

1) **Emphasize Front-to-Back Design** - start with the user experience in mind and adapt technology to achieve it. There should be no contempt for users, only a focus on delighting them.
2) **Build Features in Workflow Order** - do not build the most important feature first. Instead build the first feature a customer will use first. Know the true bounds of the user's workflow and inject the tool as far upstream as possible to maximize adoption.

Because speed was the focus, the team avoided hard features like data cleaning and building powerful user interfaces. Just data cleaning could have arguably been its own product, but in a rush to ensure delivery in the timebox the team chose a safer, less transformation feature set for the MVP. Agile Teams need to set bold feature goals that will be truly transformational to offset a natural tendency to play it safe with delivery inside the sprint timebox.

Phase 3 - Distributing Rocketfish with a Hybrid Model

Rocketfish was now in the hands of early evaluators, but the feedback was that the tool was incomplete with data cleaning and some better user interfaces for understanding the data.

Meanwhile, the team at Second Nature needed a sale and feedback. Although one purchase order was made based on the Alpha, it was canceled when the customer didn't receive the data they were going to use in Rocketfish.

The team decided it had enough information for two sprints using Agile and would then build both planned and requested features from current users in the following six sprints using a Lean/Agile approach for continuous releases every month. The result was a four-month release plan to generate the "Full Beta" with enough features for trials in NIH at the National Cancer Institute (NCI) and National Institute of Allergy and Infectious Diseases (NIAID).

Along the way, the team would learn that certain additional features were needed for distribution and managing trials. There was a need for licenses and license management for tracking users. A need for enabling persistence across not just tool sessions, but also version updates for continuous delivery.

Lean/Agile Hybrid Mechanics

Lean/Agile Hybrid planning sets up a Release plan, but lowers the pace of delivery for major feature development because of expected enhancements and defects. A Release Plan and Story Plan are needed to ensure that continuous improvement is made to the product to achieve the vision. However, that new feature scope must be limited or decomposed to enable the development team to respond to customer requests for improving the tool.

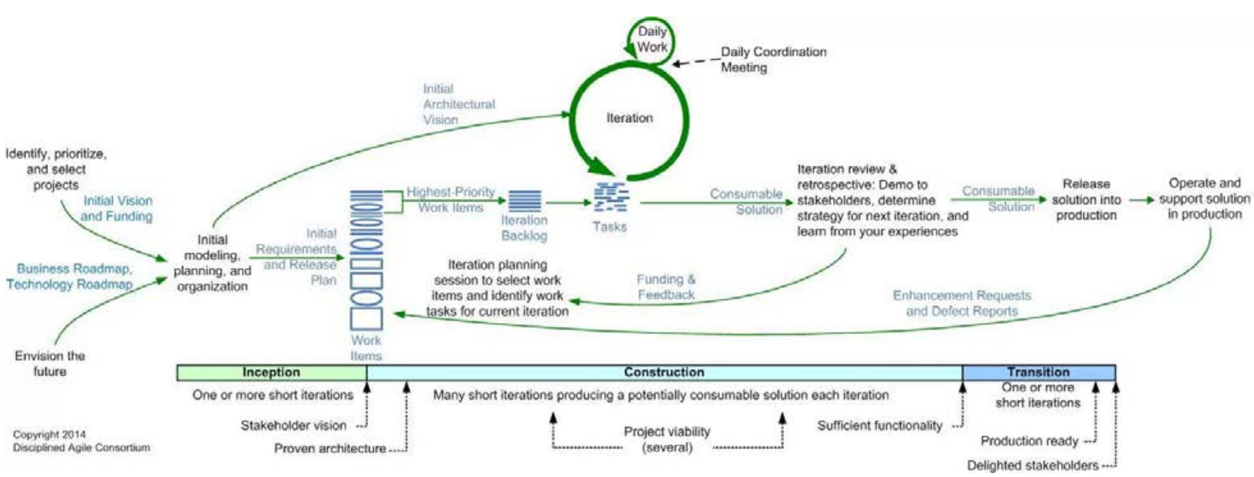

Figure 9: Lean/Agile Framework for Continuous Delivery [9]

Therefore, Release planning should therefore guide development, but not each sprint must prioritize the customer demands and feedback. In this way, the planning is much more Lean than Agile because it is driven by learning how to meet the needs dictated by customer feedback and still accomplish essential new product features efficiently and quickly.

Agile processes are used to manage the day-to-day Mechanics, with set sprints that include Sprint Planning, Execution, and Review. This enables limits the planning churn impact on the team, and allows for managing the scope change in the Release Plan driven by customer feedback.

Results of Phase 3

Phase 3 was a partial success, with the Product Development team building a tool that had all the features needed for a trial, but not actually achieving the features planned in the Release Plan for Rocketfish Beta.

The final product was (and is) a very powerful data preparation (management and processing) tool for researchers with all the essential features included:

- **Data Management** - saving, copying, deleting, and exporting data files.
- **Dynamic Data History** - tracking and rollback for all data processing actions.
- **Data Cleaning** - variable and value cleaning, as well as row and whitespace removal.
- **Data Formatting** - one-touch splitting, filtering, and capitalization of values
- **Data Integration** - enhanced data merging with auto-matching for linking variables.
- **Advanced Calculation** - text, date, number, and logical expression evaluations
- **Aggregations** - roll-up of record-level information to summary-level observations.

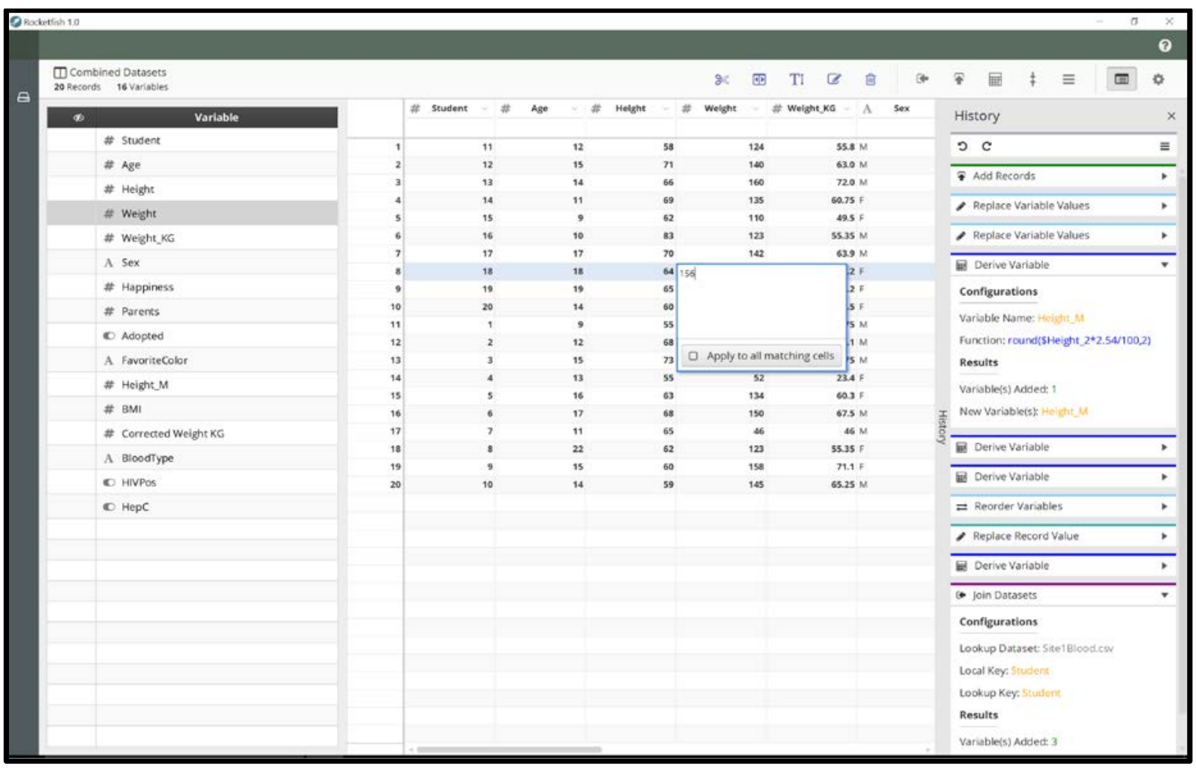

Figure 10: Rocketfish version 1.0 Screenshot

Although not all essential features or differentiating features were built, many organizations showed interest in Rocketfish. The list of organizations in or starting trials as of the end of the Phase 3 included:

1. National Cancer Institute (NCI)

2. National Institute of Allergy and Infectious Diseases (NIAID)
3. National Center for Advanced Translational Sciences (NCATS)
4. Johns Hopkins University, Bloomberg School of Public Health
5. University of Maryland, School of Medicine, Institute of Human Virology
6. Rutgers University, Division of Infectious Disease

This constituted a true success for the first year of development. A fully functioning product in pilot with the top research organizations in the country. However, the company still did not have a sale and that meant that the team had missed somewhere on requirements, development, and especially distribution.

Analysis of Phase 3

The Lean/Agile methods of Phase 3 were hard to balance with competing demands from customers for must-have-now features and the planned features to achieve the assessed market needs. The most critical features planned for Phase 3 that involved innovating new technologies were designed, but never built. The feature, an advanced cleaning capability using visuals, was delayed as mounting feedback came in demanding modifications for specific customer needs.

For example, the University of Maryland needed better calculation features, which would also enable more cleaning and validation. This feature, along with others, was implemented instead of the planned data cleaning using visuals. So, the tool met the needs of the customers but lacked a truly differentiating component.

Another phenomenon occurred, which is that the tool began to reach its limits as a standalone tool built with open-source Java components. This meant that the team began to hesitate to put in features because the team knew the features would be rebuilt once Rocketfish inevitably migrated to new JAVA software components. This is typical in Agile development, but was also likely exacerbated by the many aesthetic updates since most of the trouble was with the Javafx components used for the user interface.

Lastly, with the hope that the tool would sell quickly the team began to plan less and less for transformational capabilities. Pushing the tool forward technically was no longer priority. This led to almost no new planning for the second half of Phase 3 when it came to Story Plans and Release Plan modifications. It was clear at the end of the Phase 3 that with better planning, more features of higher importance would have been completed.

Lessons Learned from Phase 3

There was a general lack of new development because of trying to integrate Lean planning and Agile execution. Lean Planning resulted in many features being caught up in design because the team was uncertain what the total scope would be for the Release. This meant there wasn’t enough time in a timebox to complete complex stories and still respond to defects and enhancements. The Second Nature team didn’t want to risk building features without enough space in the Sprint due to growing tool instability which would create more rework for later, or "technical debt." The result was a lack of true progress towards building features that could differentiate Rocketfish from its competitor tools.

Without a stable plan for feature development and clear deadlines for feature completion, the Lean/Agile approach falls into incrementalism. Simply building one small improvement at a time without vision or confidence to risk.

1) **Maintain a Story & Release Plan** - for Lean/Agile to work effectively, there must be continuous master planning (Release Plan) and mid-range planning (Story Plan). Without it, the team will lose direction and motivation.
2) **Plan a Hardening Sprint** - Hardening Sprints are used to catch up on and clean up technical debt. Knowing the Hardening Sprint is coming will ensure the team can confidently build complex stories in packed Lean/Agile sprints.
3) **Build Differentiating Features First** - as a startup, one cannot just "meet the requirements," one must also sell the tool while building it. The delay of building the differentiating capabilities, or "star feature," of the tool hurt sales although it made development easier. Therefore, plan to build the most important features early when defects and enhancements requests are low.

Conclusion

For Startups, the recommendation is to use Agile for speed and adaptability as the *team learns what the business needs truly are*; and to only go with Lean or Lean/Agile hybrid approaches for sustainment and improvement of a working, selling product. Even at the beginning of Second Nature's journey, when the team was following roadmaps to discovery a product, Agile would have been more effective. The methods would have been questioned, interviews sped up, evaluation methods questioned, and a lot of wasted effort (scope) avoided. Without significant expertise on the team, operating as "Lean Startup" is recipe for incrementalism and scope creep that consumes resources while adding frustration.

If the team has little to no control or concern over what scope must be accomplished, and if the goal is to deliver as fast and efficiently as possible, then Lean is more effective. Lean is especially appropriate when the team is highly experienced with the technical work that is being performed. In many scaled Agile frameworks the architects respond in a Lean process to the Agile teams -- subordinated to the scope determined by those Agile teams. This works for Lean teams because instead of focusing on what to do, the team can learn how to predict, build, and test designs that will meet the needs of the customer(s) as efficiently as possible. Lean is the most responsive to customer demands, if the customer knows what they want.

However, if there is a possibility the business needs will change or should change, either by the ability to target customers or include the customer in the development process, then Agile is far faster and more stable. The timeboxing and planning efforts are clearer and provide a consumable vision for developers and business analysts to focus on. The focus and planning makes Agile much more effective than Lean at managing changing or uncertain business needs.

The question of “Lean or Agile?” in theory comes down to a question of whether the area of uncertainty is in the *how* to deliver the technology or *what* technology to deliver. But based on the real-world experiences of using Lean, Agile, and Hybrid methods - Lean and Hybrid models lack the dedicated time and process to address *why* the technology is even needed. This doesn’t mean the team stops asking the question -- it just stops answering it as a team. Agile provides this time for team planning with Release Plans, Story Plans, and Sprint Planning days. All that planning challenges, shapes, and reinforces a shared vision. Lean methods lack this time for the team to think together as a team, and, therefore, is not conducive for rough and tumble challenges of an uncertain project, like a startup company.

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LIFE CYCLE COST ANALYSIS OF PRECAST CONCRETE PAVEMENT

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ABSTRACT

The focus of this research is to analyze the replacement of concrete pavements with precast concrete pavements which will potentially result in faster construction, thinner slabs, and a more durable life. Precast concrete pavements also provide longer construction seasons throughout the year, and it reduces the duration of construction while carrying out the maintenance of roads or reconstruction of roads.

This research focuses on the study of the Life Cycle Cost Analysis (LCCA) of precast concrete roads with the traditional method (cast-in-place) by comparing the initial cost of precast concrete roads with traditional casting method, the methodology of construction, the material used, environmental impacts, recurring cost, maintenance cost, life assessment and life expectancy. Furthermore, the traditional method is basically carrying out all the activities on site i.e. casting of pavements on site, curing of pavement and then opening it for traffic use. All these procedures of the traditional method can be eliminated if precast concrete pavements are used. The results which are expected after this study will identify how feasible it is to replace traditional casting of pavements with precast concrete pavements with respect to cost, time and life expectancy.

INTRODUCTION

Historically, two top priorities of construction projects are time and cost considerations. In construction projects, the owner, together with a manager, utilize the minimum available time with the minimum possible cost to get maximum output. Today, the construction projects consume a lot of time and money to complete the task. The infrastructure projects which are reconstructed with the traditional casting method causes inconvenience to the public during construction. Applying the concept of precast concrete pavement over cast-in-place pavement will help to reduce the time and cost.

As construction enters a new age of development, the research focuses on the implementation of precast concrete pavement for the construction of new pavement and retrofitting of the existing pavements on the roads. Using precast concrete pavement will reduce the construction time and duration. Furthermore, if the precast concrete pavement is prestressed, maintenance will be low for its lifespan.

Precast concrete pavement panels are fabricated offsite, transported to the site, and installed on the prepared subbase. These are also used for retrofitting pavements, maintenance of pavements, construction of new pavements, urban street rehabilitation, isolated repair, intersections and ramp rehabilitation. As site conditions, may vary, several precast pavement systems can be adopted for construction. These systems include jointed precast pavement systems, super slab, Kwik slab system, roman road system, con-slab system, full depth slab and joint replacement method.

The main objective of this study will be the LCCA of precast concrete pavement on roads which will facilitate the development of existing infrastructure.

CONSTRUCTION METHODOLOGY

For the construction of precast concrete pavements, full panel replacements or maintenance and construction of new pavement can be done on severely cracked panels, punched out panels, deteriorated joints and prepared sub-base. Furthermore, the detailed methodology of construction has been mentioned below for the construction of unpaved road and maintenance of the paved road. Repairs and maintenance are usually conducted in full lane width. The materials used in the base should be of good quality and should be easily placed, graded and compacted within the time limit. Materials which will be used in the base are dense-graded, granular base or lean concrete. In this technique, the settled base may be used and if any unsettled base is found it will be levelled to its past level utilizing compactors. Another base will be constructed if the current base does not serve the necessities of the precast concrete pavement. A slight layer of finely screened granular material or sand may be used to give a level surface to set the board. A granular subbase might be reworked, compacted and graded. Extra bedding materials will be given if necessary to keep up the camber. The bedding materials for the base, which will be utilized, are sand and cementitious grout.

For both maintenance and construction of pavements, bedding should be kept as thin as possible, because thicker bedding causes weaker support. Support conditions for the precast concrete pavements should be far better than onsite casting pavements. Once the base is prepared, graded and compacted properly, precast concrete pavement panels can be assembled together at the site. Initial cleaning of the exposed base and drying of the base are done by air cleaning or by using gas flames. The dowel bar slots are air cleaned and sandblasted. Placement and levelling of the panels are done with the help of equipment such as cranes and labor. The placement of the precast panel is adjusted with the adjacent panel camber with grouts before opening to the traffic. Various critical steps, which shall be performed prior to opening, are temporary post-tensioning, filling or covering the stressing pockets and providing a smooth transition from the end of the installed panel to the existing pavement. After assembling the precast pavements, post-tensioning of the pavement is carried out.

Our proposed research is about LCCA of precast concrete pavements and construction of pavements using precast concrete. The focus of the research is to find ways on how to implement and improve road infrastructure with precast concrete pavement considering the time of construction, design, cost and life expectancy of this technique.

LCCA METHODOLOGY

Life Cycle Cost Analysis provides an approach for computing the cost of a product or its serviceability. It is used to compare design alternatives over its life of each alternative, considering all parameters of cost and benefits. For infrastructure, major total cost over the lifetime of these assets is encountered after construction, i.e. during its serviceability life. The decision about the pavement design relates to the selection of pavement alternatives and recognizing the best alternative based on the present scenario, whilst achieving the project objective. Life cycle costs are usually associated with two types of costs, Agency cost and User costs. Agency costs are usually the cost that is paid by the department of transportation (DOT's) to contractors which includes initial construction cost, future maintenance and support cost of rehabilitation. User costs are usually the cost which is associated with the public motorists for added travel time and vehicle operation costs caused by construction-related traffic delays converted to the amount.

The different elements which we require to perform LCCA are as follows: Set up alternative design strategies, establish activity timings, evaluation of agency costs, estimation of user costs and determine the life-cycle cost (Scheving, A. G., 2011). The first step is to define realistic design alternatives (Scheving, A. G., 2011). For every design options, identify the initial construction or rehabilitation activities, as well as future rehabilitation and maintenance activities for individual actions. Therefore, each design option should have a plan of activities. After design alternative is defined, the next step is to outline all costs. It is recommended to consider both agency and user cost for an enhanced image of the construction or maintenance output. The next step is to calculate the total life cycle costs for each competing alternative. It uses the discount rate to convert the future cost to present values so that different alternatives could be compared directly. Figure 1, signifies costs that could be involved in calculations and LCCA process. Figure 2, signifies the selection of pavement alternative.

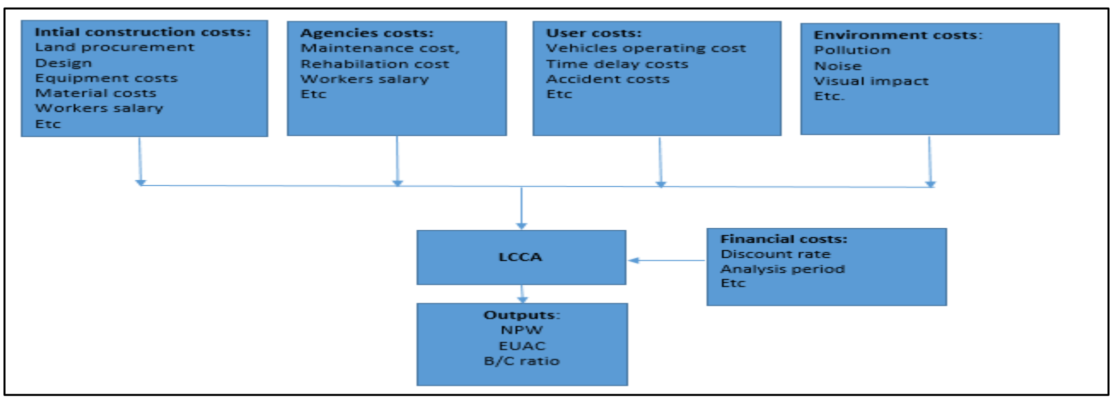


Figure 1. A flowchart describing LCCA process for pavement selection Scheving, A. G. (2011).

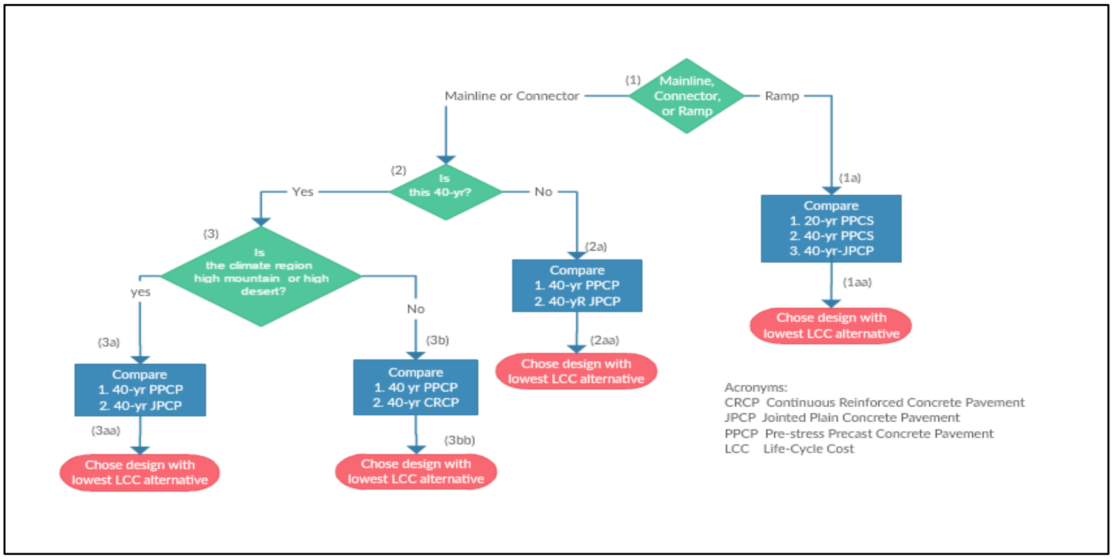


Figure 2. A flowchart describing selection of Pavement Alternative.

Economic analysis components

The following are the various components for economic analysis that must be considered.

1. Evaluation methods

Various economic analysis techniques can be utilized to assess types of pavement options. Some of the most popular are the Net Present Worth (NPW) method, The Internal Rate of Return method (IRR), Benefit-Cost Ratio (B/C) and Equivalent Uniform Annual Cost (EUAC). The best method to adopt depends on the content and level of analysis which must be performed. This research will utilize NPW as it is the most widely used method for LCCA.

Net Present Worth is also called Net Present Value (NPV). The output of the NPW method is a lump sum of initial and future costs in present value. For the first year of the analysis period, the NPW cost is the same as the actual cost, as there will not be any correction for inflation and interest. For future maintenance and rehabilitation activities, the NPW cost is less than the actual cost since total costs are discounted (VDOT,2002). It gives an indication on how a pavement alternative will cost over the analysis period and can be used to compare various alternatives to find the minimum cost. The equation for NPW of an alternative is:

$$NPW = Co + \sum_{n=1}^{N} \frac{Mn+On+Un}{(1+i)^n} - \frac{S}{(1+i)^N} \qquad (1)$$

Where, C_O = Initial construction cost; n= specific year of expenditure; i= discount rate; M_n= maintenance cost in year n; O_n= operating cost in year n; U_n= user cost in year n; S= Salvage value; N= Total analysis period (Scheving, A. G., 2011).

2. Analysis period

As per the Federal Highway Administration (FHWA) technical bulletin, LCCA period should be long enough to observe differences associated with maintenance strategies.

In general, the analysis period should be longer than the design period and long enough to include at least one complete rehabilitation activity (VDOT, 2002). The FHWA recommends a period of at least 35 years for all pavement projects, including new or total reconstruction projects and rehabilitation, restoration and resurfacing projects (Walls and Smith, 1998). However, most of the DOT's are using an analysis period of 40 to 50 years. As pavement condition and pavement life are dependent on each other, appropriate strategies of maintenance and rehabilitation should be implemented in a timely manner. Figure 3 demonstrates the relationship between the pavement condition and pavement life.

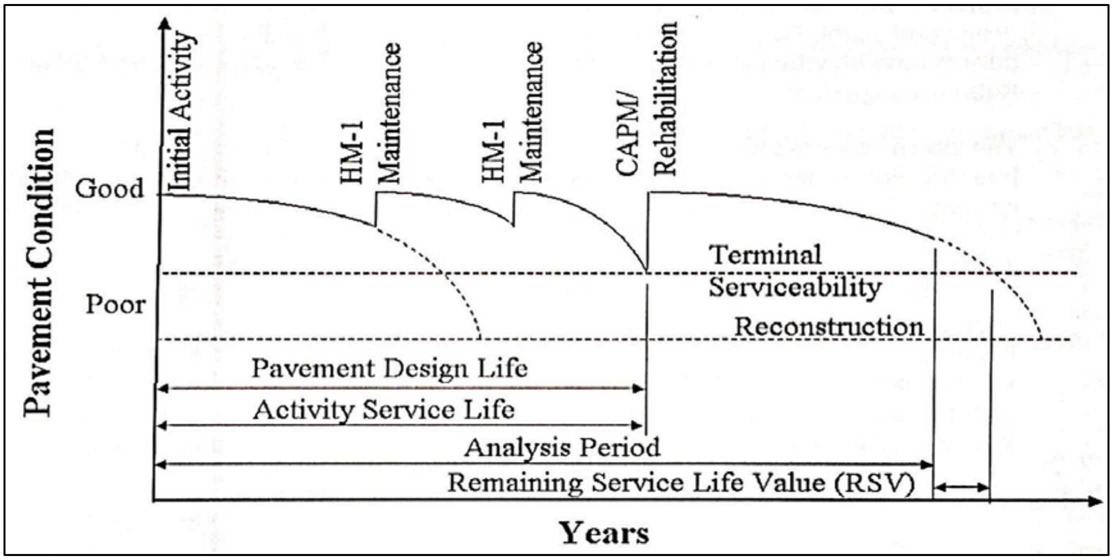


Figure 3. Pavement Condition vs. Years (Caltrans 2013).

3. Discount rate

The discount rate in LCCA is considered because the time value of the money must be measured to calculate the cost of future activities. The discount rate is also the interest rate by which the future costs will be converted to present value (Caltrans 2011). The FHWA suggests using discounts rates in the range of 3% to 5% (Walls & Smith, 1998). Traditionally, these values have ranged from 2-5% in United States of America (USA). Caltrans currently uses a discount rate of 4% in LCCA of pavement structures.

4. Sensitivity analysis

As with any type of research, it is important to analyze which parameters are more sensitive and makes the largest contribution to the result. For LCCA, many parameters can affect the NPW value for a pavement alternative. For example, the unit price for materials is very important and can cause the alternative to go from very high NPW to low NPW. Other factors that can affect the LCCA results are the discount rate, analysis period and timing of activities (Buncher, 2004).

Cost Factors

Agency Costs

It consists of the following two major costs: initial construction cost, maintenance and rehabilitation cost.

1. **Initial construction cost**

The NPW has a major impact due to the initial construction cost. The initial costs are determined at the very beginning of the project at the year zero of the analysis period. Several activities are carried out during construction, reconstruction or major rehabilitation of a pavement, only specific activities which are related to pavement alternative should be considered with the initial cost. By concentrating on the specific pavement alternatives, estimators can focus on the quantities and costs related to these activities. It is difficult to estimate the exact initial costs, as there are unique situations and depends on many aspects: geological, economic, environmental. Total construction costs can exceed the estimated cost or can also be lower than expected. Therefore, we need to add up an extra percentage of unseen costs.

2. **Maintenance and rehabilitation cost**

All pavement types need maintenance which can be routine during their service life, and after a certain point pavement must be renewed. Maintenance and rehabilitation include costs such as materials, equipment, staff salaries etc. The duration of these activities for maintenance and rehabilitation will vary from year to year. Cost data for preventive maintenance are very difficult to predict. A common type of maintenance which is required in the concrete pavement is crack sealing, diamond grinding and joint sealing. Crack sealing attempts to reduce the infiltration of moisture in the crack, to reduce the deterioration of cracks. Crack sealing is carried out with high -quality sealing materials. The diamond grinding removes a thin layer from the concrete pavement to repave it. Diamond grinding is usually carried out when there are signs of slab wrapping, wheel path rutting or crack faulting. Joint sealing is a treatment process where longitudinal and transversal joints are repaired.

User costs

User cost helps to understand the impact of road work on road users. User cost may vary to different conditions i.e. it will be on the higher end when the maintenance work is carried out. Road work may cause delays and number of accidents too. User cost can be categorised as follows:

1. **Vehicle operating costs**

It mostly results in an increase of fuel usage, wear on tires and other vehicle parts, Vehicle operating cost increases during maintenance and rehabilitation. In service vehicle operating costs are a function of pavement serviceability level, which is often difficult to estimate (Tapan, 2002).

2. **User Delay costs**

It is cost which are related to road users time. Usually saving time is the main factor considered in transportation projects. User delay cost are usually more during the maintenance and rehabilitation periods when traffic is completely closed or diverted to other lanes. Time delay cost is mostly due to changes in speed. Speed changes are the additional cost of slowing from one speed to another and returning to the original speed (Walls & Smith, 1998). Time value depends on the vehicle type and the purpose of the trip (USDOT,1997). Moreover, user delay cost is one of the most difficult and most controversial life cycle cost analysis parameters: they are extremely difficult to calculate because it is necessary to put a monetary value on individuals' delay time (Walls & Smith, 1998).

3. **Crash costs**

Crash costs include damage to the users' and others' and public/private, as well as injuries (Tapan, 2002). Road accident cost is computed from accident rates and economic costs. This LCCA model is not considering crash costs due to lack of information. Additionally, Caltrans does not include the crash cost in LCCA model. (Caltrans 2013)

Salvage value

The FHWA, in its Interim Technical Bulletin in LCCA, recognises that a pavements functional life represents a more significant component of salvage value than does its residual value as recycled material (FHWA, 1998). As per the bulletin, the salvage value has very little impact on LCCA results when the value is discounted over 35 years or more (VDOT, 2002). Therefore, this LCCA model is not considering salvage value.

LCCA Model

All the cost categories should be gathered into a single equation converted to present dollar value, which will help to develop an LCCA model. In this model, cost categories include initial construction cost, maintenance and rehabilitation cost, user cost and salvage value. Using this model, a comparison between precast concrete pavement and traditional casting method will be carried out. Equation for LCCA is:

$$\boldsymbol{LCCA} = (\boldsymbol{I} + \boldsymbol{M}\&\boldsymbol{N} + \boldsymbol{U} + \boldsymbol{O} + \boldsymbol{S}) \qquad (2)$$

where:

I= Initial construction cost,

M&N= present value of maintenance and rehabilitation cost,

U= present value of user cost,

O= present value of operating cost,

S= present salvage value.

Case Study

In this model, hypothetical dimensions of pavements are considered. All the pavement alternatives are assumed to be designed at an axial load of 80 KN. The quantity calculations are carried for the length of a one-mile road, and the comparison is done between different pavement alternative design models such as Precast Prestressed Concrete Pavement (PPCS), Joint Plain Precast Concrete Pavement (JPPCP), Jointed Plain Concrete Pavement (JPCP) and Continuous Reinforced Concrete Pavement (CRCP). The standard specifications related to construction activities such as aggregate sub base and lean base concrete for the above hypothetical situation were adopted from the Department of Transportation, California. The dimensions for the prefabricated precast panel are 40ft x 8ft x 1ft. The components which were considered while estimating the initial construction costs are aggregate subbase, lean base concrete, polythene sheets, pre-tensioned and post-tensioned steel, dowel bars, equipment used and labor required. The model considered an overall discount rate of 4%. All the future costs were converted to present value with the help of the NPW equation. While calculating the maintenance and rehabilitation cost, joint sealing and diamond grinding costs were considered. Furthermore, User delay costs were calculated considering vehicle operating cost and user delay cost. The salvage value was not taken into consideration for this model. The calculation focuses on the variation obtained in initial construction cost with different design alternatives in calculating life cycle cost. The tables and graphical representations below show the calculation output and comparison carried out between the design alternative for Life Cycle Cost and Initial construction cost.

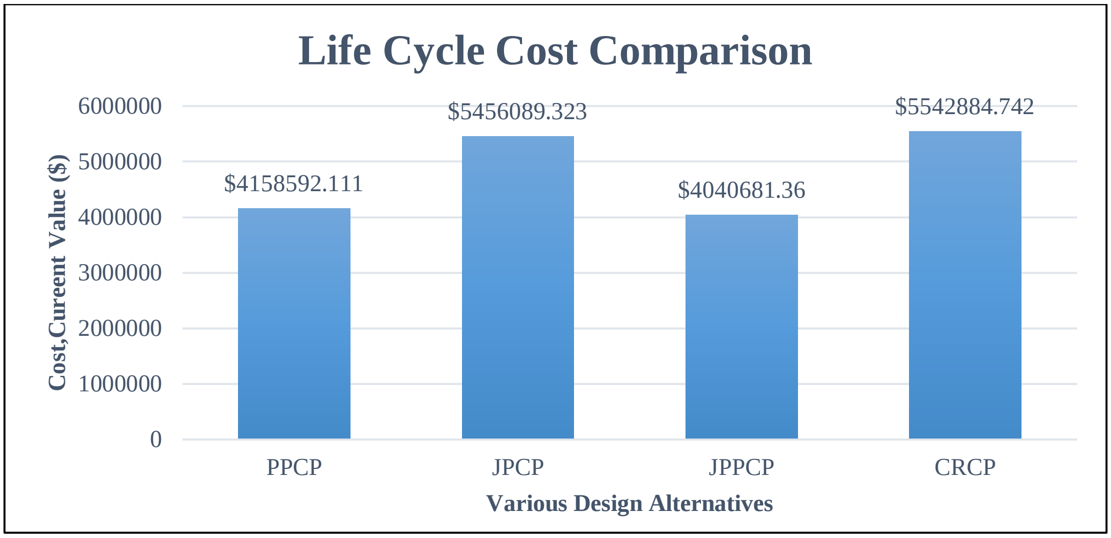
Result and Analysis:

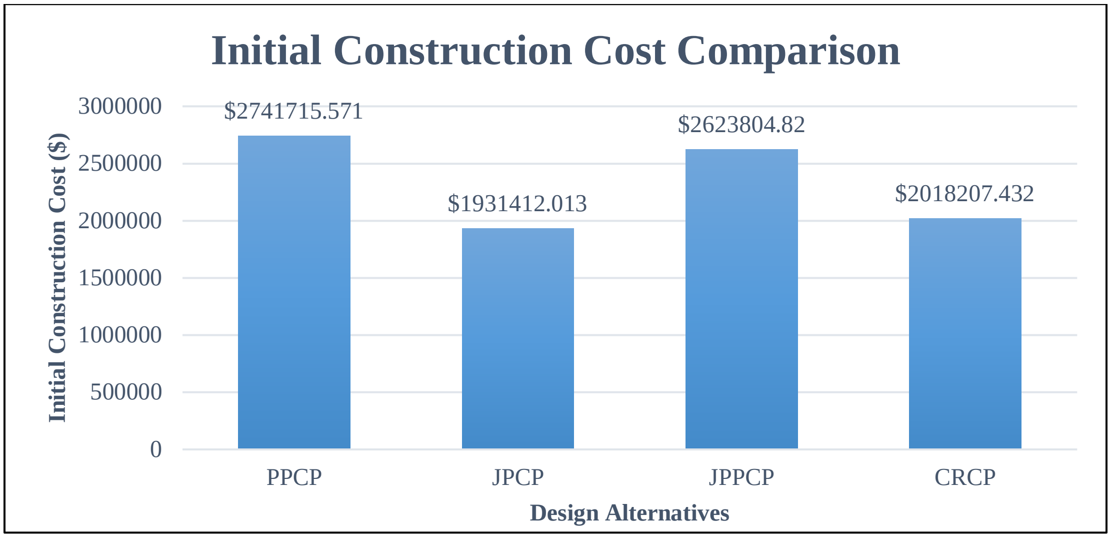
Cost calculation:

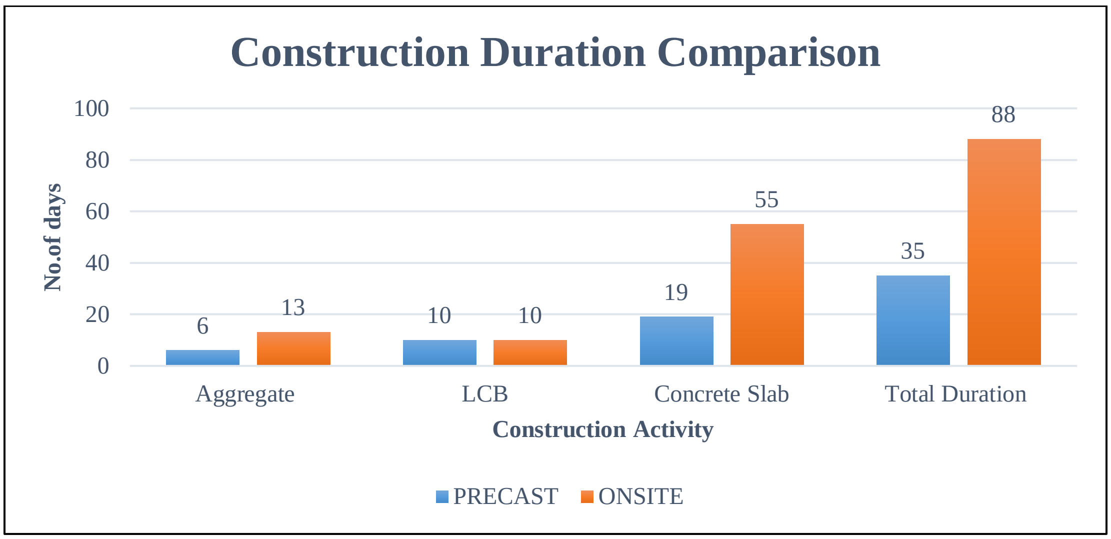
Activity	PPCP	JPCP	JPPCP	CRCP
Initial Construction Cost ($)	2,741,715.57	1,931,412.01	2,623,804.82	2,018,207.43
Maintenance and Rehabilitation Cost ($)	379,493.99	872,140.29	379,493.99	872,140.29
User costs ($)	1,037,382.55	2,652,537.02	1,037,382.55	2,652,537.02
Life Cycle Cost ($)	4,158,592.11	5,456,089.32	4,040,681.36	5,542,884.74

Construction duration calculation:

Activity	Precast (Days)	Onsite (Days)
Aggregate	6	13
LCB	10	10
Concrete Slab	19	55
Total Duration	35	88







From the above analyzes, it can be determined that the Life Cycle Cost of precast concrete pavement for both alternatives are less than the traditional method. The construction duration for onsite casting is 88 days which is way higher than the precast concrete which is 35 days.

The initial construction cost for PPCP ($2,741,715.57) and JPPCP ($2,623,804.82) is higher than the traditional method JPCP ($1,931,412.01) and CRCP ($2,018,207.43),because of the high cost assocaited of using cranes to place panels. It can be determined that maintainence cost for precast concrete pavement ($379,493.99) is less than the traditional onsite method ($872,140.29). Furthermore, the user cost for precast concrete pavement ($1,037,382.55) is less than the tradtional onsite casting ($2,652,537.02). From the above graphs, it can be determined that JPPCP has the lowest Life Cycle Cost.

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Performance Management Readiness

How to Assess Your Organization's Foundation for Performance Management[1]

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Executive Summary: *Many organizations create project teams to implement performance management processes and dashboards before they are ready. When is an organization actually ready to put meaningful metrics in place to assess performance and derive the promised benefits? This paper discusses the organizational-level performance management framework needed to implement a well-functioning measurement system and a method for assessing your organization's foundation for performance management readiness.*

The paper covers the role and importance of the following concepts in setting and assessing a foundation for a mature performance management framework for the organization:

- *Executive commitment to improved organizational performance*
- *Priority setting for performance improvement*
- *Management buy-in for performance improvement*
- *Process readiness for managing and controlling scope, schedule, and budget*
- *Process readiness for managing resource assignments*[2]
- *Process readiness for assessing product quality and customer satisfaction*[3]
- *Data readiness for performance measurement*
- *Staff passion for being the best at what they do*
- *Culture of respect for process, standards, and evidence-based decision-making*

Additionally, the paper covers the pre-conditions and processes used for an evaluation, and considerations for an organizational-level performance management implementation roadmap.

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[1] *This paper is released to inform interested parties of ongoing operations and to encourage discussion of work in progress. Any views expressed on operational issues are those of the authors and not necessarily those of the U.S. Census Bureau and The MITRE Corporation. Approved for Public Release; Distribution Unlimited. 16-4012.*

[2] The term "resource" in this paper refers to an individual member of the organization's workforce.

[3] The term "customer" in this paper refers to the organization(s) and/or individual(s) who are expected to derive value from the products or services delivered.

Performance Management Readiness

The sidebar at right[4] lists many reasons an organization should implement performance management. All are desirable, such as "improve performance for the future," and many are common sense, such as "catch mistakes before they lead to other mistakes." Experienced project managers will tell you, however, that implementing a performance management process is not easy, especially if the benefits are not obvious to the staff, or the data needed to support it is fragmentary or suspect. Many organizations attempt to implement performance management before they are ready. Is it possible to determine when an organization is ready to put meaningful metrics in place and derive promised benefits? In this paper, we share our experience and describe the evaluation process we used for this evaluation.

During the summer of 2016, we assessed the current "AS-IS" state of organizational-level performance management for a division within the U.S. Census Bureau[5]. Our intent was to identify and document existing performance management processes and metrics and establish the AS-IS baseline for a subsequent improvement effort. We knew at the outset of the assessment that this organization, although strong in mission, was weak in performance management. We did not expect to discover, however, that the organization had neither the basic foundational project management and data collection processes needed nor much support for the idea that performance metrics would be useful. We quickly realized that, because of the weakness of the foundation, moving the organization from the AS-IS state directly to a state of generating performance metrics that informed management decisions would be very difficult.

This was the "Aha" moment that became the central idea of our report. Performance management requires a solid foundation composed of an executive vision, robust project management processes, and a good store of current and historical data. Our "Aha" moment suggested that, rather than simply providing an assessment of the current state, we had an opportunity to encourage the organization to build this foundation.

Performance Metrics…

- Tell us if we are hitting the targets/milestones, getting better, or getting worse
- Allow you to catch mistakes before they lead to other mistakes
- Lead to informed decision making
- Assess performance accurately
- Allow for proactive management in a timely manner
- Improve future estimating
- Improve performance for the future
- Make it easier to validate and maintain baselines with minimal disruptions
- Can more "accurately" assess success and failure
- Can improve client satisfaction
- Are a means of assessing the project's health
- Track the ability to meet the project's critical success factors

Harold Kerzner
Project Management 2.0, p79

[4] Taken from Kerzner, H. (2015) Project Management 2.0, Hoboken, New Jersey, John Wiley & Sons, Inc.,
[5] We did not assess the processes or effectiveness of performance management at the individual level, which is conducted according to governing policies of the Federal Department is which the organization is located.

With that idea in mind, we developed criteria for assessing the strength of this foundation, titled the Performance Management Readiness framework. We then used these criteria to guide the interpretation of our observations and the development of our recommendations.

This paper is a direct result of the work we performed. The first two sections, Strategic Readiness and Operational Readiness, cover the criteria in the Performance Management Readiness framework. The third section, Evaluation of Readiness, describes the approach used.

Strategic Readiness

We defined strategic readiness for performance management as a state where the vision, attitudes, motivations, and culture necessary for performance management are in place. As we assessed this federal organization, we realized that, unless an organization is strategically ready, identifying meaningful performance improvement goals or cooperatively driving toward those goals would be difficult at best. The strategic readiness segment of the Performance Management Readiness framework is made up of multiple components, which are building blocks that must be in place for an organization to support and grow performance management:

- Executive commitment to improved organizational performance
- Performance improvement is a priority for the organization
- Management buy-in for performance improvement
- Staff passion for being the best at what they do
- Culture of respect for process, standards, and evidence-based decision-making

Below, we discuss each of these components and its role either in identifying performance improvement goals or in supporting ongoing efforts to implement performance management.

Executive Commitment to Improved Organizational Performance

We identified two aspects of executive commitment necessary for setting and achieving organizational performance improvement goals: being committed and being a champion.

The first of these is executive leadership commitment to a strategic plan that defines and documents executive vision, goals, objectives, and strategies. This plan supports performance management when it translates executive vision into specific, quantifiable objectives and implementable strategies that can be further translated into specific actionable and measurable performance improvement goals.

Many performance improvements require the organization to redesign work processes or approach situations with a different view. Doing this successfully requires strong leadership to champion the change. Therefore, the second critical aspect of executive commitment for improved performance is having an executive champion who can make the vision real and instill a passion for change across the organization.

Performance improvement is a priority for the organization

All performance improvement efforts require an investment of time and resources, and for most organizations, these resources are limited. Organizational leadership committed to prioritizing the achievement of performance improvement goals against other resource commitments is important to strategic readiness. We find that this controlled, resource-based approach provides an organization the ability to create a sustainable performance management effort and increases the likelihood of achieving performance improvement goals.

Management Buy-In for Performance Improvement

Second- and third-tier managers not committed to performance improvement can derail a performance management initiative from achieving its goals. Therefore, another aspect of strategic readiness is having these managers on board with the performance improvement efforts and using them as active change agents. Buy-in across the full management chain will help ensure that performance management is implemented correctly, measures are meaningful, and performance data is timely and accurate.

Staff Passion for Being the Best at What They Do

We find that staff with a passion for great work will naturally have a passion for performance improvement. Motivated staff are much more likely to embrace performance management and not view it as “just another” management-imposed burden. This acceptance is important to strategic readiness as it enables change at the very root of the organization. Staff closest to the work have an inherent understanding of how to best measure performance. With an engaged workforce, an organization is more likely to develop measures that capture meaningful results on organizational performance.

Culture of Respect for Process, Standards, and Evidence-Based Decision-Making

We find that a culture that values process and standards is important to the success of a performance management implementation. A foundation of documented processes and performance standards that are consistently followed creates an excellent springboard for organizational achievement of performance improvement goals. Without this foundation, the organization will have a hard time determining whether its performance is improving, excelling, or failing in relation to the improvement goals.

Operational Readiness

An organization measures its performance in order to answer two related questions:

- Are we meeting or exceeding the goals we have set for ourselves?
- What improvements are necessary for us to meet or exceed our goals?

Fully formulating these questions requires that the organization’s goals and strategic outcomes be well defined, and that the capabilities to measure and improve performance are in place. In the previous section on strategic readiness, we discussed goals and several intangible characteristics (such as commitment, buy-in, passion, and culture) that enable an organization to embrace performance management. Along with the strategic readiness, we also need to have the defined capabilities in place, or what we are calling operational readiness. We define operational readiness in terms of the maturity of the organization's project management processes, structures, and data.

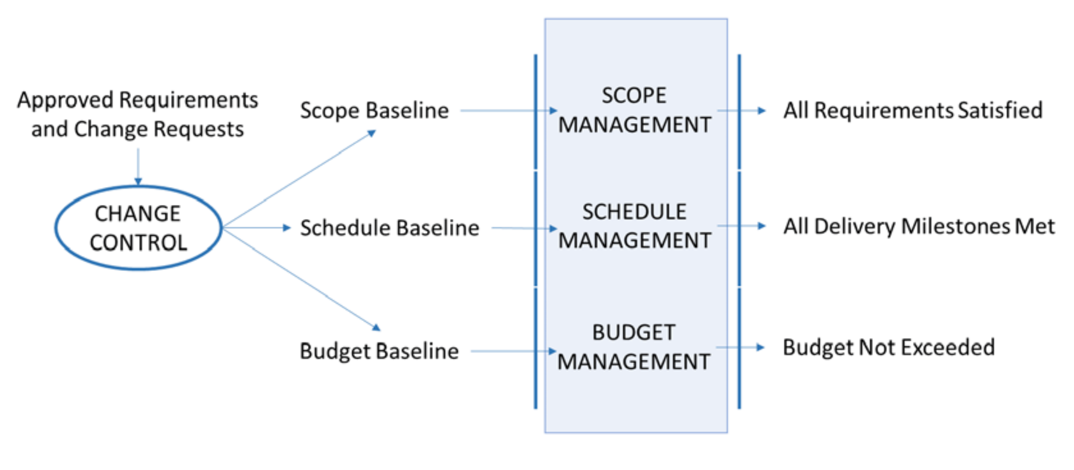
Although it is possible to gauge the performance of an organization operating with poorly formed or undocumented project management processes, such a measurement is likely to yield only gross information about organizational productivity. Obtaining the detailed information necessary to focus the organization on changes that yield performance improvement requires, at minimum, a basic set of project management processes, data collection processes and governance structures.

We strongly encourage an organization put this operational foundation in place before dedicating resources to performance management. Below, we discuss the four components of operational readiness that must be evident before performance management can deliver value to the organization:

- Process readiness for managing and controlling scope, schedule, and budget
- Process readiness for managing resource assignments
- Process readiness for assessing product quality and customer satisfaction
- Data readiness for performance measurement

Process Readiness for Managing and Controlling Scope, Schedule, and Budget

Organizations often refer to scope, schedule, and budget management as the triple constraints because they are strongly interdependent. A change to one always necessitates a change to one or both of the others. For example, changing required capability (scope) after project initiation normally means more money and time are needed, while reducing budget typically results in the organization delivering less capability on a shorter timeline. The figure below illustrates how changes to these constraints are intertwined.



Managing the Triple Constraints

Although mature versions of these processes do not need to be in place prior to initiating performance management, we find that the organization, at a minimum, must be reliably capable of:

- Establishing initial scope, schedule, and budget baselines for each project
- Assessing impacts of change requests and revising project baselines to reflect them
- Determining whether project deliverables meet scope, schedule, and budget constraints

Process Readiness for Managing Resource Assignments

Before initiating performance management, the organization must have a minimal set of resource management processes in place. These processes are necessary for an organization to understand how resources were used in the past, to match staff skill sets to project skills needed in the present, and to predict the size and skill sets required of the future workforce.

Process Readiness for Assessing Product Quality and Customer Satisfaction

Product quality refers to the characteristics of a deliverable, other than the triple constraints, that affect customer satisfaction and acceptance. An organization could build quality into a product, for example, by adhering to standards designed in response to customer perceptions and assessing adherence through product reviews. We find that an organization must have standards for product quality and the ability to assess adherence to those standards, even if they are measured only in “pass-fail” terms, before quality performance measurements will have benefit.

Customer satisfaction refers to the customer’s perception that the product, service, and/or interaction with the organization meets, does not meet, or exceeds their expectations. The ability to measure customer satisfaction is not a prerequisite for initiating a performance management program. However, we find that an organization will more readily adopt performance management metrics in this area if it has prior experience with soliciting, collecting, analyzing, and responding to both positive and negative customer comments.

Data Readiness for Performance Measurement

Having the processes described above in place is one of the two strongly intersecting components of operational readiness. The other is data readiness. Without data describing current and past performance, an organization cannot confidently state that it will meet its goals, that performance is improving over time, or that it can effectively isolate and correct process problems affecting performance. For an organization to use data effectively for performance management, the data must have the following critical characteristics:

- *Comprehensive:* Collected for all performance topic areas of interest[6]
- *Comparable over a project lifetime:* Reliably informs an evaluation of project performance against planned performance
- *Comparable across project iterations:* Reliably informs workload and resource forecasting, project planning, and future project performance

[6] The performance topic areas we evaluated for data readiness were: scope, schedule, budget, resources, product quality, and customer satisfaction.

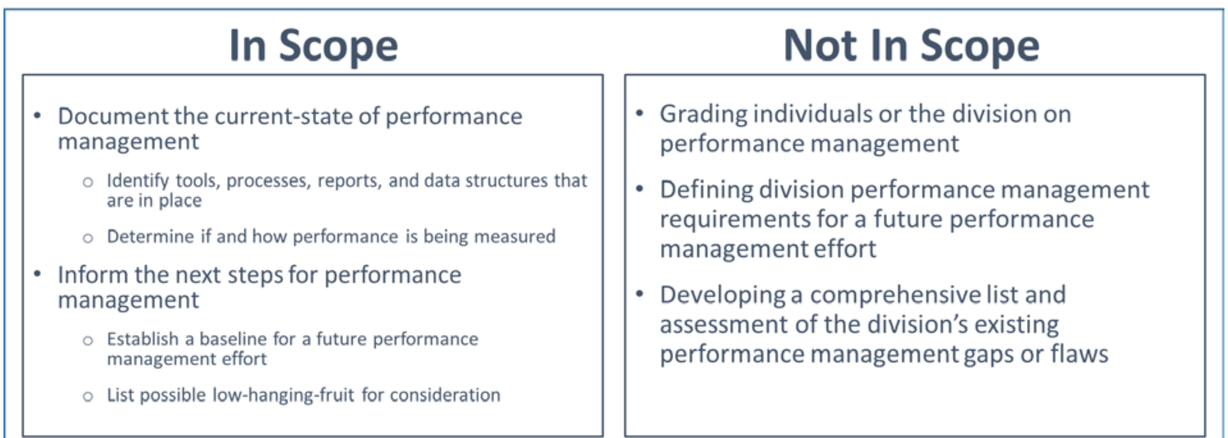
Data readiness includes collecting performance data with these characteristics, maintaining current and historical data in a secure repository, and ensuring that the data is accessible for the organization's decision makers. The maturity of processes for using this data by the decision makers is only marginally important for determining data readiness, although we find an implementation of performance management will be easier if that maturity exists.

Evaluation of Readiness

Understanding strategic and operational readiness is a start, but how do you evaluate your organization's readiness to implement performance management? In this section, we outline the process we used to assess and analyze the organization's strategic and operational readiness.

Evaluation of Readiness Defined

An evaluation of readiness is performed before an organization commits physical and intellectual resources to building up its performance management capability. This evaluation gauges the actual strategic and operational readiness of the organization, identifies if and how performance data is being used for decision making at all management levels, and establishes the "AS-IS" baseline for a subsequent and more intensive performance management improvement effort (see figure below).



Objectives of the Evaluation

Necessary Pre-Conditions for an Evaluation of Readiness

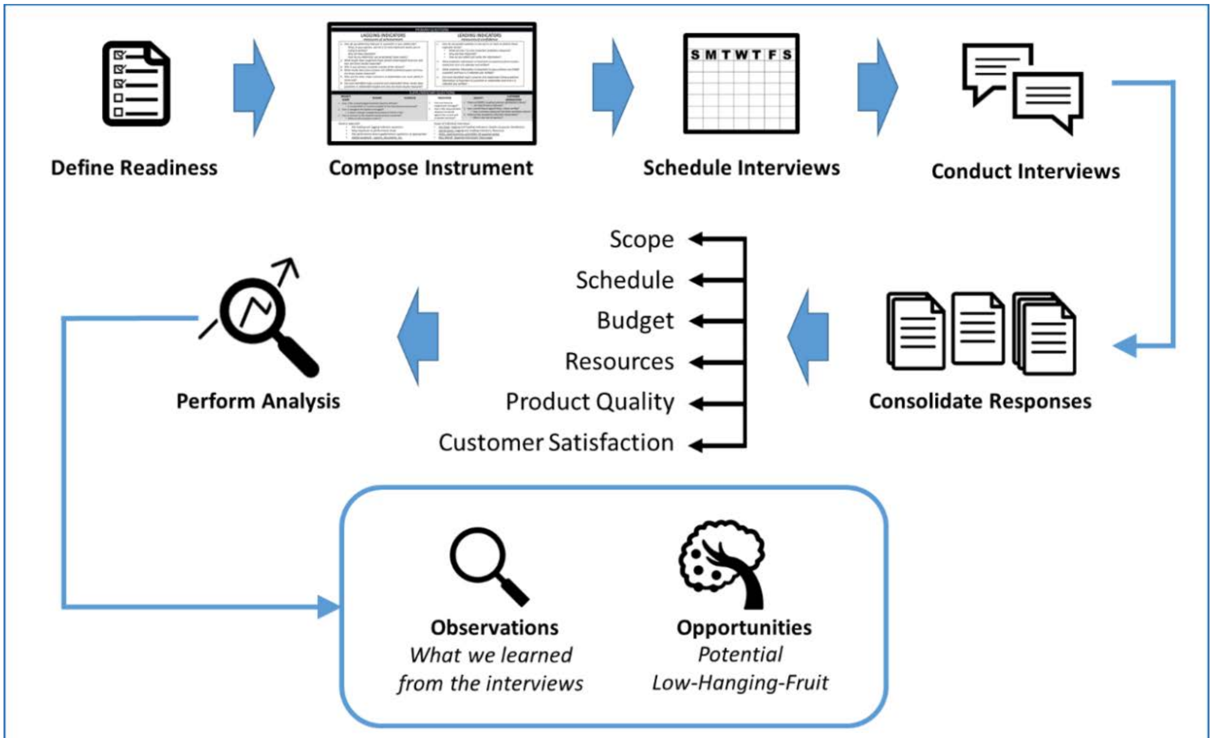
Before considering an evaluation of readiness, the following pre-conditions must be met:

- An organizational assessment of any type must have the full support of the executive in charge and the backing of the management team. Major pushback is a signal that leadership needs to communicate more about the purpose of the evaluation and the importance of their participation.
- The assessment team must have access to the full management team to accurately determine an organization's readiness, including all managers who employ or could be employing performance metrics for making management decisions.

- The assessment team must be unbiased and perceived as such by the management team. This usually requires using outside resources to conduct the assessment.
- Three months or more to must be allowed for a full evaluation to be conducted

Readiness Evaluation Approach

The evaluation, in summary, comprised individual interviews of every member of the management team, consolidation of their responses, analysis of the responses, generation of a specific set of observations derived from the responses, and, finally, preparation of a number of low-hanging fruit improvements suggested by the observations (see figure below).



Readiness Evaluation Approach

Readiness is composed of strategic and operational readiness as described in this paper. We designed the interview instrument to elicit information on the tools the organization's managers use to assess performance, how the information is obtained, and how it is employed for leading and lagging indicators[7] with additional detail in six specific performance areas: Scope, Schedule, Budget, Resources, Product Quality, and Customer Satisfaction (see table on next page). The actual instrument was prepared as a script used with only minor wording changes. There were a few exceptions where we did not use the whole script. For example, we did not ask the executive for detailed Scope, Schedule, Budget, or Resources performance information.

[7] Leading indicators are predictive; they give and an organization confidence that the triple constraints for future goals or milestones will be met. Lagging indicators are assessments; they describe how close the triple constraints were met for goals that have already been achieved.

A week before the first interview, the executive notified the management team (branch chiefs and above) that they would be contacted to schedule an interview, explained why it was important, summarized what we would be looking for, and asked for full cooperation. We then conducted 21 one-hour interviews over a period of slightly more than two weeks.

The Performance Management Readiness Interview Instrument

Leading Indicators	1. How do you determine that you're successful in your role? 2. What results does (*your supervisor*) expect from you and how are those results measured? 3. Who is your primary customer outside of the division? 4. What results does (*your primary customer*) expect and how are those results measured? 5. Who are the other major customers or stakeholders you must satisfy in some way? 6. What results does (*each major customer or stakeholder*) expect and how are they measured?
Lagging Indicator	1. How do you predict whether or not you're on track to achieve those expected results? 2. What predictive information is important to (*your supervisor*) and how is it collected and verified? 3. What predictive information is important to (*your primary customer*) and how is it collected and verified? 4. What predictive information is important to (*each major customer or stakeholder*) and how is it collected and verified?
Scope/ Budget/ Schedule	1. How is the [scope/budget/schedule] baseline defined? 2. How is change to the baseline managed? 3. How is variance to the baseline measured and monitored?
Resource	1. How are resource assignments managed? 2. How is the resource/skills baseline monitored against the current and projected workload?
Product Quality/ Customer Satisfaction	1. What are the organization's criteria for [product quality/customer satisfaction]? 2. How is performance against these criteria verified? 3. What are the acceptance criteria for deliverables?

All three team members kept notes using an expanded copy of the interview script so that responses could easily be associated the questions asked. No electronic records of the interviews were made. We assured each interviewee that responses would not be attributable to individuals.

We consolidated the raw, attributable notes into six groups corresponding to the six performance areas. Each of the three interview team members did the initial analysis for one of these sets of performance areas: scope/schedule, budget/resources, and product quality/customer satisfaction. The analysis included identifying common themes, crafting a set of observations to reflect the themes, selecting representative quotes from the interview records to support the observations, and identifying and drafting related improvement opportunities for the organization to consider.

During a series of team meetings, we critiqued, revised, and refined the observations, quotes, and opportunities for each performance area. Only when this work was nearly completed did the team shift focus to the overarching aspects of the analysis, including:

- *Organizational priorities:* Performance measures should be expected for the highest priority items
- *Primary leading and lagging indicators for each performance area:* These illuminate how important or unimportant performance metrics are for current state decision making
- *Performance management strengths and weaknesses*: These characterize the performance management maturity of the organization
- *Overarching opportunities*: These consist of a short list of easily accomplished potential actions (low- hanging fruit) for effectively establishing foundational processes

Roadmap to Performance Management

Although not every organization may be open to hearing that they are not ready for performance management, we were fortunate that the organization we worked with was receptive to our recommendations and the roadmap we provided for implementing performance management.

Organizations and their specific needs vary, and there is no one way to implement performance management. Below are some considerations for building a performance management roadmap.

Performance management is a process that is built on other processes

A performance management implementation is more likely to succeed and generate meaningful data when the organization is strategically and operationally ready. The roadmap should make it clear that the organization should apply resources to build the foundation described above before they use them to define a performance management process or attempt to measure performance.

Performance management requires effective change management and communication

The roadmap should include efforts to educate staff on performance management. Many staff members believe that they will be personally measured and judged. Proper communication and education will help overcome fear and reduce resistance to performance management.

Performance management cannot be built in a day

The readiness evaluation described in this paper is a necessary first step in the planning process and discovering, through the evaluation, that there are weaknesses in organizational readiness is not an excuse to delay the start of that journey. Even as these weaknesses are being addressed, the roadmap could include the organization looking at what they do or can measure now, comparing that to their strategic goals and objectives, and begin planning for what they should measure in the long-term.

The roadmap should also reflect the organization's maturity and capabilities. Setting realistic expectations will help staff to achieve success and keep leadership from abandoning the project before it can be of value. Additionally, identifying quick wins will keep staff engaged in the process.

Performance management requires a significant investment.

The roadmap should include activities for developing measure frameworks and selecting the metrics with the highest priority and value for implementation. These steps will help the organization focus their resources on the best return for their investment.

Profit Maximization and Strategic Management for Construction Projects

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ABSTRACT

Profit maximization is the first goal for any construction company whether it is stated directly or hidden in between the strategic management lines. At the same time construction projects are known for frequently being over budget and behind schedule. As it is known the resources are limited not only for the contractors, but also for the clients. In order to allow construction companies to make a profit on projects they need to practice intelligent approaches and find ways of minimize its costs. Traditional approaches no longer serve the industry and informed decision-making is important for any construction company to be profitable and stay in the market.

In the mission of helping the industry in the process of informed decision-making and strategic management a decision-support tool is developed called Strategic Management for Construction Projects (SMCP). The aim of the tool is to help in deciding on optimal resource allocation for any construction project with consideration of resource availability and the stakeholder guidance. The decision-support tool takes into consideration the technical aspects of projects as well its business perspectives for cash-flow and activity planning. The tool can be used for project contract management as well, since it provides the information necessary to consider for having a successful project.

Within its constraints the tool allows to analyze the sustainability compliance of projects if such imposed or pioneered. As such the decision-support tool can aid the construction management industry for optimal decision-making in strategic management.

INTRODUCTION

In capitalistic economy production for profit and accumulation is the driving force for continuous development. As stated by Joseph Schumpeter (1911) in his book titled *The Theory of Economic Development*, “Without development there is no profit, without profit no development,". From economic development perspective the profit maximization or cost minimization serves as the driving force for many businesses if not for all. Construction industry is no different from this perspective, yet has many specificities that make it a distinct industry by its nature (Koskela, 2000).

In construction industry compared to other manufacturing industries projects are unique, must be in place and can be completed by different assembly teams. Such setup in many cases may cause the anomalies related to the resource allocation and availability, which when seasoned with stakeholder needs may push projects to be delayed as well as be over budget. From Project Management Institute’s Talent Triangle perspective this is where all the pieces of project management come together and try to overcome the obstacles (PMI, 2017). With talent triangle consideration it assumes a meeting of minds and skills for the potential best outcome for successful project delivery. With meeting of minds it seeks to utilize the available resources and by complying with actual limitations or considerations for project completion.

In the industry this process when directly linked to scheduling of a project is frequently known as a resource-constrained project scheduling problem (Koulinas and Anagnostopoulos, 2012). In resource-constrained scheduling the availability of limited resource is assumed at any time. The goal under such assumption is to minimize the duration of projects by efficiently rescheduling all project activities. As long as the solution is found the next phase of analysis assumes resource allocation. This in its turn is assumed to be helpful in cost minimization by reducing the need of temporary addition of required resources. Then it comes to the resource leveling to smoothen day to day resource needs which under CPM method still consider the unlimited availability (Demeulemeester and Herroelen 2002). With unlimited resource availability it seems to be much easier to allocate resources for project completion. When the limitation of resources is added to the picture the scheduling may become more challenging. When such setup is associated with the input from stakeholders the picture becomes more and more complicated.

In this paper the goal is to develop a decision-support tool that will aid management from multifaceted perspective such as lower costs, in time completion with resource constrained setup. The developed model is used on a hypothetical problem based on unlimited resource version adopted from Winston (2004). Results indicate that the impact of resources can be analyzed beforehand and may indicate the projects’ resource infeasibility range or will tell how much investment is necessary in order to finish the project under enforced conditions.

Resource usage and limitations for resources in projects may be both continuous or in integer values. To allow more practical usage of material among projects it was decided to allow the model variables to be continuous which on the other side allows more efficient solution times for solving the problems more reliably without worrying of the solution being local or global . For analyzing the developed tool GAMS and LINDO software packages were utilized to solve the sample problem on a laptop computer that has Intel® Core™ i3-3110M CPU @ 2.40GHz with 64-bit operating system and 4.00GB RAM. Computational time of the problem was in terms of 00:00:00 as reported by the solver for the sample case study problem with 17 variables, which will be slightly different for a full scale problem analysis, but is not expected to cause any significant issues due to the linear and effective formulation of the tool and constraint formulation. Results are analyzed at the Results section of the paper.

PROPOSED METHODOLOGY

For any construction project there are many competing contractors that bid and expect to get the projects based on more accurate cost and duration estimates, as well as their reputation. From managerial perspective it can be seen that the resource availability would be the other dimension which when analyzed accurately can aid in such competition and goal of getting a project.

In this paper, an optimization-based methodology is developed and proposed for management to consider resource limitations that can be expressed in terms of quantity or budget and time. Such approach allows to proceed with the best potential strategy to evaluate and complete construction projects within considered limitations if such option is at all feasible.

Schematic representation of the proposed decision-support system is presented in Figure 1. The top-level in Figure 1 is the decision-making unit for strategic and business management that analysis and optimizes the resources along with schedule among construction sites. The lower-level represents construction sites from which an updated data on a continuous basis is supplied to the top level. The arrow in the third-level on Figure 1 indicates that the information exchange is not solely between the centralized decision-making system and the sites, but also among the construction sites managed by single company.

In Figure 1 the top-level unit is responsible for all decision-making and problem solution activities, while the lower levels are required to supply data and adopt the decisions provided from the top level.

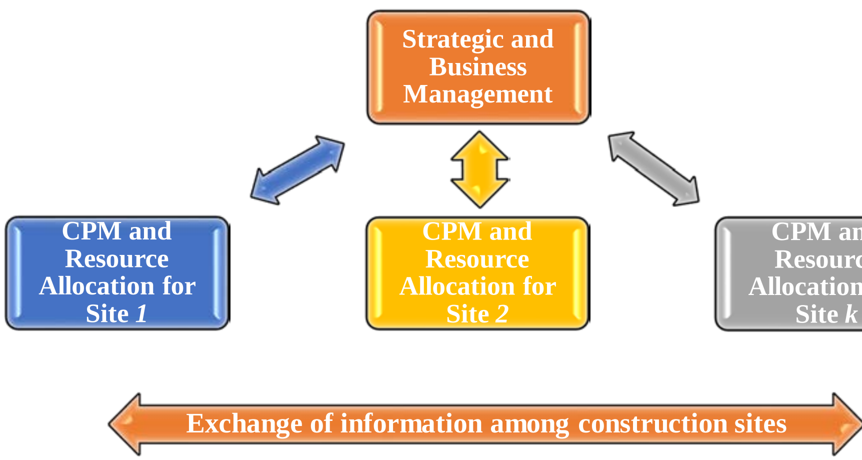

Figure1. Schematic representation of a Management System

The limited details of the system formulation as an optimization model is provided in the next section followed by preliminary results of a case study. The developed approach utilizes the strengths of CPM and PERT (Program Evaluation Review Technique) where the duration of activities or resources can be based on the optimistic, pessimistic and average values. For the sake of simplicity and space limitation only one site setup is partially presented.

MATHEMATICAL MODEL

In order to develop the mathematical model for the scheduling problem with constraint resources it is necessary first to formulate the problem with unlimited resources setup. To find the critical path of a project using Critical Path Method it is important to define the list of activities and the predecessor relationship along with the corresponding durations. Once this step is complete the network diagram can be built and the physical or logical connections can be presented. In general the mathematical formulation allows to set up the models for project crashing or shortening the duration of individual activities.

The model of CPM is presented in its general form with unconstrained resources followed by the model for crashing the project duration, which in its turn is followed by partial representation of a novel approach that considers the constrained nature of resources with stakeholder requirements presented in terms of limitations.

The Model

Notation employed in the mathematical formulation of the *SMCP's* objective function are defined next.

I	=	set of origin where activity starts
J	=	set of destination where activity finishes, J* is the last element in the set
TD	=	total duration right hand sight value where necessary
R_k	=	construction resource types right hand sight value where necessary (e.g. material, labor, budget, time, stakeholder needs, sustainability, etc.) $k \in K$
R_{ijk}	=	usage of resource type *k* for activity *ij* $i \in I$, $j \in J$, $k \in K$
CC_{ij}	=	cost of crashing activity *ij* $i \in I$, $j \in J$
L_{ij}	=	right hand side value as limitation on crashing activity *ij* $i \in I$, $j \in J$
La_{ij}	=	estimate of the activity's crashing duration under the most favorable conditions
Lb_{ij}	=	estimate of the activity's crashing duration under the least favorable conditions
Lm_{ij}	=	most likely value for the activity's crashing duration
ta_{ij}	=	estimate of the activity's duration under the most favorable conditions
tb_{ij}	=	estimate of the activity's duration under the least favorable conditions
tm_{ij}	=	most likely value for the activity's duration

Decision variables

x_i *and* x_j	=	start and finish times of activity *ij*, $i \in I$, $j \in J$
CT_{ij}	=	crashing duration of activity *ij*, $i \in I$, $j \in J$ where applied
Z	=	objective function value

Formulation of a traditional CPM as Linear Program:

Objective function:

$$\min Z = x_{J*} - x_1 \qquad (1)$$

Subject to:

$$x_j \geq x_i + t_{ij} \qquad \forall\, i \in I, j \in J \qquad (2)$$

$$x_i \; and \; x_j \; URS \qquad \forall \; i \in I, j \in J \qquad (3)$$

With the need for crashing the project the linear programing allows using a unique formulation that can minimize the crashing cost of the activities.

With such set up the formulation looks as the following:

Objective function:

$$\min Z = \sum_0^{J*} CC_{ij} * CT_{ij} \qquad (4)$$

Subject to:

$$CT_{ij} \leq L_{ij} \qquad \forall \; i \in I, j \in J \qquad (5)$$

$$x_j \geq x_i + t_{ij} - CT_{ij} \qquad \forall \; i \in I, j \in J \qquad (6)$$

$$x_{J*} - x_1 \leq TD \qquad \forall \; i \in I, j \in J \qquad (7)$$

$$CT_{ij} \geq 0 \qquad \forall \; i \in I, j \in J \qquad (8)$$

$$x_i \; and \; x_j \; URS \qquad \forall \; i \in I, j \in J \qquad (9)$$

In formulations (1)-(9) the time of each activity duration is set as deterministic value, while PERT allows consideration of estimated time values for each activity duration. When combining the PERT time estimate approach in CPM combined with project crashing formulation along with consideration that any crashing duration is also an estimate the linear program formulation can be structured as the following:

Objective function:

$$\min Z = x_{J*} + \sum_0^{J*} CC_{ij} * CT_{ij} - x_1 \qquad (10)$$

Subject to:

$$CT_{ij} \leq \frac{(La_{ij} + 4Lm_{ij} + Lb_{ij})}{6} \qquad \forall \; i \in I, j \in J \qquad (11)$$

$$x_j \geq x_i + \frac{(ta_{ij} + 4tm_{ij} + tb_{ij})}{6} - CT_{ij} \qquad \forall \; i \in I, j \in J \qquad (12)$$

$$x_{J*} - x_1 \leq TD \qquad \forall \; i \in I, j \in J \qquad (13)$$

$$CT_{ij} \geq 0 \qquad \forall \; i \in I, j \in J \qquad (14)$$

$$x_i \; and \; x_j \; URS \qquad \forall \; i \in I, j \in J \qquad (15)$$

The objective function (10) overall value would not be intuitive for the use. Since both CPM formulation and project crashing formulation are minimization objectives the combination of these functions for overall lowest value detection in a linear set up allows to solve the problem while identifying the shortest completion time of a project and applying the crashing strategies. The estimated time consideration is also applied in constraints (11)-(12) which allows decision-makers values to be considered in the optimization process. Such approach helps to overcome the difficulties that traditional PERT approach faces for justification of activity duration independencies and the issue of assuming that critical path found through CPM will be the critical path at all the times. This formulation allows to find the critical path and the crashing strategies while considering the estimated durations for activities. To report the actual project duration and the cost of crashing the project two additional equations can be added to the formulation. Those will be:

$$\text{TPD} = \left(x_{J*} - x_1\right) \qquad (i)$$

$$TPCC = \sum_0^{J*} CC_{ij} * CT_{ij} \qquad (ii)$$

Where TPD is total project duration and TPCC is total project crashing cost.

Proposed formulation can be seen as a goal programing problem where multiple objectives are considered, but with one difference that the preference value is not imposed on the functions. FOR SMCP as multi-objective optimization problem the resource availability is being added to the formulation (10)-(15) combined with (*i*) and (*ii*). The formulation for the stakeholder requirements and resource constrained formulation with an objective to reduce the resource usage is partially presented below:

Objective function of SMCP:

$$\min Z = x_{J*} + \sum_0^{J*} CC_{ij} * CT_{ij} + \sum_0^{J*} \dots\dots\dots - x_1 \qquad (16)$$

Subject to:

$$CT_{ij} \le \frac{(La_{ij} + 4Lm_{ij} + Lb_{ij})}{6} \qquad \forall\ i \in I, j \in J \qquad (17)$$

$$x_j \ge x_i + \frac{(ta_{ij} + 4tm_{ij} + tb_{ij})}{6} - CT_{ij} \qquad \forall\ i \in I, j \in J \qquad (18)$$

$$x_{J*} - x_1 \le TD \qquad \forall\ i \in I, j \in J \qquad (19)$$

$$\dots\dots R_{ijk} \dots\dots \le \dots R_k \dots \qquad \forall\ i \in I, j \in J \qquad (20')$$

$$CT_{ij} \ge 0 \qquad \forall\ i \in I, j \in J \qquad (21)$$

$$\text{TPD} = \left(x_{J*} - x_1\right) \qquad (22)$$

$$TPCC = \sum_0^{J*} CC_{ij} * CT_{ij} \qquad (23)$$

$$x_i \text{ and } x_j\ URS \qquad \forall\ i \in I, j \in J \qquad (24)$$

Stakeholder requirements in terms of limitations are structured in constraints (20’), where “’” indicates that it is more than one constraint, which are not presented in full for this paper.

Next section presents project analysis using the models presented between (1) and (24).

SACE STUDY

Case study analyzed in this paper is considering the project specifics presented in Winston (2004) as discussed above. As such the project activities and corresponding durations are presented in Table 1 and the Activities on Arc (AOA) network diagram is presented in Figure 2. Using model presented between (1)-(3) we find that the project duration is 38 days with a critical path including critical activities B, D, E, F through Dummy arc.

Table 1. Duration of Activities and Predecessor Relationships for the Case Study Project

Activity	Predecessors	Duration in Days
A	None	6
B	None	9
C	A and B	8
D	A and B	7
E	D	10
F	C and E	12

The AOA network diagram would be:

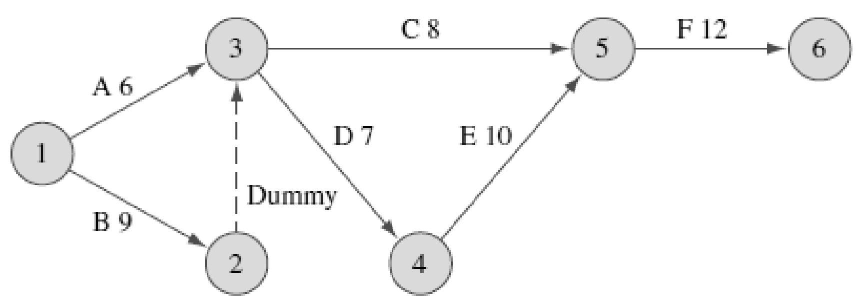

Figure 2: Activities on Arc Network Diagram for the Case Study (Winston, 2004).

When considering data for project crashing to complete it in 25 days based on crashing costs and maximum crashing days per activity from Winston (2004), which are presented in Table 2, we find that using the model between (4)-(9) the duration limitation of 25 days is achievable with a cost of $390.

Table 2. Crashing Cost of each activity and the crashing duration limit for the Case Study Project

Activity	Crashing Cost Per Day ($)	Limit on Crashing Duration (Days)
A	10	5
B	20	5
C	3	5
D	30	5
E	40	5
F	50	5

Solution of the problem suggest crashing activities A, B, D and E for 2, 5, 5 and 3 days accordingly. After adopting the model proposed solution the project is possible to complete in 25 days. The updated network with activity durations can be presented as in Figure 3.

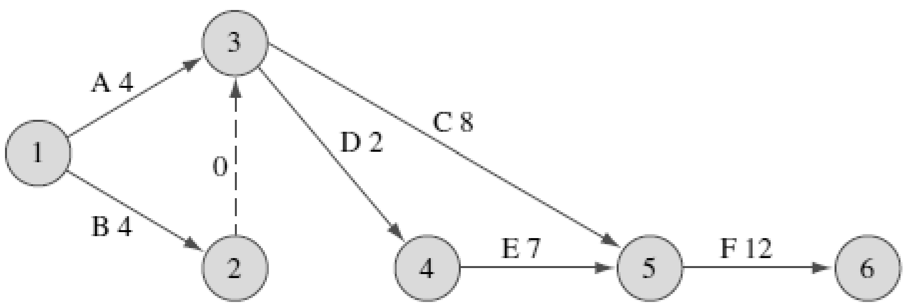

Figure 3: AOA Network Diagram for the crashed project Case Study (Winston, 2004).

With traditional approach the decision-maker should verify that the crashed activities are on a critical path and observe the presence of any changes in the diagram. In this particular case it is noticed that after crashing the project the critical path now becomes two, with both having the same duration of 25 days. The current critical paths go through activities A, D, E, F and as before B, D, E, F again through Dummy arc.

This problem can be analyzed using developed SMCP model given between (10)-(15) extended to (*i*) and (*ii*) or (16)-(24). After running the model it was noticed that the decision-maker can automatically track the critical path as with the case of CPM linear program (1)-(3). Moreover, the output of the model indicated two critical paths that were generated as a result of crashing the project as marked above. The sign of the Dual Price in front of each activity representing constraint is negative indicating that the activity is on a critical path and any increase of those values may negatively impact the completion time of the entire project. Table 3 presents the optimistic, pessimistic and most likely completion times for each activity used to run the model presented in (16)-(24).

Table 3. ta, tb, tm values for activities in the Case Study Project

Activity	Predecessors	Duration in Days		
		ta	tb	tm
A	None	5	13	9
B	None	2	10	6
C	A and B	3	13	8
D	A and B	1	13	7
E	D	8	12	10
F	C and E	9	15	12

For simplicity La, Lb, Lm values were all considered to be five in this example by allowing at most five days for crashing each activity. In other problems based on the decision-maker's analysis this value may change as necessary. For the rest of the resource allocation, sustainability and stakeholder input and resource leveling analysis the model is extended to the full formulation of (16)-(24), which is not presented in this work due to space limitations and for privacy.

RSULTS AND SUMMARY

Results indicated that the novel approach by combining and structuring accurate constraints any project can be analyzed without loss of generality of the model (16)-(24) indicating its flexibility for such analysis. The key component in the efficiency of the model is to keep it linear, but structure the model in a way that the output will be useful for practical implementation. The output of the model (16)-(24) after running it on LINDO is presented below in Table 4:

Table 4. LINDO output variable values from running SMCP for Case Study

LP OPTIMUM FOUNR AT STEP 11					
OBJECTIVE FUNCTION VALUE IS 415					
VARIABLE	VALUE	REDUCED COST	VARIABLE	VALUE	REDUCED COST
X6	25	0	F	0	10
X1	0	0	X3	4	0
A	2	0	X2	4	0
B	5	0	X5	13	0
C	0	3	X4	6	0
D	5	0	TPD	25	0
E	3	0	TPCC	390	0

Objective function value of SMCP as discussed above is not intuitive and therefore values for Total Project Duration (TPD) and Total Project Crashing Cost (TPCC) (shaded cells) are also reported as 25 days consistent with the constraint for duration limitation and $390 as crashing cost. The model is verified through the results obtained from models given between (10)-(15) extended to (*i*) and (*ii*). Shaded cells in the Table 4 correspond to constraint lines representing activities that are on a critical path as discussed above. The negative sign is present for any critical activity.

Table 4. LINDO output slacks and dual prices from running SMCP for Case Study

ROW	SLACK OR SURPLUS	DUAL PRICES	ROW	SLACK OR SURPLUS	DUAL PRICES
2)	3	0.00000	10)	6	0.00000
3)	0	10.00000	11)	0	-6.66667
4)	5	0.00000	12)	0	-6.66667
5)	0	10.00000	13)	0	-6.66667
6)	2	0.00000	14)	0	-30.00000
7)	5	0.00000	15)	0	39.00000
8)	0	-1.66667	16)	0	0.00000
9)	0	-5.00000	17)	0	0.00000

Slack or Surplus values indicate an excess amount of resources or value for other constraints and consequently represent non-critical activities with none zero values. Resource constraints in this Case Study were added with large right hand side values and did not impose any additional restrictions on the solution.

Multisite project management scenarios with profit maximization are not presented here due to space limitations as well. When the linkage and communication of data between multiple projects are imposed the solution output presents valuable and at the same time non-intuitive information for decision-makers and hence serves as useful and practical tool for strategic management of any project. Without loss of generality the model can be applied to any project management process where resource and other limitations are present. For any project where the resources are optimally utilized and costs are minimized the potential profit share is maximized.

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Project Management Adoption for Social Projects of Built Environment Sector

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ABSTRACT

Social projects of built environment sector are either planned as part of social responsibility initiatives or taken up as post disaster reconstruction/rehabilitation projects. Individually these projects are of small scale and low financial value, but collectively the national expenditure of a country on these projects is high. These projects are primarily executed by small scale construction organizations in non-formal project environment and sometimes in remote areas with locally available technology and human expertise. Thus, successful planning and implementation of these projects requires adoption of Project Management (PM) methodologies. Through global literature survey and case study approach, this paper studies the parameters impacting PM adoption in these projects. For case studies, toilet construction projects being implemented under a flagship social scheme of Government of India, the Swachh Bharat Abhiyan Scheme have been studied. Though Indian projects are studied, results would be applicable for other developing countries having similar project work environment.

INTRODUCTION

Social projects for built environment refer to the community-based construction projects planned as a part of social welfare initiatives or taken up in response to natural disasters. These projects are often in the areas of habitat, health or education, benefit the community as a whole and are not focussed on business benefits. These are a proposal of activities organized around a specific objective, to perform in a certain period of time, in a defined geographical area, for a group of beneficiaries, with the aim of solving specific problems or improving a situation (Montes-Guerra et al., 2015). These characteristics stress the need to adopt PM for successful completion and achieving objectives of these projects. But project manager is not a common role in these projects and research has also highlighted that project management in these projects is not the same as in commercial projects (HKCSS, 2013 cited in Chui-ha and Tsz-ying, 2014).

Globally, social projects for built environment sector are often funded and executed by the government departments, by corporate organizations who take up such initiatives as a part of their Corporate Social Responsibility (CSR) initiatives and by non-governmental foundations. These are facilitated by non-profit/non-governmental organizations (NGOs) and executed under the constraints of limited human resources and financial funding (Chui-ha and Tsz-ying, 2014).These projects are generally carried out in an informal manner mainly due to the small magnitude of each individual project, are based in remote areas and implemented with limited manpower and technology.

Moreover, the nature of economic assistance and the complex web of stakeholders hinders the implementation of management tools in the project cycle (Montes-Guerra et al., 2015). Thus, the adoption of PM principles for such projects are primarily restricted to basic time and cost planning, with little attention paid to the formal PM processes of pre-planning and execution. Social projects are reported to face unusual delays or even failures at times. Hence, it is important that for success of such projects, PM principles are incorporated, irrespective of the scale and location of the projects. In the recent years, some of the global organizations like U.S. based organization Construction for Change (CfC), in collaboration with NGOs have successfully incorporated construction project management in community aid projects (Construction for Change, 2014).

Swachh Bharat Abhiyan/Mission (SBM) or Clean Indian Mission is a flagship social scheme of Government of India (GoI). This national level campaign with the budget of USD 29.25 billion[1] was launched in October 2014 with an objective to accomplish the vision of a 'Clean India' by 2019 (Deshpande et al., 2015). One of the sub-objectives of the mission includes construction of individual household, public and community toilets to make the country open defecation free (ODF). The scheme includes construction of around 110 million toilets including toilet blocks, water connection and storage facility and solid waste management system. GoI has established detailed guidelines and structure for planning, implementation, reporting and post completion review of construction work of toilets. Funding for these projects is planned through Central government, respective State governments, Private Sector Participation, CSR, Beneficiary Share, Swachh Bharat Kosh (Clean India Fund), Swachh Bharat Cess (Clean India Tax), User Charges and External Assistance (SBM (U) Guidelines, 2014).

This nationwide scheme requires standard guidelines in terms of planning and implementation, but also needs to be customised for each regional location and for different stakeholders, including implementing organizations and beneficiaries. This highlights the requirement of adoption of Program Management at national level and PM at regional level for successful completion and benefits realization of this scheme.

This paper studies the construct of PM adoption for social projects through literature survey. Through case study approach, the paper analyses adoption of PM for construction of toilets under Swachh Bharat Abhiyan/Mission (SBM) and validates the constructs established through literature survey. For study of cases, their PM adoption was mapped to ten knowledge areas established by PMI. This paper documents part of the research work being conducted by authors to study sustainable adoption of PM for social projects of built environment.

LITERATURE REVIEW

Social projects of built environment can be categorized as social upliftment/ initiative projects, community aid projects, cooperation projects, international

[1] *The conversion rate has been taken as 1 USD = 67 INR.*

development projects or similarly. In such projects, the target "customer" or beneficiary is a community being benefitted from the project output, but its members generally do not fund the project and often they do not have high technical and managerial capabilities (Golini et al., 2015). As a consequence, they are often not included in the project design phases, leading to fatal errors in the execution of the project (Golini et al., 2015). This requires exploiting local practices and skills in the design and construction of such infrastructure (Dillon, 2016). Projects are delivered by people and in projects for social good, volunteers with their knowledge, professional expertise, experience and personal networks are essential to project success. These projects are implemented through a formal construction contract or a voluntary community approach (Dillon, 2016).

In reference to International Development projects, it has been discussed that different contexts reflect different approaches towards PM and empirical evidence also shows that such projects often lack efficiency and effectiveness (Golini et al., 2015). Internal success of a project is measured in terms of achieving estimated Time, Cost and Quality and for these parameters, the performing organizations are directly accountable to donors. External success of projects is w.r.t. achieving stakeholder satisfaction in terms of involvement, long term impact and economic sustainability after the end of the project (Golini et al., 2015).

Literature shows that PMBOK (PMBOK® guide, Fifth ed., 2013) is the most referred document for PM guidelines for social projects, though the percentage of organizations applying it is low, as a high proportion of organizations use their own methodologies and logical framework approach (Montes-Guerra et al., 2015). PM tools have often a scattered adoption and tools usage at a certain stage is influenced by the use of tools at other stages. Researchers have categorized stages of tools adoption and their impact areas as shown in Table 1 (Golini et al., 2015).

Table 1: Stages of tools adoption & their impact areas

Stages	Tools
Stage 1	Progress reports, Logical framework
Stage 2 *Significant Impact on Internal Performance*	Cost accounting, GANTT diagram or project schedule, Risk analysis/management
Stage 3 *Significant Impact on External Performance*	Communication plan, Organizational chart or OBS, Milestone planning, Stakeholder matrix, Scope management, Contingency allocation, Responsibility assignment matrix
Stage 4	Work Breakdown Structure, Critical path method Issue log, Earned value management system

Results indicate that overall adoption of PM tools and techniques is low and logical framework methodology, the most widely used tool is found to be appropriate during the stage of approval and financing and also acts as a common language among stakeholders, enabling cooperation (Montes-Guerra et al., 2015). Golini et al. (2015) have explained this stage wise adoption phenomenon. At the first stage only the basic tools are adopted to receive funding, but there is a lack of knowledge of practical principles of PM and this brings to a lower performance. As the project manager feels the need to improve performance, he or she learns to use new tools (second stage) and acquires core knowledge about PM principles and practices, strongly increasing the project's internal performance. In stages 3 and 4 there is a refinement of managerial techniques through the acquisition of new expertise, which expands the core competences acquired at stage 2. Stage 3 tools and methodologies, besides the positive effects, require additional costs and time, thus their impact on internal project performance is neutral. Though Stage 3 tools focus on addressing short-term, project-related issues, they may indirectly contribute positively to enhancing long-term performance, and thus have a strong positive impact on external performance. Research indicates that internal project performance strongly and positively affects external (strategic) performance.

Research indicates that (Montes-Guerra et al., 2015): primary objectives of these projects being meeting social objectives, and also compliance with the funding agencies, cost management and stakeholder satisfaction are important considerations; Project scope and quality, two fundamental performance variables are less important; Techniques most often used are the ones related to budget control and progress monitoring; and most widely used software is the electronic spreadsheet, and generally there are no other PM computer applications used. Use of some tools is beneficial regardless of the characteristics of the projects or size of the organization executing the project.

Parameters for adoption of PM tools and techniques are identified as (Golini et al., 2015): Private or Non-profit organization and PM maturity level of the organization implementing the project. Impact of tools adoption on project success and performance are summarized as (Golini et al., 2015, Montes-Guerra et al., 2015):

- Project managers who adopt only a small set of basic tools are likely to manage only a few small projects despite the type of project or the geographical location.
- Project managers who adopt a wider range of tools are more likely to achieve higher external and internal performances.
- Using tools would help efficiency, leading to projects being able to meet the social aspects, and also appropriate management of limited resources.

SWACHH BHARAT ABHIYAN/MISSION (SBM)

SBM launched in October, 2014 includes two sub-missions: SBM (Gramin) for rural areas and the SBM (Urban) for urban areas. At National level, this Mission is envisaged and planned as a Program with the sub-objective of making India open defecation free. This sub-objective is to be achieved by construction of around 110 million toilets across the country as per the requirements of identified beneficiaries, bringing behavioral change and capacity development of beneficiaries for effective usage, operations and maintenance of constructed toilets. School and college children have been identified as key stakeholders and potential agents of change in homes (SBM (G) Guidelines, 2014).

The total budget of the mission includes funds for IEC (Information Education and Communication), start-up activities, capacity building and also for solid/liquid waste management (SBM (G) Guidelines, 2014). The government provision for unit cost of individual household toilet is USD 179 and it’s a stage based funding

(SBM (G) Guidelines, 2014). While the CSR activities are currently largely confined to financing household toilets or school toilets for girls in rural areas, Public toilets are funded through PPP models. At national level, the Swachh Bharat Cess (Tax) of 0.5 % has been levied from November 2015. Different organization structures, beneficiary identification mechanisms and funding options have been institutionalised for construction of toilets.

Program and Project Management approach has been constituted at five levels of governance, Central/State/District/Block/Gram Panchayat (GP) or Village level (SBM (G) Guidelines, 2014; Guidelines for IHHL works, 2015).

- At Central level, for SBM(G), concerned Ministry has contracted services of a Project Management Consultancy firm to support the implementation of the scheme. Indicative areas of work include: Program management, Communications, Knowledge Management, Training and Capacity Building, Monitoring and Evaluation, Social Development, Solid Liquid Waste Management/Environmental Engineering, Finance/Grant Management, IT/Web based communications and Procurement.
- Sanitation is a State subject and flexibility is provided to State governments for designing their implementation policy and mechanisms. Each State has to prepare an Implementation Framework with a road map of activities covering *Planning, Implementation and Sustainability Phases*. These plans need to be five year plans, including annual plan for each year.
- An effective monitoring mechanism has been constituted for monitoring both – Outputs (Toilet Construction) and Outcomes (Toilet usage).
- Each State has to develop a customised communication strategy, plan and material and train community mobilisers to use these tools.
- Scheme includes setting up Rural Sanitary Marts, Production Centres for availability of sanitation material in rural areas.
- Application forms and related documents to be used by locals are in local regional language
- Photographic evidence is maintained regarding progress of toilet construction and MIS has been setup for progress reporting.
- Program is to be audited as per GoI and Comptroller Auditor General's guidelines.
- Incentive for success of projects are planned to be provided to facilitating organization on per toilet basis. Two third incentive is to be released six months after completion of toilet and one third after inspection after another six months.

Beneficiaries for individual household toilets are provided a menu of options for technology, design and cost (SBM (G) Guidelines, 2014). The type of technology to be adopted in any SBM toilet project is also defined by the implementing or the funding agency.

Reports suggest that the targets are not being met. As per report of April 2016, of a target of 2.5 million household toilets in urban areas by March 2016, 24 percent (0.6 million) had been constructed. Of a target of 100,000 community and public toilet seats in urban areas by March 2016, 28 percent (28,948) had been constructed. With nearly 16 million toilets constructed over two years (in rural areas), according to the government; 95 million are still needed to be built over the next three years to meet the government's target of making India open-defecation free by 2019 (Hindustan Times, 27 April, 2016).

There are documented technical and non-technical challenges faced by these projects, especially at the implementation level. Some of the reported challenges are (FICCI, and IPE Global, 2015): Data collection and data inconsistency arising due to the various government and non-governmental agencies working in the villages; Unauthorised habitation on the government land and inadequate space in the houses; In remote areas, availability of water and construction materials; Behavioural practice to defecate in open; Mishandling of taps, commodes etc. by the beneficiaries. There are reports that due to lack of water and sewerage connections, poor construction quality and lax maintenance, difficulties with managing faecal sludge, either some constructed toilets are not being used consistently, or people are relapsing into open defecation as the toilets become unusable (Deshpande, 2016).

CASE STUDY ANALYSIS

Case 1: Construction of Individual Household Toilet in Bahadurpur Village, Rajasthan State, India , (Model 1 as shown in Fig. 1), 2015

Most of the households of Bahadurpur village located in Rajgarh of Alwar district, Rajasthan did not have toilets at homes, leading to open defecation. Under the initiative of SBM(G), the villagers, with the help of GPs applied for the established government financial assistance of USD 179 for construction of each household toilet. Substituting this assistance with more funding from their side, the villagers were able to build household toilets just about meeting the basic recommended guidelines. Construction was carried out either by the beneficiaries themselves or by hiring a local mason with limited supervision at the GP level. One such case has been taken up for the case study where a family constructed the individual household toilet in 2015 and is presently using it. Construction of toilet and subsequent maintenance is not of required quality. *(Information collected by discussion with the beneficiary)*

Case 2: Construction of Household Toilets in Villages of State of Sikkim, India (Model 1 as shown in Fig. 1), 2013-15

With the introduction of SBM in 2014, the Sikkim government decided to make the state 100% ODF. Under this initiative, 4391 households without toilets were identified in the East Sikkim district. Sikkim being a special category state, received 90% of the funds from the central government and the rest 10% were contributed by the state government. The construction of these toilets were monitored at the Village (GP) level with technical support provided by the state engineers. By involving self-help groups and related NGOs, the GPs ensured that there was no household without toilet and open defecation was totally stopped. The construction started in 2013-14 & was completed by December 2015. State level Independent Third Party verifications were carried out from January 2016 and after necessary documentation, the state was declared ODF in March 2016. Sikkim is one of the very few states which have achieved the ODF status under SBM. (District Collector East Sikkim, 2016 and RMDD, South Sikkim, 2016)

Case 3: Construction of Individual Household Toilets at Ganesh Mala Slum, Pune, Maharashtra State, India, (Model 1 as shown in Fig. 1), 2014
NGO Shelter Associates partnered with Pune Municipal Corporation (PMCorp.) for implementing Individual Toilet Projects for the identified 81 beneficiary families. In this partnership, PMCorp. sponsored the cost of the toilet hardware and construction, while Shelter Associates was responsible for providing slum data and information on any infrastructure gaps in the drainage system, identification of the beneficiary families, monitoring and supervision of the actual toilet construction and Community Mobilization for proper utilization of the provided individual toilets. The NGO documented the post occupancy evaluation of the toilets and it was found that the toilets are being used by the beneficiaries as they have a sense of ownership. (Associates, 2015 and PM Corp. website, "Individual Toilets"*)*

Case 4: Construction of School Toilets in a District in State of Uttar Pradesh (UP), India, (Model 2c as shown in Fig. 1), 2015
A private engineering company was planning to utilise its CSR funds for construction of school toilets in UP. The company appointed a Govt. instituted apex organization/council setup to take up and promote activities for the development of the Indian construction industry for the identification of beneficiaries & implementation of the project. The Council identified seven schools requiring toilets in a District in UP State and carried out the design and construction of toilet blocks. Financial assistance was provided by the Client and the Council completed the construction of toilet blocks through its manpower & resources. The Council conducted post occupancy surveys observed that with proper training & workshops given during the construction of the toilets, the beneficiaries have been using the toilets. (*Information collected after discussion with the implementing organization)*

Case 5: Construction of School Toilets across six States in India, (Model 2c as shown in Fig. 1), 2015
An oil and gas sector Public Sector Undertaking (PSU) of the GoI was desirous to provide sanitation facilities under its CSR initiative in six states across the country. The PSU and an NGO specialising in providing social sanitation solutions entered into an agreement through which the NGO implemented the construction of 1552 school toilets across the six states & the PSU provided the financial assistance. The identification of the beneficiaries was done by the NGO through surveys and interaction with the local Authorities. The NGO carried out the construction of the toilets through its team of sanitary workers & masons headed by a Field Officer & a Supervisor. With the total project cost of USD 5.85 million, the project was completed in one year as per the scheduled timeline. The constructed toilets have a high success rate due to the active stakeholder awareness programs conducted by the NGO at pre-construction & post-construction stages. (*Information collected by discussion with the NGO*)

Each case was studied and analysed for adoption of PM tools, techniques and methodologies and these were mapped to ten knowledge areas of PM as defined in PMBOK 5th Edition. (PMBOK® guide, Fifth ed., 2013). Subsequently tools used in each case were mapped under four stages of tools adoption as identified in the literature (Table 2). Authors have also included a fifth stage of Tools adoption to which 'Post-occupancy evaluation' tool is assigned.

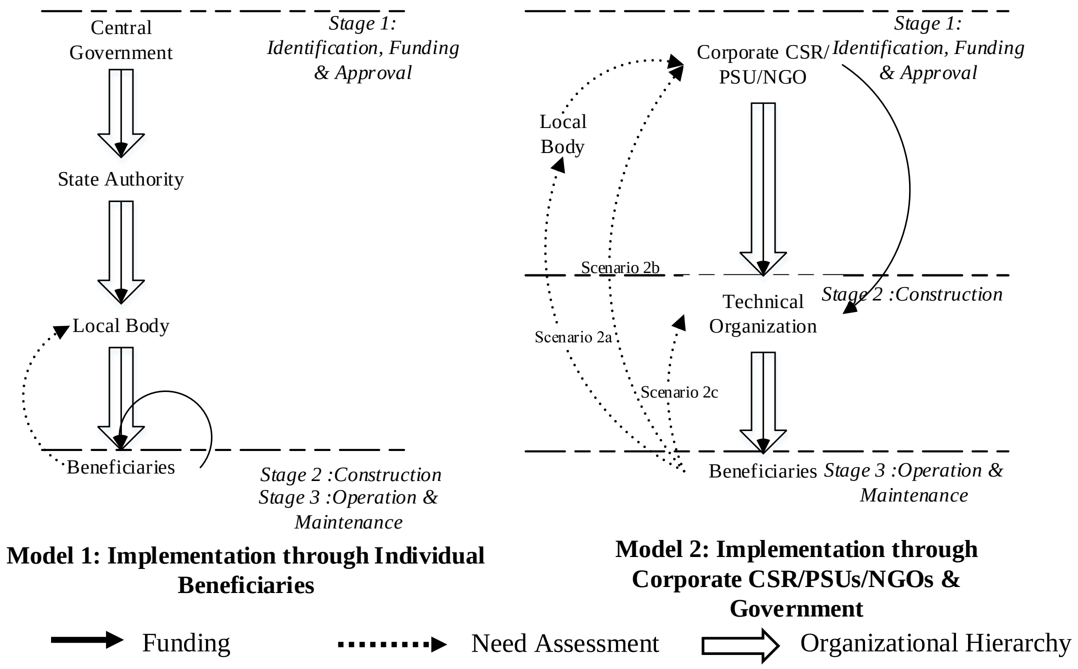

Figure 1: Models for Construction of Toilets

Table 2: Mapping of PM tools used in each case

	Tools Adopted	Case 1	Case 2	Case 3	Case 4	Case 5
	Stage 1					
1	Logical Framework	☑	☑	☑	☑	☑
2	Progress Reporting	☑	☑	☐	☑	☑
3	Expert Judgement	☐	☐	☐	☐	☑
	Stage 2					
1	Project Scheduling (MS Excel/MSP)	☐	☐	☐	☑	☑
2	Cost Accounting	☐	☑	☑	☑	☑
3	Scope Management (Surveys/Interviews)	☑	☑	☑	☑	☑
4	Formal Agreement/Work Order	☐	☑	☑	☑	☑
5	Inspection	☑	☑	☑	☑	☑
	Stage 3					
1	Organisation Chart	☐	☐	☑	☑	☑
2	Responsibilty Matrix/Chart	☐	☑	☑	☑	☑
3	Milestone Scheduling	☑	☐	☑	☑	☑
4	Communication Plan (Meetings/visits)	☐	☐	☐	☑	☑
5	MIS Reporting	☐	☐	☐	☐	☑
6	Procurement Negotiation (Tendering)	☐	☐	☑	☐	☐
7	Quality Assurance (Third Party Audit)	☐	☑	☐	☐	☑
8	Performance Reporting (Factsheets/Report)	☑	☑	☑	☑	☑
9	Capacity Building Workshops/IEC	☐	☑	☑	☑	☑
10	Quality Control (Inspection)	☐	☑	☑	☑	☑
11	Scope Management(GIS Mapping)	☐	☐	☑	☐	☐
12	Stakeholder Analysis Matrix	☐	☐	☐	☑	☑
	Stage 4					
1	Issue Log	☐	☐	☐	☐	☑
2	Work Breakdown Structure(WBS)	☐	☐	☐	☐	☐
3	Critical Path Method (CPM)	☐	☐	☐	☐	☐
4	Earned Value Management System (EVMS)	☐	☐	☐	☐	☐
	Others					
1	Post Occupancy Evaluation	☐	☐	☑	☑	☑

CONCLUSIONS AND DISCUSSION

Case studies analysis shows that if the planning and implementation of social built environment projects is totally assigned to the beneficiaries, as in Case 1, PM adoption is only to fulfil the basic requirements of the guidelines and there is no assurance of internal as well as external performance. Study of similar cases and cases reported in the media, also report this scenario. Also, beneficiaries were required to augment the funding personally, which is difficult for the beneficiaries and also impacts achieving quality construction and building comprehensive facility. For a toilet facility, no/inadequate water supply or sewage management system impacts post-completion usage of the toilet, though as per the records, toilet would be constructed and would be physically existing. Case 2 and Case 3 are also examples of individual household toilets, but with structured intervention of local authorities, augmentation of funding by the authorities, as well as support by the self-help groups for changing community behaviour/behavioural practice. In Case 3, PM adoption is more matured and post-occupancy evaluation has also been conducted. Case 4 and Case 5 were implemented through CSR funds, so availability of funds was not a concern. In Case 4, the implementing agency is a construction council, with knowhow of quality construction, project management and experience of conducting skill development programs. This resulted in quality design and construction, and adoption of formal PM including progress reporting and stakeholder analysis. In Case 5, the client was an oil and gas sector PSU with matured PM adoption in their core work, contributing to establishing systems for internal success factors. The implementing NGO had experience of executing sustainable sanitation projects. Though they do not adopt formal PM methodologies, but they have structured established processes for achieving external success of projects. These factors led to internal and external success of these projects and it is the only case in which a Stage 4 tool was adopted. All cases have adopted Logical framework methodology, formal time scheduling has been done only in Cases 4 and 5, progress reporting in different formats has been done in all cases as it is a requirement of the government established system. But, other tools are not adopted in all cases.

The study indicates that structured Program Management/ Project Management approach of the government has given a framework to the projects for PM adoption. But, formally these tools are adopted if the financing, implementing or facilitating organizations have exposure to PM adoption in their core work or otherwise. Single beneficiary finds it difficult to adopt these tools. Since significant work in these projects is conducted or managed by volunteers, it is important to train volunteers in adoption of these tools. Post-completion evaluation is an important factor to validate benefits realization of these projects as it is important that projects' use is as envisaged at the planning stage. Achieving planed Outputs and Outcomes are both important as benefits realization of these projects/programs are possible only if Outcomes are also achieved.

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Project Management for R&D and Innovation

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ABSTRACT

Research and development (R&D) efforts differ from traditional projects in a number of ways. The desired result of R&D may be intangible with desired outcomes including increased knowledge, a design or prototype, or an initial version of a new product or process. The outcome of the project and the steps to get there may be ill-defined or even unachievable. This paper presents distinctive characteristics of R&D projects and a set of guidelines, gleaned from experience, which apply to managing such projects.

INTRODUCTION

The triple constraint of project scope, time, and cost is well-known in project management (PM), and project management generally assumes that the dimensions of these constraints are well-known and generally well-balanced at the start of a project. Research and Development (R&D), which develops new knowledge and matures that knowledge into products and capabilities, may be undertaken without knowing whether the planned scope is at all achievable and with an incomplete understanding of what it will take to achieve the project's goals.

The Project Management Institute's (PMI) definition of a project as, "a temporary endeavor undertaken to create a unique product, service or result," does incorporate research projects in that PMI's definition of a *result* can include creation of new knowledge or publication of a paper (Project Management Institute, 2013). However, R&D covers a much broader swath, wherein a project will typically have concrete but potentially poorly understood or articulated goals and products. This paper describes approaches that have been successfully employed in managing a spectrum of R&D projects within the technology domain.

CATEGORIES OF R&D

The Organisation for Economic Co-operation and Development (OECD), and the U.S. government-wide Office of Management and Budget (OMB) each define three sub-categories of R&D, including Basic Research (the earliest stage, consisting of "experimental or theoretical work undertaken primarily to acquire new knowledge"), Applied Research (which retains the goal of acquiring new knowledge, but is "directed primarily towards a specific, practical aim or objective"), and Experimental Development (which draws upon knowledge gained from research to improve or produce new products or processes) (OECD, 2015)(US OMB, 2016). The U.S. Department of Defense offers a finer-grained categorization with five sub-categories of R&D, as shown in *Table 1*. (US DoD, 2016)

Table 1: U.S. Department of Defense R&D Categories

Category	Description
Basic Research	Systematic study directed toward greater knowledge or understanding of the fundamental aspects of phenomena and of observable facts.
Applied Research	Translates basic research into solutions. Systematic study to gain knowledge or understanding necessary to determine the means by which a recognized and specific need may be met.
Advanced Technology Development	Focused on development and integration of hardware for field experiments and tests with a goal of providing proof of technological feasibility and assessment of operability and producibility.
Demonstration/ Validation	Includes all efforts necessary to evaluate integrated technologies in a realistic operating environment to assess performance and cost impact of the technology.
Engineering and Manufacturing Development	Translates integrated technologies into product designs through engineering and manufacturing development.

Figure 1, adapted from (Wingate, 2015), represents characteristics across the R&D continuum. Basic Research may have an end product that is defined only by outcomes such as increasing knowledge or testing a hypothesis. As such, the project contains a great many unknowns and the project plan is expected to undergo considerable change in ways which cannot be completely forecast *a priori*. Each step through the R&D continuum builds on the knowledge gained in previous steps, leading to reductions in uncertainty and more concretely definition of the desired outcome. Put another way, research creates technological possibilities, while development is the set of applying a stable set of technological possibilities to the complex requirements of an application context (Iansiti, 1997). The characteristics of the phases of R&D drive differences in project management approaches across the

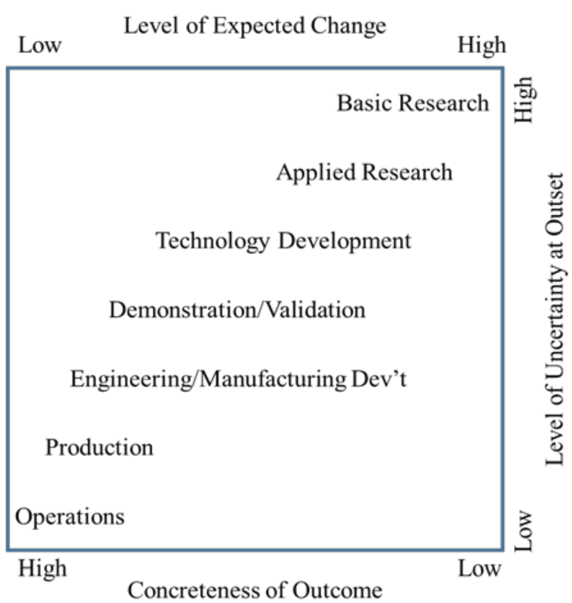

Figure 1: Characteristics of the R&D Continuum

continuum, which will be discussed in subsequent sections.

DISTINCTIVE CHARACTERISTICS OF R&D PROJECTS

Distinctive characteristics of research and development projects, as noted in (EFCOG, 2010), (Jain, 1990) and (Cassanelli, 2017), include:

Uncertainty/Risk: The scope of an R&D project may be incompletely understood at initiation. Project end goals may be well defined but the path for achieving them may not be known, and it may not be clear that the goals are even achievable. Conversely, technical approaches may be well known but the goals may be poorly understood. Scope may be expressed in terms of vision, operational objectives or performance goals rather than hard definitions, with requirements defined only in general terms.

Instability/Change: The internal discovery process that is an inherent part of R&D projects will change the project over time, as may external factors such as shifting application needs or changes in technologies. Changes in the research environment such as sudden breakthroughs, unexpected barriers, or changes in collaboration, can all induce significant change.

People: Freedom of action and a high degree of autonomy and control have significant value for all knowledge workers (Badawy, 1978); this is particularly true for the highly creative, inquisitive, "outside the box" thinkers who populate research and development environments. Teams made up of free-thinking researchers can have dynamics including experts who work prefer to work individually, strong personalities who force their ideas in the project, collaborative teams, internally competitive teams, disciplined or undisciplined teams, and drift (Kuchta, 2017).

Dual Control: An R&D project may separate technical and project management by having both a Principal Investigator (PI), who is responsible for the technical activities of the team, and a Project Manager (PM), who has responsibility for elements including cost, schedule, scope, and risk. There may be a tension between the two as the PI defines and executes a technical plan subject to project constraints. In addition, it may be the case that the PI and PM each have relationships with different subsets of stakeholders, creating factions affecting project governance.

Transition and Relationship of R&D to the Enterprise: Unlike many projects, the product of an R&D effort is not an end unto itself. R&D must be sensitive to its context (such as a market need or operational requirement), and R&D outcomes must be structured to feed into subsequent development cycles.

R&D MANAGEMENT TECHNIQUES

The characteristics of R&D projects result in a need to apply techniques beyond those used in well-specified, lower risk projects. Some useful approaches include:

#1: Even if you don't know how you're going to get there, define "there". The desired end state of an R&D project may not be completely known at the outset. Still, R&D

should rarely be unguided exploration. An important step is to define the outcome as best as possible at the outset. Examples include an increase in understanding of a phenomenon (define what you want to learn), an increase in technology maturity (such as an increased Technology Readiness Level) (United States Department of Defense, ASDR&E 2011), and development of a prototype (define the goal).

#2: Plan your route like an explorer: Research can be trajectory-oriented. You might know the direction you want to go, but not necessarily how far you can get down the path. Whether or not the desired end-state is believed to be achievable, it's important to analyze and decompose what it would take to get there, even if one or more steps are undefined. Such a decomposition can be by one or more of system function, product breakdown structure, technology area, and phase (e.g., product R&D vs. production R&D). It is important to understand where the complexity and risk are and where the decision points are along the way. There should also be a Work Breakdown Structure (WBS) guiding the work, though it will be more dynamic than the typical WBS. Adequate decision points need to be included in the plan to avoid excessive expenditure of resources trying to overcome obstacles.

#3: Measure the unmeasurable: It is important to assess results in R&D even though quantitative measures of outcomes can be elusive, particularly at the research end of the R&D spectrum. Measures can be indirect (for example, the number of publications generated is an indirect measure of the amount of knowledge generated) or direct (such as the number of experiments performed or the number of sub-system designs completed). Recognize that key metrics may comprise the results of multiple elements of the Product Breakdown Structure or even multiple projects (e.g., a decrease in the cost per lumen of solid state lighting may be the result of a combination of advances in both materials science and manufacturing) (United States Department of Energy, 2016) or a coordinated R&D strategy (such as the number of clinical candidate molecules generated in a year from an entire drug research portfolio) (Pisano, 2012). R&D metrics should consider the larger context of the organization; the best outcome for a business may be based on revenue rather than technical elegance.

#4: Plan for risks and reflection: While every project has risks, fundamental assumptions within R&D may turn out to be in error, resulting in major changes in the project plan. In addition, even when project activities are successful it's important to plan in time to reflect on the outcome: for example, why was a test successful: for the expected reasons, or was luck involved? Sometimes, R&D yields a feasible design, but not necessarily the best solution. Therefore, it's appropriate to routinely ask questions like: with the understanding gained from the work so far, would another approach have been better and is it worth re-working the effort accordingly? Overall, for R&D projects it is important to recognize that the project will be incrementally defined and serially redefined, and therefore projects require a significant risk reserve plus a reflection and re-work reserve. This make sure that there are resources

available to take advantage of knowledge gained during the project. There also need to be both internal informal checkpoints and formal, external reviews. The R&D project manager must be prepared to re-work and re-baseline as understanding of the project develops, and should not be overly attached to the initial plan.

#5: Know when good ideas are bad: As already discussed, research and development projects include changes in trajectory based on new ideas generated as the project progresses. However, the project manager must evaluate each idea in light of its contribution to the desired outcome. During initiation of a project and buildup of the initial approach, technical uncertainty (the difference between the information possessed by the team and that required to complete the project) will be high. In this phase, creative ideas contribute strongly to developing an approach. As the project progresses through execution new ideas which perturb the plan should be carefully vetted before being introduced, except at planned milestones such as the reflection checkpoints identified in #4 or if it becomes clear that an execution issue has arisen. The goal is to allow the project to be flexible while controlling tangential work, cycling and drift.

#6: Consider the people: Researchers may desire autonomy and administrative control of their environments and resist accountability to schedules and budgets (Jain, 1990). R&D project management requires diplomacy in terms of holding researchers and teams to the project plan. The R&D project manager should recognize that unstructured slack time, risk taking, mistakes, and "bootlegging" into other areas are all part of the process, but should bound those activities where needed to keep the project on track. The project manager should also be vigilant in fostering an environment that is open to new ideas from all contributors, ensuring that individual strong personalities do not overly dominate the team.

#7: Invite review: The goal of R&D is always to transition the results to subsequent development or research effort. External review by experts and stakeholders serves several goals. First, it provides fresh perspective at reflection points. Second, it helps ensure that the research trajectory is aligned with transition to a product. Third, it serves as a communications mechanism to inform stakeholders on progress, build advocacy, and set expectations.

CONCLUSION

R&D is an umbrella for efforts that range from abstract exploration to the early stages of product development. Success in these types of projects requires adapting project management to the high level of uncertainty and creative effort involved. "Fail fast, fail often" may be a Silicon Valley mantra (Tobak, 2017), but proper application of project management techniques can allow projects to succeed often, even in the exciting and uncertain world of invention and innovation.

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UMD Project Management Symposium
Stop Predicting, Start Forecasting

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ABSTRACT

This whitepaper evaluates two types of estimates: deterministic (single-value) estimates, and stochastic (probabilistic) estimates. Deterministic estimates do not reveal how likely they are to occur, do not align stakeholder expectations, and do not lead to well-informed business decisions by organizational leaders. In contrast, stochastic estimation depicts future project uncertainties, like task duration or project cost, using the language of statistics. Stochastic estimates indicate how likely they are to occur, align stakeholder expectations, allow an organization to match project estimates to the risk policy of the organization (or project), permit dynamic and right-sized project buffering, and create better, more informed decision-making by organizational leaders. Project practitioners can learn how to create stochastic estimates using a freely licensed, stochastic estimation technique called Statistical PERT, which uses the built-in statistical functions of Microsoft Excel.

INTRODUCTION

One of the most important skills a project manager learns is to **estimate** future project outcomes. Project managers and other project professionals—such as cost engineers, project schedulers and others—are collectively responsible for estimating a project's duration and cost. For agile projects where project duration and/or project budget are fixed, project managers are usually expected to predict a release date for new or enhanced product functionality.

Project predictions involve deterministic estimates—single value estimates that represent future uncertainties. However, deterministic estimates do a poor job of communicating risk and uncertainty, and they fail to effectively align stakeholder expectations about future events.

Weather forecasters have made an entire profession of estimating uncertain, future events. Like project managers, weather forecasters use historical data, statistical models, computer simulation, and their own, expert opinions that draw upon their instincts, intuitions, and personal experience. Weather forecasters collectively use these resources to create both weather ***forecasts*** and ***predictions***. Of these two, *forecasting* is superior to *predicting* because forecasting explicitly reveals a sense of risk and uncertainty about future events. Forecasting better aligns stakeholders and fosters better stakeholder decision-making about the future. Project managers can learn to effectively use statistics, the language of weather forecasters.

WEATHER FORECASTING

The American Meteorological Society (AMS) describes a meteorologist—what this whitepaper casually refers to as a "weather forecaster"—as someone "who uses scientific principles to explain, understand, observe, or forecast the earth's atmospheric phenomena and/or how the atmosphere affects the earth and life on the planet" (All About Careers in Meteorology, n.d.). Weather forecasters provide the public with vital, sometimes life-saving information with respect to severe weather patterns and storms. The mission of the United States' National Weather Service (NWS) is to provide weather forecasts and warnings to protect life and property, and to enhance the national economy (NWS Products and Information Guide, 2011) To do that, weather forecasters collect data about atmospheric conditions from 10,000 weather stations around the world, use thousands of ships around the globe to gather even more weather facts, and supplement all that with 500 weather balloons, plus aircraft and satellites, to learn all about the world's ever-changing weather conditions (Meteorology Fields, n.d.)

Forecasting remains the core of meteorology. Gathering thousands of data points each hour of the day would be unfruitful without the ability to convert all that data into an actionable weather forecast. Like project managers, weather forecasters need to effectively communicate both certain and uncertain future outcomes so their stakeholders can make informed decisions about the future.

Before proceeding, it is important to distinguish between *predictions* and *forecasts*, because these terms are often used interchangeably. The AMS uses both terms to describe the work of meteorologists. Meteorologists *predict* the daytime high and low temperatures, but they make *forecasts* about the likelihood of precipitation, and the impact and direction of major storms, like hurricanes and tropical storms.

Dr. Jeffrey C. Bauer, an economist who also formally trained in meteorology, offers a good distinction between *predicting* and *forecasting*. Dr. Bauer explains that *predicting* is, "a specific estimate of the expected value of a key variable at a future point in time," while *forecasting* is, "an estimate of the probabilities of the possibilities for a key variable at a future point in time" (Bauer, 2014, p. 4). This whitepaper will use Dr. Bauer's definitions to differentiate *predictions* from *forecasts*.

Weather forecasting involves statistical probabilities. Everyone is familiar with the nature of a weather forecast described using probabilities. Weather forecasters commonly make statements such as these:

- "Today we will have partly cloudy skies with a 20% chance of rain"
- "Tonight will be mostly clear skies with only a slight chance of rain"
- "Tomorrow, however, there is an 80% chance of rain"

In each statement above, a weather forecaster has given probabilistic answers to the question of, "How likely will it rain in the future?". For people living in the weather forecaster's service area (usually a county), these weather forecasts provide important, actionable information that lets people make appropriate plans for their immediate future (Forecast Terms, 2017). If someone were planning a picnic, the weather statements above might result in a picnic held later today—but not tomorrow.

Imagine if a weather forecaster calculated that there was a 40 percent chance of severe thunderstorms in the forecast area over the next 12 hours, but instead of offering a probabilistic forecast, the weather forecaster instead made the following *prediction*: "It will not rain tomorrow,"—because, the forecaster reasons, there is a greater likelihood (60 percent) that the storm will *not* affect the forecast area than the chance it *will* affect the forecast area. Such a prediction would violate the NWS's mission by unnecessarily endangering life and property. It would give people living in the forecast area a false sense of security regarding potentially threatening weather. They would fail to take proper precautions to protect themselves and their property from severe thunderstorms that *might* move through the forecast area.

Project managers often give their sponsors and key stakeholders an improper sense of security by creating project *predictions* rather than project *forecasts*.

DETERMINISTIC ESTIMATES

Project managers face many uncertainties. They must estimate when a project will finish, how much the project will cost, and, for agile projects, they may estimate how much of the product backlog will be accomplished by the end of the project's fixed schedule. Uncertainty arises from incomplete and/or unavailable data that is useful and reliable, making it challenging to estimate how long project tasks might take to complete, or how much project materials might cost (Liang, Huang, & Yang, 2012).

Often, project managers create deterministic estimates for their project uncertainties. Project managers estimate the duration of scheduled tasks with precise, single-value estimates (usually in hours, days or weeks). They construct a project budget to find the total cost of the project (sometimes down to the penny!). When these deterministic estimates—predictions—are initially shared with the project sponsor and other stakeholders, they immediately set sponsor expectations even though these estimates are created when there is the least amount of project knowledge available.

Most experienced project managers have had to navigate the difficult waters of sharing an initial project prediction with a project sponsor, who then expects the project to be completed according those early project predictions for both schedule and budget. Later, when better project information is available to the project manager, it can be politically unviable for the project manager to get approval for a revised (usually longer) project schedule and (usually increased) project budget. To avoid this hazard, some project managers create, then share, initial project schedules and budgets that they know are bloated because their sponsor will hold them accountable to whatever schedule and budget the sponsor first sees.

Project predictions—deterministic estimates—are inferior to stochastic estimates because project predictions do not indicate how likely they are to occur, they fail to align stakeholder expectations, and they do not lead to informed decision-making by organizational leaders.

Project predictions do not indicate how likely they are to occur. They do not indicate whether they represent the mode, median, mean, or some other value along an implied, bell-shaped, probability curve. When a weather forecaster predicts a daytime high temperature that is normal for the area and time of year, people generally assume a bell-shaped probability distribution and add or subtract five degrees (Fahrenheit) to the predicted high temperature value to reach an expectation of how hot it will be (Jocelyn & Savelli, 2010). People inherently assume that the predicted high temperature is the mode. When project managers offer project predictions, there often is no similar, common understanding of what that prediction represents: is it the mode? an optimistic P10 estimate? a pessimistic P90 estimate? Recipients of project predictions do not know the predicted reliability of the project predictions they receive.

Project predictions fail to align stakeholder expectations. Whether the prediction is the delivery date for a new project, or a project budget, or the number of story points for an agile product backlog—project predictions do not convey any sense of uncertainty or risk. A deterministic estimate is just one possible outcome for a project uncertainty. Usually, many other outcomes are possible, some of which are both possible and probable, while other outcomes are merely possible but improbable. Deterministic estimates do not convey the range of other, alternative outcomes that are possible. The majority of people who learn of a weather forecaster's prediction for the daytime high temperature or the nighttime low temperature regard those predictions as one of many other, possible outcomes (Jocelyn & Savelli, 2010). But project sponsors and other stakeholders sometimes do not similarly regard project predictions as one of many possible outcomes. Failure to recognize this leads to misalignment between project sponsors, key stakeholders, the project manager, and the project team.

Project predictions do not lead to well-informed decision-making by organizational leaders. An organizational leader evaluating three project proposals, each with an expected revenue benefit of $1M, cannot evaluate the relative riskiness of each proposal using deterministic benefit estimates. Organizational leaders making business decisions based upon project predictions may regrettably choose to fund a high-risk project proposal that has the same expected benefit as another project proposal that has much less risk surrounding its predicted benefit.

STOCHASTIC ESTIMATES

Weather forecasters at the National Hurricane Center (NHC) use stochastic (probabilistic) estimates to create a forecast cone for a hurricane or tropical storm. The so-called "cone of uncertainty" is well-known to residents living along the Atlantic seaboard of the United States. The forecast cone represents a stochastic estimate of where NHC believes a hurricane or tropical storm is likely to go that is within approximately one standard deviation of the forecasted track (Definition of the NHC Forecast Cone, 2016). Residents living near the cone of uncertainty understand that they are still at-risk of a direct hit, albeit with much less chance of occurrence than residents living inside the cone of uncertainty. NHC's cone of uncertainty aligns stakeholder expectations, and fosters better, more informed decision-making by residents who are threatened by impending, severe weather conditions.

Stochastic estimates indicate how likely they are to occur, align stakeholder expectations, allow an organization to match project estimates to the risk policy of the organization (or project), permit dynamic and right-sized project buffering, and create better, more informed decision-making by organizational leaders.

Stochastic estimates indicate how likely they are to occur. They can be conveyed via single-value estimates associated with a cumulative probability, or via confidence intervals. For instance, single-value schedule estimates rarely have a reliability of less than 50 percent, and most critical-path method projects, common in the construction industry, are scheduled with probabilities of 80 percent or greater (Cioffi & Khamooshi, 2013). Using confidence intervals, project managers can make statements like this one: *"This project's budget is estimated to be between $1.1M and $1.4M with 90% confidence."* Here, sponsors will expect to pay up to $1.4M (with a small chance the project will cost more), and they will similarly expect to pay no less than $1.1M.

Stochastic estimates align stakeholder expectations. In the example given in the previous paragraph, project stakeholders—which includes the project sponsor, project manager, project team, business managers, and others participating in or affected by the project—all know a range of possibilities for how much the project will cost. Sponsors must be willing to pay up to $1.4M, and even then, there is a small likelihood that the project cost might exceed that amount. If project sponsor is only willing to spend $1.2M on the proposed project, a 90 percent confidence interval of $1.1M to $1.4M should suggest to the sponsor that the current project proposal may be too risky to proceed without exploration and possible modification of the project's charter.

Stochastic estimates allow an organization to match project estimates to the risk policy of the organization and of the specific project proposal. If the risk policy of an organization stipulates that all task duration estimates should be 80 percent reliable, a scheduler using a statistical model can fit a risk distribution to each uncertainty, then calculate schedule estimates (which the scheduler must add to a project schedule) that are all 80 percent probable. If the risk policy *for a specific project or task* is either relaxed or made more stringent than the organizational risk policy, the scheduler can easily choose other, alternative, task duration estimates that match the reliability policy for the specific project or task.

Stochastic estimates permit dynamic and right-sized project buffering. Often, project buffers are calculated using a simple heuristic of adding 5 or 10 percent to the project budget (Meredith & Mantel, 2006, p. 339). Dr. Moselhi, who has 30 years of construction industry experience, argued that such a simple method of calculating a project budget "is not sufficient unless this level of contingency is linked with some probability (or confidence) at which cost overruns will not exceed the allocated contingency" (Moselhi, 1997). With stochastic estimates, project managers can use dynamic, right-sized project buffers derived from statistical models that satisfy Dr. Moselhi's call for confidence. One such method is the Unified Scheduling Method (USM) created by George Washington University's professors, Dr. Homayoun Khamooshi and Dr. Denis Cioffi (Cioffi & Khamooshi, 2013). USM allows project managers to create a dynamic, right-sized schedule reserve that is tied to the reliability of the task duration estimates in a project schedule, and that corresponds to the need for schedule safety by the project manager and sponsor.

Finally, stochastic estimates foster better, more informed decision-making by organizational leaders. When organizational leaders are presented with probabilistic estimates, leaders have a range of probabilistic estimates to consider. They gain a sense of relative risk for each estimate, and they make informed, risk-based decisions about future project uncertainties.

GETTING STARTED WITH STOCHASTIC ESTIMATION

Project managers unfamiliar with stochastic estimation may wonder how they can start creating stochastic estimates and probabilistic project forecasts? These same project managers may already be familiar the Program Evaluation and Review Technique (PERT), a stochastic estimation technique created by the United States Navy in the 1950s when the Navy developed the world's first, submarine-launched, ballistic missiles (Seymour & Hussein, 2014, p. 235). What project managers may not realize is that PERT is a stochastic estimation technique capable of approximating the mean for a bell-shaped uncertainty—like task duration or cost—using the familiar PERT formula: *Minimum + 4(Most Likely) + Maximum / 6*. However, the PERT mean is only about 50 percent reliable (the actual reliability depends on the skew and kurtosis of the implied bell-shaped curve).

Another, easy way to get started with stochastic estimation is to use Statistical PERT®[1]. Statistical PERT is a freely-licensed, probabilistic estimation technique that relies upon the built-in statistical functions of Microsoft Excel®. The Normal Edition of Statistical PERT uses Excel's two normal distribution functions, NORM.DIST and NORM.INV, and the Beta Edition of Statistical PERT uses Excel's two beta distribution functions, BETA.DIST and BETA.INV. Neither edition requires special software beyond Excel, but the Normal Edition is easier to modify. The Normal Edition is suitable for any project uncertainty that has bell-shaped properties and is either symmetrically shaped or mildly-to-moderately skewed.

Statistical PERT Normal Edition was presented to project managers at the 2016 Project Management Institute's Global Congress (Davis, 2016). This technique uses five steps to create stochastic estimates[2]. The five steps are:

1) Create a three-point estimate for any bell-shaped uncertainty
2) Estimate the mean using the PERT formula
3) Render a subjective opinion about the most likely outcome (the mode)

[1] https://www.statisticalpert.com

[2] Using a freely available Statistical PERT spreadsheet template eliminates the need to manually perform steps 2 and 4.

4) Create a Statistical PERT standard deviation
5) Choose a planning estimate per a specified confidence level

Statistical PERT is a simple way to create probabilistic estimates and range forecasts of project uncertainties, like project finish date or the project budget. The technique takes advantage of the built-in statistical functions of Excel, so every project manager can begin experimenting with probabilistic forecasts for their projects.

When the need for greater accuracy arises, or when a project's complexity is too great for simple estimation techniques like PERT and Statistical PERT, project managers can use computer-based simulation models (often called Monte Carlo simulation). However, Monte Carlo simulation requires time to construct and calibrate, a deep knowledge of statistical functions and probability distributions, and the software is expensive to purchase. Nevertheless, Monte Carlo simulation affords project teams a sophisticated way to forecast uncertain project outcomes similarly to the way weather forecasters forecast the future path of hurricane.

CONCLUSION

Deterministic project estimates are commonly created by project managers, but such estimates do little to align the expectations of their project sponsors and other key stakeholders. Project predictions do not indicate how likely they are to occur, and they do not lead to informed decision-making by organizational leaders.

In contrast, stochastic project estimates have a calculated reliability value (confidence level) to indicate how likely they are succeed. Stochastic estimates align stakeholder expectations because the expected reliability of each estimate is calculated and disclosed to project stakeholders. Stochastic estimates support organizational and project risk policies, so project estimates are neither too risky nor too conservative. Additionally, stochastic estimates permit dynamic, right-sized project buffering (rather than just adding 5 or 10 percent to the project timeline or budget), so project schedules and budgets are safeguarded without wasting organizational resources. Finally, stochastic estimation supports better, more informed decision-making by organizational leaders.

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The Enterprise Program Management Office: Another Best Practice at the National Nuclear Security Administration

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ABSTRACT

The project management office (PMO) and in recent years the program management office (PgMO) are recognized best practices in organizations around the world. An Enterprise PMO (EPMO) extends the functions and benefits of a PMO to multiple projects within an organization. An Enterprise PgMO (EPgMO) extends the functions and benefits of a PgMO across multiple programs, portfolios and projects within an organization in the same manner that an EPMO does, but often with a broader scope.

The National Nuclear Security Administration (NNSA) within the U.S. Department of Energy maintains and enhances the safety, security, reliability and performance of the U.S. nuclear weapons stockpile without nuclear explosive testing; works to reduce global danger from weapons of mass destruction; provides the U.S. Navy with safe and effective nuclear propulsion; and responds to nuclear and radiological emergencies in the U.S. and abroad. NNSA's Office of Safety, Infrastructure and Operations (NA-50) is responsible for enabling safe operations, ensuring effective infrastructure and providing enterprise services to NNSA programs and national laboratories, plants and sites around the United States.

NA-50 has established an enterprise-level program management office (EPgMO), one of the first in the US government. A relatively new approach in the program/project management field, the NA-50 EPgMO at NNSA is one of the first of its kind in the US government. This paper will describe the purpose, functions and value of an EPgMO and the related experience to date within NA-50 at NNSA.

INTRODUCTION

The terms project and project management have been in use for many years and are widely understood worldwide. For purposes of this short paper, we assume that readers are familiar with these concepts and terms. The PMO itself is a relatively new concept, but has grown in acceptance and popularity around the world in the last 25 years. It is now widely known and used in many organizations and industries, including government agencies at all levels.

Program Management concepts and terminology have also been used for many years in some industries, especially those associated with government funding such as aerospace, defense, energy, environmental remediation, nuclear research and security, space (NASA) and many public services. The PgMO is less widely used but is growing in acceptance, partially due to its inclusion in *The Standard for Program Management* first published by the Project Management Institute (PMI®) in 2006.

One of the problems associated with both PMO and PgMO is the proliferation of acronyms that are used by various authors, consultants and organizations. For the sake of this paper, we will stick with PMO, EPMO, PgMO and EPgMO. Another confusing issue has become the relationship of projects and programs to portfolio management, which is somewhat beyond the scope of this paper. In our experience, however, portfolios can consist of both projects and programs, while programs can also consist of portfolios of projects. This latter is the case for NA-50 at NNSA.

THE PROJECT MANAGEMENT OFFICE

PMO Defined

PMI's PMBOK Guide defines PMO as an organizational body or entity assigned various responsibilities related to the centralized and coordinated management of those projects under its domain. The responsibilities can range from providing project management support functions to actually being responsible for the direct management of a project. The primary function of a PMO is to support project managers in a variety of ways which may include, but are not limited to:

- Managing shared resources across all projects administered by the PMO;
- Identifying and developing project management methodologies, best practices and standards;
- Coaching, mentoring, training and oversight;
- Monitoring compliance with project management standards, policies, procedures and templates via project audits;
- Developing and managing project policies, procedures, templates and other shared documentation (organizational process assets); and
- Coordinating communication across projects. (PMI 2008)

According to Professor Peter Morris, a globally-respected researcher, author and authority on project management in the UK, functions of a PMO can be to:

- Define the enterprise project management standards, including methodologies, guidelines, etc.;
- Define the required project management competencies;
- Assess staff competencies and organizational capability gaps (maturity);

- Specify and hold central knowledge on program/project management tools and techniques, especially the enterprise PM information system (PMIS);
- Assess enterprise long term resource needs related to project management;
- Gather lessons learned in the context of knowledge management and organizational learning;
- Arrange periodic project/program reviews; and
- Own the PM training, learning and staff development. (Morris 2013)

According to Monique Aubry and Brian Hobbs, respected project management researchers at the University of Montreal, some roles or functions of a PMO include:

- To monitor project performance (reporting, PMIS, scorecard, etc.);
- To develop and implement standards (methodology, tools, etc.);
- To develop PM competencies (training, mentoring, support of staff);
- To implement strategic management (portfolios, planning, advising senior mgmt.);
- To ensure organizational learning (archives, reviews, audits, risk management, lessons learned, knowledge database, sharing, etc.)
- To help managing customer (stakeholder) interfaces (committees, communications, etc.); and
- To support projects and project managers in various ways. (Aubry 2014)

These are representative discussions of the common activities, functions and responsibilities of a PMO. They generally reflect common practice in many organizations.

PMO as Best Practice

Harold Kerzner, one of the world's leading authors of project management textbooks, devotes chapter 12 to the PMO in his 2014 book *Project Management Best Practices: Achieving Global Excellence*, where he also describes PMOs in a number of large successful corporations. According to Kerzner, "the concept of a project office (PO) or PMO could very well be the most important project management activity in this decade. With this recognition of importance comes strategic planning for both project management and the PO/PMO. Maturity and excellence in project management do not occur simply by using project management over a prolonged period of time. Rather, it comes through strategic planning for both project management and the PO/PMO." He goes on to list 24 typical activities for a PMO, including standardization of estimating, planning, scheduling, control and reporting; clarification of PM roles and responsibilities, and many others. (Kerzner 2014)

Rise of the Enterprise PMO

From the beginning, it was generally understood that a PMO oversees and/or supports multiple projects. Those project could cover part or all of a business unit, division or entire organization. The rise of the enterprise PMO (EPMO) can be attributed to the promotion of enterprise project management (EPM) in the nineties, culminating in the landmark book by Paul Dinsmore, *Winning in Business with Enterprise Project Management* (Dinsmore 1999). Dinsmore's book normalized the use of the word "enterprise" for PMO's, which in turn directly supported the development of project portfolio management as an enterprise solution for advancing EPM itself.

The rise of project governance quickly followed. "The corporate project management office … acts as a link between executive vision and the project-related work of the organization. Its functions include overseeing strategic items such as project management maturity, project culture, enterprise-wide systems integration, managing quality and resources across projects and portfolios, and project portfolio management." (Dinsmore, Rocha 2012)

PROGRAM MANAGEMENT OFFICES

PgMO Defined

PMI defines a program as a group of projects managed in a coordinated way to obtain benefits and control not available from managing them individually. Programs may include elements of work outside the scope of discrete projects (PMI 2008). The DOE defines a program as an organized set of activities directed toward a common purpose or goal undertaken or proposed in support of an assigned mission area. Programs are made up of technology-based activities, projects and supporting operations (USDOE 2014). Program management is centralized coordinated management of a program to achieve the program's strategic objectives and benefits (PMI 2008).

According to PMI, the PgMO provides support to the program manager by:

- Defining the program management processes that will be followed;
- Managing schedule and budget at the program level;
- Defining quality standards for the program and the program's components;
- Providing document configuration management; and
- Providing centralized support for managing change, and tracking risks and issues. (PMI 2008)

The scope of activities and responsibilities for a PgMO can mirror those of a PMO but serve the broader needs of a program, program manager, team, and organization.

The Enterprise PgMO

Summarizing the range of possible responsibilities mentioned above, an EPgMO will generally need to address the following subjects and activities:

- ➢ Strategic alignment – support the alignment of programs, portfolios, projects, operations and other change-related activities with enterprise strategic goals and initiatives, and track benefits and results;
- ➢ Standards and tools – identify and support the use of appropriate program and project management standards, tools, processes and procedures;

- Planning – coordinate and summarize plans, budgets and resource needs;
- Communication – support enterprise monitoring, reporting and communications, both internally and externally with various stakeholders;
- Risks – coordinate and support enterprise-wide risk management;
- Personnel – provide and support program/project management-related training, mentoring and development to program staff and teams
- Knowledge – establish and maintain project/PM knowledge repositories, databases, histories, lessons learned, organizational learning, tools and systems-related documentation and information; conduct audits and reviews;
- Governance – support appropriate program/project governance policies, processes and activities, including reviews and oversight; and
- Support – provide actual program/project management support to program and project managers, teams, contractors and others as needed.

THE NA-50 ENTERPRISE PROGRAM MANAGEMENT OFFICE

NA-50 Programs and Projects

NA-50 plans, directs and oversees the maintenance, operation and modernization of NNSA infrastructure and facilities at eight sites around the United States, NNSA is comprised of a vast and complex enterprise of 39,000 employees, 36 million square feet of active facility space,400 nuclear and hazardous facilities, 2,000 miles of roads, on 2,100 square miles of land. With an annual budget of over $1.5 billion, NA-50 manages multiple programs and projects ranging in size and complexity each year.

This enormous effort requires the planning and execution of hundreds of projects within a smaller number of programs, all managed within portfolios of facilities and contracts. The facilities include production, fabrication, testing, and secure transportation and storage of nuclear/radioactive materials and equipment, plus very advanced laboratory, computing and communications facilities.

NA-50 has the complex challenge of safely operating and modernizing the NNSA enterprise, a challenge made more difficult as more than half of NNSA's facilities are over 40 years old, nearly 30 percent date to the Manhattan Project era of 70 years ago, and 12 percent are excess to current needs. NNSA's capability to achieve programmatic goals obviously depends upon safe and reliable infrastructure. Maintaining and upgrading these older facilities is both enormously important and extremely challenging.

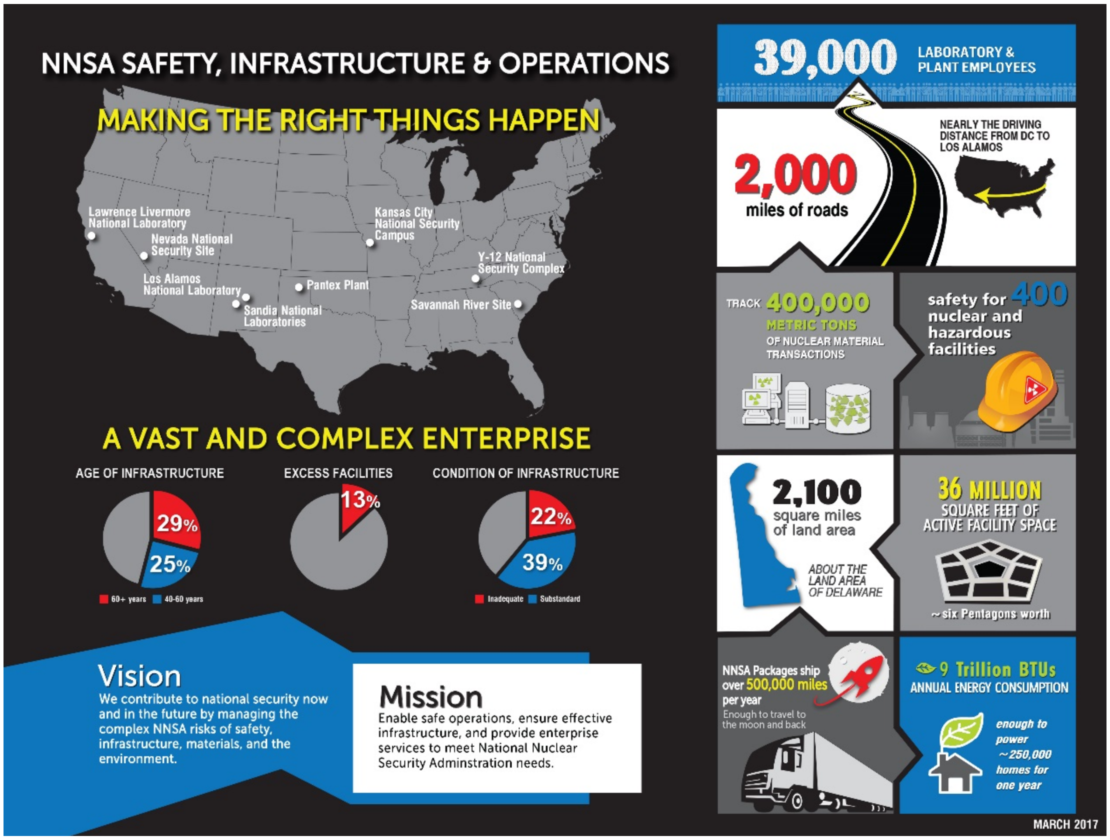

Figure 1. NNSA Infrastructure Snapshot

NNSA's sites are managed by experienced private contractor companies, in some cases in partnership with major universities, under the direction of Federal Government personnel in NNSA's Headquarters and Field Offices. In 2014 NA-50 implemented a new enterprise program management approach that included long range, enterprise-wide planning and the use of innovative management tools to facilitate data-driven, risk-informed investment decisions at the enterprise level. These efforts included deploying, for the first time, an NNSA infrastructure Enterprise Risk Management (ERM) methodology and NNSA’s G2 Program Management Information System. The NA-50 EPgMO was established to support these enterprise program management processes and tools.

NA-50 Enterprise PgMO Structure and Vision

The NA-50 EPgMO provides a focal point for program management improvements and implementation support across multiple programs and projects within NA-50. The long term vision for the NA-50 EPgMO is to provide best-in-government program management services to enable NNSA’s multiple, vital national security missions now and in the future.

NA-50 EPgMO Roadmap

Inspired by NA-50's program management improvement team (Abba 2016), the following functions provide the direction currently planned for the NA-50 EPgMO:

- **Standards and Processes**: maintain program management plan; define and continuously improve program management standards and processes; develop and provide program manager training; and facilitate best practice sharing

- **Programming/budgeting**: develop and continually enhance programming guidance; identify tradeoffs and advise senior leaders on strategy; lead budget formulation, and deliver OMB and Congressional briefings

- **Execution and Evaluation**: provide centralized support to program managers, including project controls, risk management, analytics, procurement, communications, performance evaluation, process improvements knowledge management, and business analysis

Implementation to Date

The NA-50 EPgMO was established in 2015, with a director appointed and staff assigned. Functions implemented to date include the following:

- Develop, maintain, and continuously improve NA-50 program management processes, definitions, and work breakdown structure (WBS), as described in the Program Management Plan (PMP).
- Provide and oversee project control and budget specialists to assist NA-50 program managers to track, monitor, and report on program, financial, schedule and contract data.
- Oversee program management training and program management career development programs for NA-50.
- Lead the NA-50 annual budget formulation process.
- Manage NA-50 budget execution activities, by facilitating the financial plan change request and cost reporting processes in support of the NA-50 Program Managers.
- Manage the change request process by facilitating all work scope and/or schedule changes.
- Provide contract management support to NA-50 program managers.

Long Term Vision

As NA-50 matures along the program management continuum, additional functions and activities will be added to the EPgMO. Currently planned long term functions for the NA-50 EPgMO include the following:

- Provide enterprise risk management and strategic planning support to NA-50.
- Support the continuing development of the NA-50 Program Management Information System (PMIS), G2, aligning with NA-50 Program Management standards and processes.

- Provide operations and business analysis to enable continued process improvements and enhanced quality management.
- Provide data analysis expertise to analyze program data to identify trends, opportunities, and risks.

RESULTS TO DATE

NA-50 has seen results since the establishment of its EPgMO in 2015. For example, the NA-50 EPgMO led the effort to develop NA-50's work breakdown structure (WBS), which was implemented in 2015 and further updated in 2016 to increase transparency to Program Managers and stakeholders. Similarly, the NA-50 EPgMO has refined and facilitated NA-50's cost and schedule performance reporting requirements, allowing Program Managers and senior leaders to make decisions using up-to-date program execution information to enhance program performance. Most significantly, the NA-50 EPgMO has enabled NNSA to gain credibility with congressional stakeholders who have rescinded reporting requirements and provided NA-50 with enhanced budget flexibilities through a new budget structure. These flexibilities have allowed NA-50 to rapidly respond to emerging infrastructure issues, thereby reducing impacts to programmatic work.

CONCLUSION

The PMO is a globally-recognized best practice for organizations with a lot of project-based work. The PgMO applies the same principles to programs, and especially for mission and program-oriented government organizations. EPgMOs extend the purpose, activities and benefits of a PgMO across an entire enterprise, whether a business unit, division or an entire organization. NA-50 at the NNSA is adapting the EPgMO concept for oversight and management of a massive portfolio of programs and projects related to the nation's nuclear facilities, infrastructure and operations. This paper has briefly described NA-50's EPgMO, actions to date and plans for the future.

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UNCERTAINTY CHARACTERIZATION IN QUANTITATIVE MODELS

Adiel N-A. Komey[1] Gregory B. Baecher[2] and Robert C. Patev[3]

ABSTRACT

The treatment of uncertainty quantification has evolved over the years. One of the main drivers of this sweeping paradigm shift has been the advances in computing power. Today, with the exponential advances in computing power relative to the past, we can collect an unprecedented amount of data over an almost unlimited period of time. Big Data, as folks in the statistical analytics field like to call it, has expanded past the barriers of previous limitations of data analytics. But there's a problem; our over-reliance on computer analytics and our insatiable appetite to 'play with the numbers' means more often than not, we cannot spot mistakes within our computer models and blindly follow what the numbers say. As powerful as computers are, and as advanced as analytics platforms have become, quantitative models perform optimally when guided by expert intuition. These computer based models grapple not only with physical variabilities in the real system they emulate, but also with potential deficiencies within the model itself due to a lack of knowledge about the system being modeled or its surrounding environment. Today, every industry seeking a competitive edge is using data to shape its decision making under uncertainty in one way or the other. This paper, following recent advances in uncertainty quantification in the leading domains of engineering, statistics and climate change, presents the current state of the practice within these domains. The paper also presents a synthesis of recent research.

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1. BACKGROUND

Model uncertainties reflect the inability of a model or design technique to represent a system's true physical behavior precisely, or the analyst's inability to identify the best model, or a model that may be changing in time in poorly known ways (e.g., a flood-frequency curve changing because of changing watershed conditions). The models used to approximate naturally varying phenomena need to be fit to natural processes by observing how those processes work, by measuring important features, and by statistically estimating parameters of the models within the broad state of knowledge that we have about the processes. In the modeling literature this is sometimes referred to as *uncertainty quantification*.

2. NATURE OF UNCERTAINTY

The character and importance of uncertainty in dam safety risk analysis drives how risk assessments are used in practice. The current interpretation of uncertainty is that, in addition to the aleatory risk which arise from presumed uncertainty in the world, it comprises the epistemic aspects of irresolution in a model or forecast, specifically model and parameter uncertainty (Figure 1). This is true in part but it is not all there is to uncertainty in risk analysis. The physics of hazards and of failure may be poorly understood, which goes beyond uncertainty in its conventional sense. All of these facets are part of the uncertainty in risk analysis with which we must deal. From a practical view, one might distinguish three types of uncertainty in risk analyses: variation in nature (aleatory uncertainty), knowledge limitations (epistemic uncertainty), and unknowns (deep uncertainty).

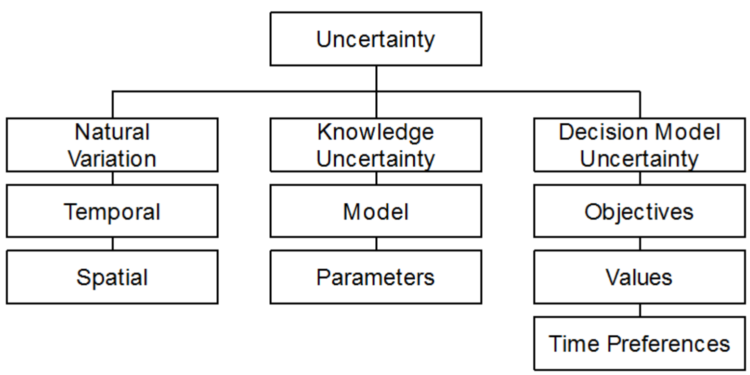

Figure 1. Sources of uncertainty (Baecher and Christian, 2000).

2.1. Aleatory uncertainty: Variation in nature

Since antiquity, people have thought of nature and the vagaries of life as uncertain. The world itself is driven by fortune and luck. In modern practice, we treat rainfall, earthquakes, hurricanes, and many other natural hazards as innately random. Their randomness is part of the natural world, irrespective of people and what people know. Were there no people, these natural processes would still go on, and the frequencies with which they occur would be unchanged. The hydrology literature has traditionally adopted this point of view. These uncertainties are said to be *aleatory* meaning innately random. In some fields, such as climate change modeling, they are referred to as *ontological* uncertainties.

Aleatory uncertainties are most often natural frequencies in time or space. They are predictable up to a probabilistic description, and their uncertainty can never be reduced below their naturally occurring frequencies, irrespective of how much we may know about them or how many data we may observe.

In applying probability measures to such uncertainties, the meaning of term *probability* is usually taken to be the frequency of occurrence in a long or infinite series of similar trials. In this sense, probability is interpreted for operational matters to be a property of the system (*i.e.,* a property of nature) independent of anyone's knowledge of it or evidence for it. We may or may not know what the value of this probability is, but the probability in question is a property for us to learn. It is innate; there is a "true" value of this probability. Two observers, given the same evidence, and enough of it, should eventually converge to the same numerical value.

2.2. Epistemic uncertainty: Limitations in knowledge

Sometime in the 1970's it became increasingly obvious that not only were aleatory uncertainties important, but parameter and model uncertainty were, too. These latter uncertainties had nothing to do with natural variations in time and space, but with information: how complete were the data upon which the model characterizations were based. These were not uncertainties in the world but uncertainties in the mind. They had to do with how much one knew, and they could be reduced essentially to zero by collecting ever greater numbers of data.

The recognition of parameter and model uncertainty as distinct from randomness is important in modern risk analysis. To simplify the task of risk assessment, one makes assumptions about how to grapple with uncertainties. By far the most important of these assumptions is separating uncertainty between aleatory and epistemic, between natural variations over space and time and lack of knowledge in the mind of the analyst or in the broader informed technical community (Table 1).

Table 1. Alternate terms describing the dual meaning of uncertainty*.*

ALEATORY UNCERTAINTY	EPISTEMIC UNCERTAINTY	CITATION
Natural variability	Knowledge uncertainty	(NRC, 2000)
Random or stochastic variation	Functional uncertainty	(Stedinger et al., 1996)
Objective uncertainty	Subjective uncertainty	(Maidment, 1993)
External uncertainty	Internal uncertainty	(Maidment, 1993)
Statistical probability	Inductive probability	(Carnap, 1936)
Chance [Fr]	*Probabilité* [Fr]	Poisson, Cournot (Hacking, 1975)

The distinction between these two types of uncertainty can have profound impact on risk, and on the meaning that one ascribed to risk. Yet, the questions raised by this fundamental distinction are by no means simple to answer. Most uncertainties are a mixture of things, so how does one practically differentiate natural variation from limited knowledge? Since the two types of uncertainty reflect conceptually different things, how does one quantify each? If probability theory is used as a measure of uncertainty, are different types of probability needed for different types of uncertainties? Can and should the two types of uncertainty be combined? If they can and should be combined, how does one do so? These issues are not limited to the analysis of dam safety and flood damage; they are just as important to seismic hazard, structural reliability, wind threat, and other risks of concern to the built environment.

2.3. Sources of uncertainty

Uncertainty enters risk analysis models in many ways (Figure 2). Hazards of various types, such as flood loading, seismic ground shaking, SCADA malfunctions, or human error serve as input to the model. These are combined and processed by the model, and consequences are predicted as output. The model itself and a characterization of the hazards also require a variety of parameters. These reflect natural and other conditions, and calibrate the model to reality.

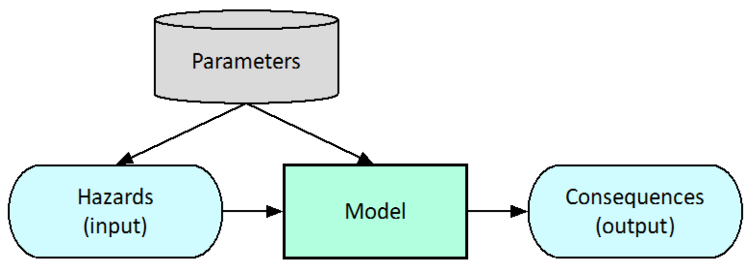

Figure 2. Predictive risk model schematic

Parameter uncertainty. The parameter values which serve as input both to the hazard characterization and to the risk model are usually not known precisely. There may be statistical error in estimating these values from historical data, or there may be experimental error in measuring these values in the laboratory or *in situ*. These are sometimes called, Type A evaluations of uncertainties. Knowledge about the parameter values may also come from engineering judgment or other information concerning the quantity. These are sometimes called, Type B evaluations of uncertainties.

Parameter uncertainties result from an inability to assess exactly the parametric values from test or calibration data due to limited numbers of observations and the statistical imprecision attendant thereto. These include data uncertainties deriving from (i) measurement errors, (ii) inconsistency of data, (iii) data handling and transcription errors, and (iv) poor representativeness of sampling schemes due to time and space limitations.

Structural or model uncertainty. The calculation will model itself and the mathematical equations by which it is expressed may themselves be inadequate or simplifications. Models are almost always approximations of reality based on assumptions which are made for expedience or for calculational convenience. There may also be latent variables in a model which are either ignored or possibly unknown. Thus, discrepancies are always expected between the model and true physics.

Algorithmic or numerical uncertainty. Algorithmic uncertainty arises from numerical errors or numerical approximations made in implementing the model in computer code. Most engineering models in dam safety are too complicated to solve exactly. For example, finite element (*i.e.,* numerical) models may be used to calculate stress or seepage patterns, or event trees may be used to propagate uncertainties through stages of a failure. Linearization, truncation, interpolation, and other approximations maybe introduced to make these calculations more efficient. This results in some level of error.

Initial and boundary condition uncertainty. The initial and boundary conditions of a model need to be specified before calculations can be made. Since many of the models in dam safety are differential, initial conditions state the value of a function or process at some time, usually *t=0.* Similarly, boundary conditions state the value of a function or process at some location or boundary to the calculation.

3. UNCERTAINTY PROPOGATION

There are two categories of problems in uncertainty quantification: the *forward* propagation of uncertainty (where the sources of uncertainty are propagated through the model to predict overall uncertainty in the output), and *inverse* assessment where the model parameters are calibrated against know output. This section considers forward propagation.

The general methodology in predictive modeling is to estimate a function that best characterizes the parameters being modeled. More generally, suppose we observe a quantitative response Y and P different predictors, a relationship between Y and p is assumed, then the general mathematical representation of this relationship is of the form

$$Y = f(X) + \varepsilon \quad (1)$$

Here f is some fixed but unknown function of *X1, . . . , Xp*, and *ε* is a random error term, which is independent of X and has mean zero. This general expression f, models the information provided by the predictors (input) variables about Y (Output variables).

This is the fundamental basis of predictive modeling with the function f representing the predictor model that allows us to understand which components of X are important in explaining Y. There are several predictive modeling techniques of varying complexities of the function f. Introducing more complexity(flexibility) into the function f, may or may not lead to an improved model but certainly reduces the interpretability of the model.

Typically, we have to estimate the form of the function f in order to be able to make predictions and inferences. For predictions, Figure 1 shows the schematic of generating the response estimates Y given the predictor variables X. In this setting, the function fo (model) can be treated as a black box since the mathematical form of the function is of little concern to us provided it's generating accurate predictions. The accuracy of the prediction for the response Y is dependent on two error quantities; the irreducible and reducible error. As expected, the function fo will not be a perfect estimate for f and will introduce some error (reducible error). Statistical learning is therefore concerned with improving this reducible error in order to improve the accuracy of our model predictions.

The reducible error by definition is an epistemic uncertainty which can be improved through fine tuning our modeling methodology. However, the irreducible error here is an aleatory uncertainty since the irreducible error is characterized by unmeasurable variation. For instance, let's consider a model estimate fo with predictor sets of X; which then yields Yo=fo(X). Assuming fo and Y to be fixed, we can deduce the mathematical form for the errors in our predictions.

$$E\left(Y-\hat{Y}\right)^2 = E[f(X)+\varepsilon - f_o(X)]^2 \\ = [f(X)-f_o(X)]^2 + Var(\varepsilon) \tag{2}$$

Where $E\left(Y-\hat{Y}\right)^2$ represents the average, or expected value, of the squared difference between the predicted and actual value of Y, and $Var(\varepsilon)$ represents the variance associated with the error term *ε*. $[f(X)-f_o(X)]^2$ is the reducible error resulting from the discrepancy between the model outputs and the true responses of the system.

The irreducible error will always restrain the accuracy of statistical predictions since it's almost always unknown in practice (James et al., 2013). Much of statistical learning is therefore concerned with finding the balance in complexity and accuracy when estimating f. There are different methods of predicting the output Y from our model fo with a variety of predictive modeling methods adopted throughout the systems model formulation and construction. Broadly speaking, these methods can be classified into two main approaches; parametric methods and non-parametric methods.

The parametric methods make an assumption about the functional form/shape of the function f. For example in a linear regression analysis the relationship between the predictor X and the response Y is assumed to be linear; thus f is linear. This greatly simplifies the analysis. Linear regression is very useful in lots of applications but has its limitations as things in the real world don't always follow a linear pattern and in such scenarios a simple linear regression function will increase the reducible error and not lead to accurate predictions. The general form of the response function of a simple linear regression is,

$$Y \approx \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_p X_p \tag{3}$$

The linear assumption here means that the task of estimating the function f boils down to estimating the set of parameters (β_0,β_1,β_2... β_p). The higher the flexibility of the parametric model, the more parameters we need to account for in our model. Linear models are the most basic form of parametric modeling. The data are normally governed by some parametric probability distribution. This means that the data can be interpreted by one or other mathematical formula representing a specific statistical probability distribution that belongs to a family of distributions differing from one another only in the values of their parameters.

Such a family of distributions may be grouped accordingly:

- Beta distribution
- Binomial distribution
- Lognormal distribution
- Exponential (Poisson) distribution

- Weibull distribution.

Estimation techniques for determining the level of confidence related to an assessment of reliability based on these probability distributions are the methods of maximum likelihood, and Bayesian estimation (Stapelberg, 2009). A couple pf these distributions are adopted throughout the modeling process.

3.1. Non Parametric Methods

Non parametric methods, unlike parametric methods make no assumptions about the shape/functional form of f. Instead the approach is to estimate f that gets us as close to the data points as possible without capturing too much of the noise in the system (James et al., 2013). With parametric methods, it is possible that the functional form used to estimate the underlying function f (i.e f_o) is substantially different from the true underlying f; leading to a model which does not accurately fit the data. In contrast, non-parametric do not suffer from this issue since they essentially make no assumption about the underlying function f. However, non-parametric methods do suffer from high variance since it does not curtail the number of parameters used to make the fit.

Parametric time series analysis-when the underlying models are correctly specified-can provide a powerful array of tools for data analytics (Fan and Yao, 2008). Notwithstanding, any parametric models are at best only an approximation to the true stochastic dynamics that generates a given data set. Meaning, parametric methods are plagued with the issues of models biases. According to Fan et al. (2003), "Many data in applications exhibit nonlinear features such as nonnormality, asymmetric cycles, bimodality, nonlinearity between lagged variables, and heteroscedasticity." They require nonlinear models to describe the law that generates the data. However, beyond the linear time series models, there are infinitely many nonlinear forms that can be explored. This would be an undue task for any time series analysts to try one model after another. A natural alternative is to use nonparametric methods. Non-parametric methods are better at reducing the possible modeling biases that plague their parametric counterparts.

3.2. Wolf Creek Turbines Example

This example shows how parametric methods are used within the systems model to characterize the availability of the turbines at Wolf Creek GS. The reliable performance of generating unit depends on its availability on demand. Grid demands on the dam facility as a whole determines what capacity the combined turbines must be operating at. The Wolf Creek dam generates power using 6 Francis type turbines. If the demand on the system require all units to be working at full capacity, then all 6 turbines will have to be available on demand.

Availability in reliability terms, has to do with two separate events—failure and repair. Therefore, assigning confidence levels to values of availability cannot be done parametrically, and a technique such as Monte Carlo simulation is employed, based upon the estimated values of the parameters of time-to-failure and time-to-repair distributions. Passing the flow through the turbines of a hydroelectric generating station requires that the generating equipment is available and that the generated power can be accepted by the grid. If the grid is unavailable then turbines can still be operated with a significantly reduced discharge capacity under commonly called “spill-no load condition”. Modeling of the availability of turbines to pass the flow can be modeled as a homogeneous or non-homogeneous Poisson Process. Homogeneous approach was applied to estimate the generating equipment unavailability. Extensive data was available for all generating stations in the Wolf Creek Dam System.

Analysis results for the Wolf Creek GS are provided below. Wolf Creek GS has six generating units with the following characteristics.

Unit numbers	Speed-no load discharge (m^3/s)	Discharge per unit m^3/s
		Max
1,2,3,4,5,6	25	142

When a unit is unavailable, the total discharge capacity through that turbine is only 25.0 m^3/s. At full capacity, the discharge capacity through turbines equals 142 m^3/s each. Occurrence of failures follows a homogeneous Poisson process with mean time between failures (MTBF) having the exponential distribution with the parameter $\lambda = 24.18$ days. These parameters were determined by fitting parametric distributions to the failure data with the best performing (fitting) distribution chosen to characterize the failure of the turbine units. The duration of the failures; which is a sum of the time to repair and the actual repair duration, is characterized by a lognormal distribution as shown below.

Duration of failures follows the lognormal distribution with the following parameters:

Mean: μ=27.72 hours
Standard deviation: σ=189.4
Location parameter: γ=0.1435

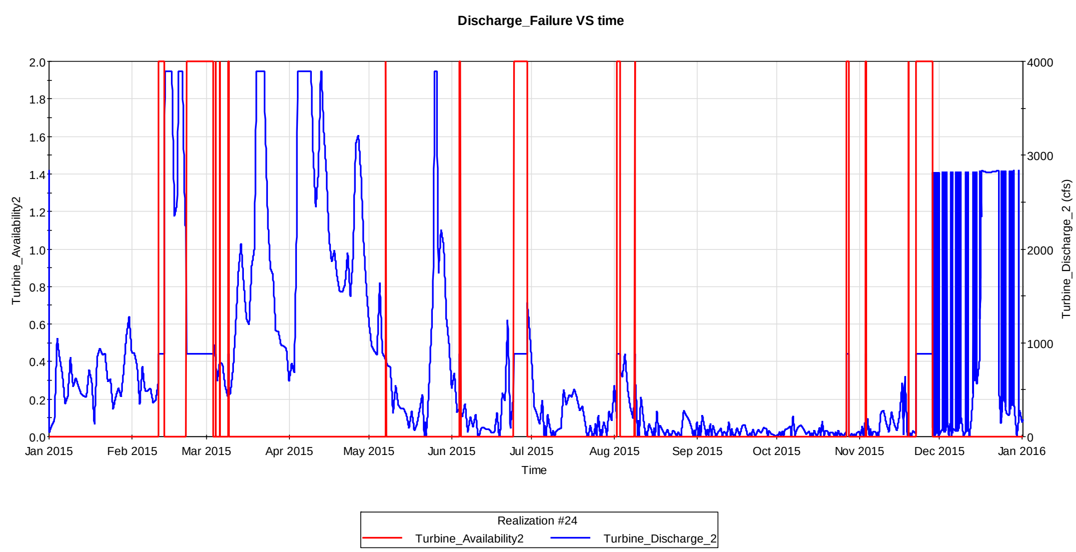

Figure 3: plot of Discharge and Availability as a function of time

Figure 2 is a plot from the preliminary model test run and shows the availability of the turbine and discharge through the turbine as a function of time. The rate of occurrence of the turbine failures are independent and identically distributed in time and thus a homogeneous Poisson process. The failure durations however, are characterized by a lognormal. It can be observed from the plot-especially the failures in the months of march, June and December-that the Unit 2 turbine has a constant rate discharge of 25 cubic meters. The rest of the time when the Turbine is available, the amount of discharge through the turbine are dictated by the SEPA curve in combination with the upstream daily flow. If Head elevation exceeds the SEPA prescribed maximum, then the turbines will be operated at capacity. On the other hand if the Head water elevation is below the prescribed Minimum SEPA level, then the turbines will be shut to conserve head.

4. MODEL (STRUCTURAL) UNCERTAINTY

Models/Simulators do not perfectly characterize a system, thus no matter how well a model is constructed, there will always be some discrepancy between the system and the simulator. Inescapably, there will be simplifications in the physics, based on features that are too complicated to be included in the model, features omitted due to lack of knowledge, disparities between the scales on which the model and the system operate, and simplifications and approximations in solving the mathematical equations underlying the system (Vernon et al., 2010). Thus, understanding structural uncertainty is one of the most challenging aspects of the uncertainty analysis.

Another challenging aspect of structural uncertainty is quantifying the uncertainty that arises due to the parametrization of only the salient aspects of the system; thus, resulting in unmodelled physical processes. In model development, certain physical processes will inevitably be neglected if there's a belief that these processes have little to no effect on the models accuracy yet adds complexity to the mathematical description. Moreover, during model development, there may be a failure to include certain physical processes due to lack of knowledge about those processes.

4.1. Input Parameter Uncertainty

Models of natural systems are made up of parameters that quantify physical processes and properties. These parameters must accurately characterize how the system properties affect system behavior. Our knowledge of the suitable values of these input parameters is often incomplete or based on limited experimental investigations (Woodhouse et al., 2015). If the underlying physics of a system is misrepresented, then the meaning of the model and the interpretation of the parameters will be called into question (Vernon et al., 2010).

This example is taken from another similar project-Mattagami Basin-Hydroelectric complex. The example here demonstrates how the input uncertainty in daily temperature is modeled using historical monthly mean (normal), warmest and coldest temperature data. A plot of the historical data can be seen in figure 3. The warmest and coldest temperatures for the day were taken to be two standard deviations from the mean of a normal distribution. Thus a truncated normal distribution was fit to the historical data to account for the uncertainty in the daily temperature. Figure 4 shows a monte-carlo simulation output plot for a 12 month period. From the plot, the variation in the daily inputs demonstrates that the normal distribution is being sampled on a daily basis to calculate the daily temperature based on the parameters of the normal distribution for that month. Of course, this is a simple approximation to capture the daily fluctuations in temperature. This model-although simple-does a good job at capturing the uncertainty in the input parameter (average monthly temperature) for calculating the average daily temperature.

4.2. Accounting for Input parameter Uncertainty: Mattagami Basin Example

This example is taken from another similar project-Mattagami Basin-Hydroelectric complex. The example here demonstrates how the input uncertainty in daily temperature is modeled using historical monthly mean (normal), warmest and coldest temperature data. A plot of the historical data can be seen in figure 3. The warmest and coldest temperatures for the day were taken to be two standard deviations from the mean of a normal distribution. Thus a truncated normal distribution was fit to the historical data to account for the uncertainty in the daily temperature. Figure 4 shows a monte-carlo simulation output plot for a 12 month period. From the plot, the variation in the daily inputs demonstrates that the normal distribution is being sampled on a daily basis to calculate the daily temperature based on the parameters of the normal distribution for that month. Of course, this is a simple approximation to capture the daily fluctuations in temperature. This model-although simple-does a good job at capturing the uncertainty in the input parameter (average monthly temperature) for calculating the average daily temperature.

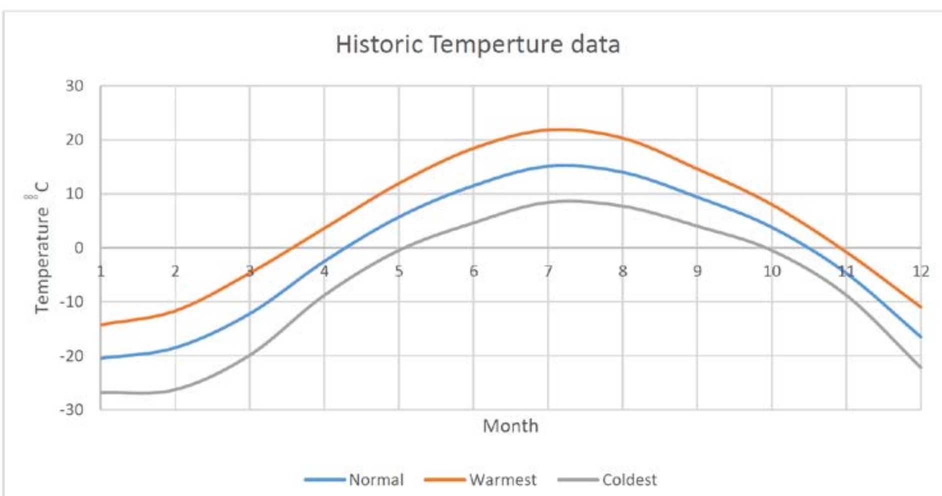

Figure 4: Plot Historical Temperature data for Mattagami Basin

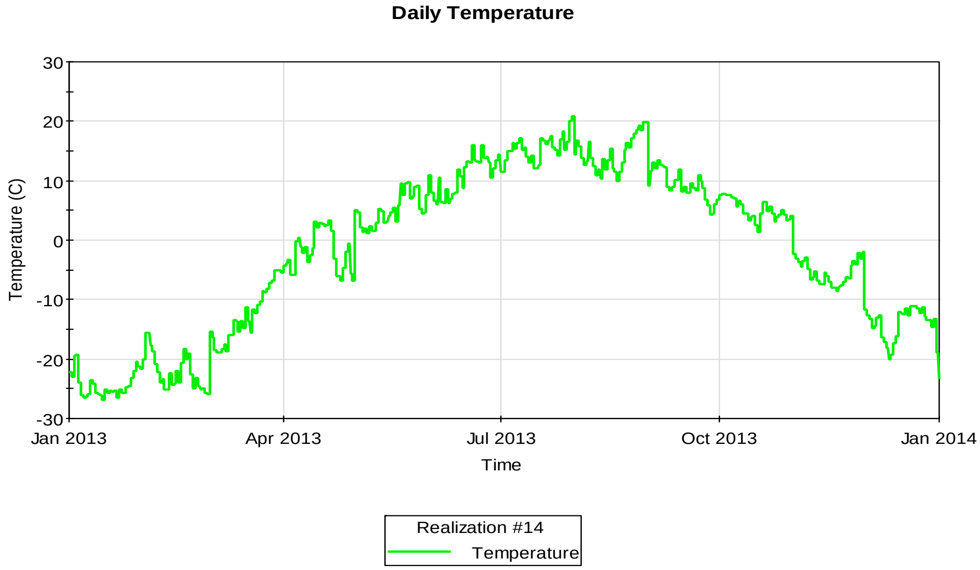

Figure 5: Plot of Simulated daily temperature values for a year

5. OBSERVATIONAL ERROR

Observational uncertainty arises due to errors in the measurement of natural systems, resulting discrepancies between the real system observations and the outputs produced by the simulator. According to Woodhouse et al. (2015), "The aleatory aspect of many natural systems precludes a precise measurement". Lack of measurement precision also adds to observational uncertainty.

For example, let's take hydrological modeling for instance; direct measurements of rainfall runoff with stream gauge sensors will inevitably have errors associated with the accuracy of the sensors. Furthermore, many observations of natural systems are not direct and rely on models to relate a direct measurement to a quantity of interest. Taking turbine discharge measurements in hydropower generation as an example, rating tables are usually used to compute the discharge through the turbines as a function of head water elevation and the opening of the turbine sluices. These indirect observations will additionally propagate errors due to the epistemic uncertainty in the models they adopt. These are similar to structural uncertainty the only difference being that these are data collected by the dam operators and not generated in the model. Thus, we have no control over these observational errors and no arrangements have yet been made to directly account for the effect of these errors. In the end, we expect the sensitivity analysis of the model parameters to account for any uncertainty propagated due to observational errors in the input data used for the modeling.

6. SCENARIO UNCERTAINTY

A scenario is a plausible description of how a system might evolve over time but absent particular probabilities. Scenario uncertainty is akin to sensitivity analysis. The basic concept is that a set of scenarios is identified based on possible combinations of input data. The output of the model for each scenario of inputs is determined and evaluated against the solutions for other scenarios. This provides an insight into the consequences of each scenario.

However, since no probabilities are associated with the respective input, correspondingly there are no probabilities, relative or absolute, for the various scenario outputs. It may not be possible to estimate the probability of one particular outcome and thus scenarios of outcomes are sometimes relied upon. A scenario is a plausible description of how a system might evolve over time but absent particular probabilities. Scenario uncertainty is akin to sensitivity analysis. The basic concept is that a set of scenarios is identified based on possible combinations of input data. The output of the model for each scenario of inputs is determined and evaluated against the solutions for other scenarios. This provides an insight into the consequences of each scenario. However, since no probabilities are associated with the respective input, correspondingly there are no probabilities, relative or absolute, for the various scenario outputs.

The scenario example in this case is taken from the Mattagami project example where there was the need to construct different scenarios of the model with different electrical backup arrangements. Table 1 shows the alternative scenarios for electrical backup arrangements. All the other aspects of the systems model remain unchanged with the only difference in each scenario model being the spillway gates electrical back-up arrangements. The idea here is to run each scenario for a very long period-in this case a 1000 years- and determine which alternative arrangement offers the safest alternative from a dam breach perspective. Of course further sensitivity of each alternative may be performed and the results aggregated over several runs to accurately arrive at the optimal electrical back-up configuration. A similar electrical back-up scenario analysis is one of the objectives of the wolf Creek GS project study.

Alternatives	Electrical Arrangement Description	No. of breaches in 1000 years	Magnitude of largest breach(breach elevation>199.3m)
Alternative A	Power From Grid Only	49	202.57m
Alternative B	2 Large Diesel Generators in parallel	24	200.11m
Alternative C	1 medium Size Diesel Generator per gate	21	200.00m
Alternative D	Grid Supplying Main Power with a Large Size Generator on Standby	21	200.58m
Alternative E	Grid Supplying Main Power with 2 Large Size Generators on Standby	12	200.34m

Table 3.Electrical Configuration Alternatives

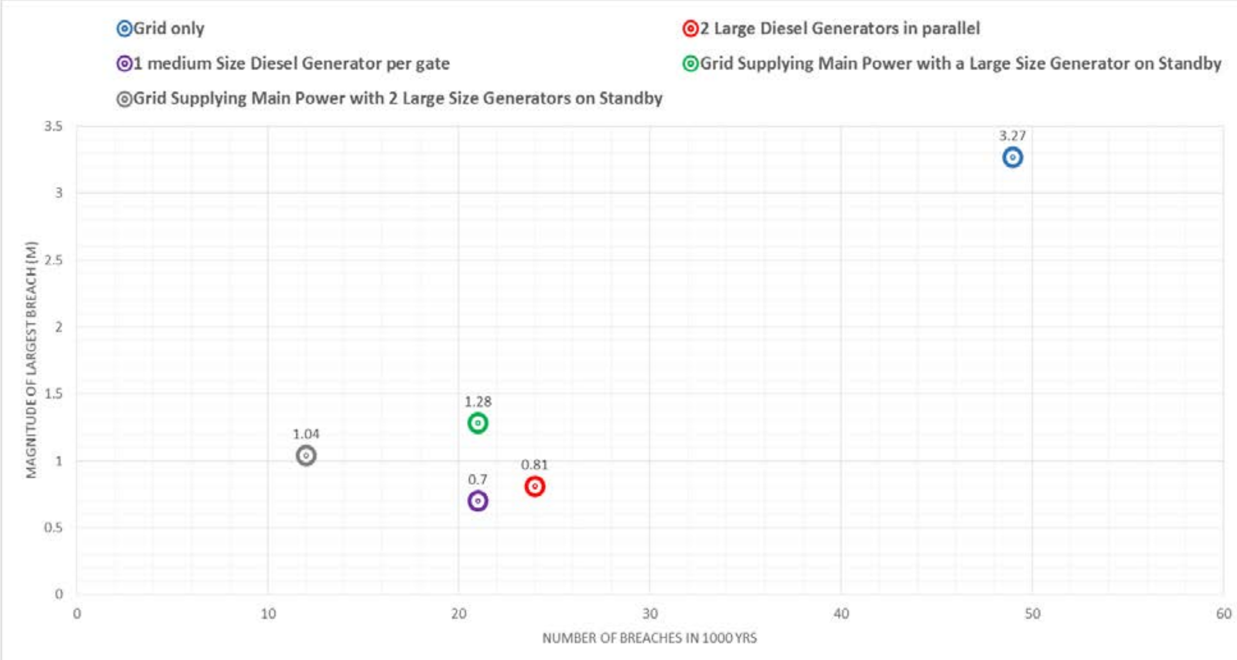

Figure 6: Electrical Configuration Alternatives

7. ACCOUNTING FOR UNCERTAINTY IN FORECASTS OR PREDICTIONS: STAMFORD EXAMPLE

The Stamford Hurricane Protection Barrier levee system model outputs both the range of F-N curves generated during the epistemic loop as well as both the aleatory and epistemic (with percentiles) of the F-N curves(Figure 9). The Logic Tree (model simulator) permits the generation of uncertainty in the simulation parameters itself and to carry them through the calculation of aleatory variability. Practically, that means that after running one simulation and calculating one mean and one set of critical percentiles, another simulation process is run, generating another mean and another set of percentiles (very similar to the first one), and a third, fourth, or nth simulation is run, thus generating a new stochastic layer around the results. The correlations caused by common epistemic uncertainties are automatically carried through the simulations to the final results. The simulator runs thousands of Monte Carlo simulations in order to find the P10, P50 and P90 epistemic percentiles as well as the aleatory curve of the uncertainty in the outputs generated (see figure 8).

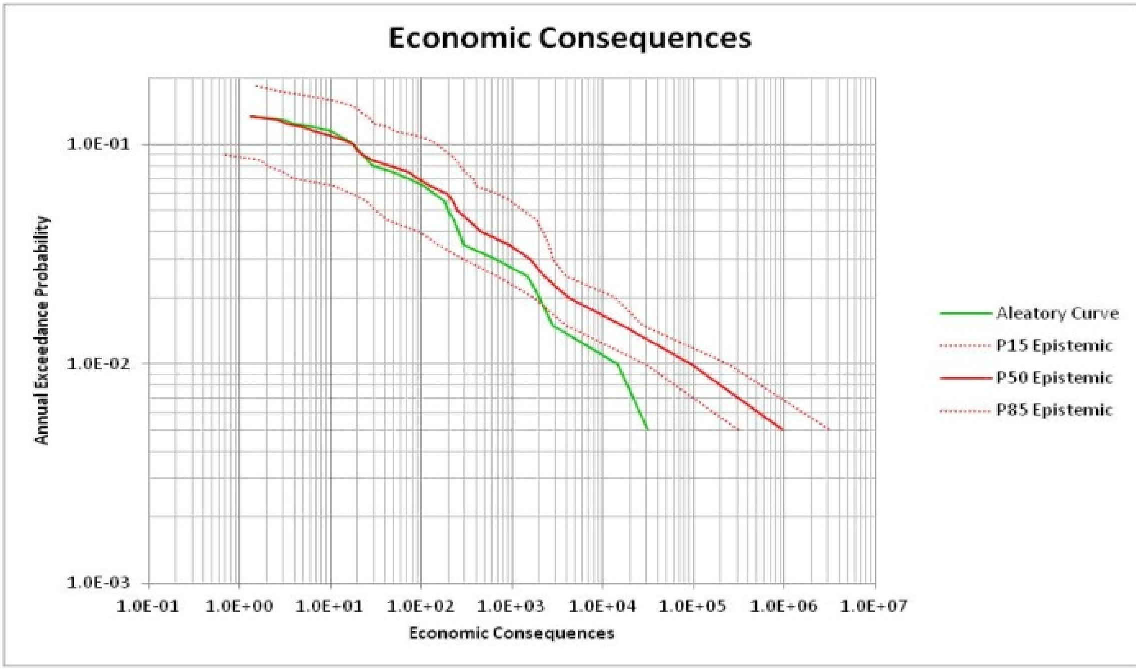

Figure 7. Aleatory and Epistemic Uncertainty Curves for Levee System

8. CONCLUDING REMARKS

The problems arising from the characterization of uncertainty in quantitative models for physical systems are exceedingly common across different domains. This involves a substantial uncertainty quantification task. The first step in finding a solution to this problem is being able to identify the varying forms of aleatory and epistemic uncertainties pertaining to the complex system being modeled. Subsequently, it is imperative to develop a framework within which to characterize the uncertainty about the complex systems. This framework is vital to unifying all of the sources of aleatory and epistemic uncertainties. Within this framework, all of the scientific, technical, computational, statistical and environmental issues can be addressed in principle and then characterized using the appropriate statistical methods. A model validation process is also needed to calibrate the model. Such validation process must provide a more unified approach to analyzing the several aspects of the overall model and the associated discrepancy between the model and the underlying system. This is typically achieved by comparing model evaluations (predictions) with real world system data/observations.

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Understanding and Leading Team Members

By Joseph D. Launi, PMP

Years ago, as a young project manager, I attended a technical conference in Washington, DC, USA. I decided to attend a talk presented by Hall of Fame coach, Joe Gibbs, the former head coach of the Washington Redskins. He began his presentation by stating that professional football, like many professions, was a people-oriented business and how he learned how important it was to properly motivate his players. You would think that with the big money players are making that motivating them would be relatively easy, but he found just the opposite to be true. One year he decided to purchase two, large La-Z-Boy® recliners and placed them right in the middle of the locker room at Redskins Park, located at the time in Reston, Virginia, USA. He proclaimed that every week, following Sunday's game, the coaching staff would proclaim the offensive and defensive players of the week. The reward for obtaining this honor was that only the winning players would be allowed to sit in the recliner all week after practice and during team meetings. **Only** the winning players were allowed to sit in the recliners during the week. This set off a flurry of competition between the players, especially on game days. Dexter Manley, for example, would come running off the field after sacking the quarterback, screaming: "That chair is mine this week!" Darrell Green, the Hall of Fame cornerback, would come to the sideline after an interception, challenging Dexter that **HE** would be the one owning the chair that week! These were well-paid, highly skilled athletic machines who, even among fanatical fans at RFK stadium, were mostly interested in where they would be sitting that week! Coach Gibbs taught me that human behavior was rarely predictable and always fascinating.

Motivation, worker behavior, and efficiency studies have been conducted since the industrial revolution. Management scientists like Abraham Maslow, Frederick Herzberg, and David McClelland all conducted studies in an attempt to better understand what truly motivates the average worker. This paper attempts to build on the works of these scientists and expand on their findings in an effort to further understand how to tap into the human psyche and position our project team members to be increasingly focused and productive. Additional studies from the Massachusetts Institute of Technology (MIT) and even my own informal survey of project managers and team members will be discussed. Finally, I'll provide some lessons learned for every manager and recommend some actions that you can take to capitalize on these lessons to create a truly satisfying and productive project environment.

Traditional Theories

As managers we often find ourselves delegating work as a standard operating procedure. Our expectation is that our team is getting paid, so of course they will accept and execute the work we assign to them. As professionals, we expect this work to be done in the highest quality manner, yet we're often disappointed when the result does not meet our expectations. Why is this? Steven Covey, in his book *The 7 Habits of Highly Successful People®*, states, "One must seek to first understand and then to be understood." For my own purpose, I've turned this around to state, "to be understood we must seek to understand." How can we possibly understand this missed expectation unless we can understand the person who performed the work? Once we can understand the worker, then we can properly motivate the worker. "To motivate, we must seek to appreciate."

Abraham Maslow developed his famed "Hierarchy of Needs." As depicted below (Figure 1), he stated that everyone exists somewhere on the pyramid of needs. To meet our most basic needs, we must have food, water, safety, and our health. It's only when these minimum needs have been met can we even begin to search for more sophisticated needs such as love, relationships, and a solid, well-formed sense of self-respect and self-esteem. Finally, we all hope to reach the point of total self-actualization — the "nirvana" of living life, for at this point we are in complete harmony with ourselves and the world around us. We have a well-developed moral compass and the confidence in our abilities to solve problems and positively influence others. We are committed to our work and our lifestyle without the need to be judgmental of others. Obtaining and maintaining self-actualization is difficult and often fleeting. Rarely do we enter and stay in complete self-actualization, because life throws us curve balls that can send us down the pyramid for the subsequent climb back up to the top. Most of us are fortunate if we can maintain the self-esteem level within the pyramid; it is at this level we want to find all of our team members. For example, professional athletes find a positive correlation between their level of confidence and their performance in their sport; that said, this confidence can only be maintained when the lower levels of the pyramid are strong and sturdy.

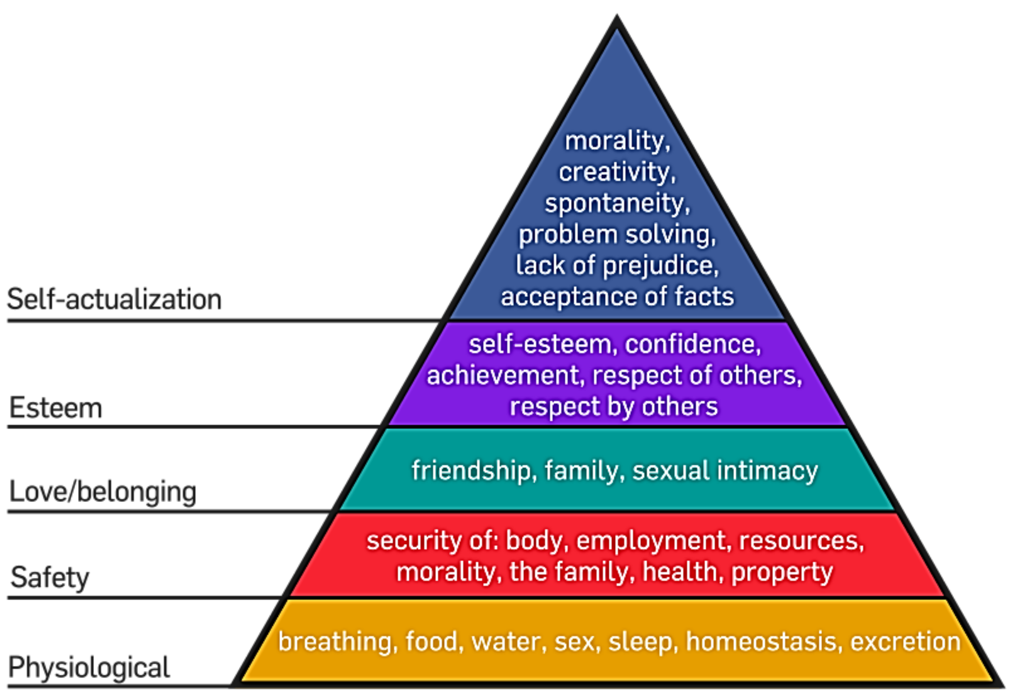

Figure 1: Maslow's Hierachy of Needs

Frederick Herzberg developed his theory on motivation and hygiene in 1959 and was one of the first theorists to state that money **was not** a motivating factor. He stated that workers needed and were often forced to tolerate "hygiene" factors, such as company policy, supervision, and working conditions but what truly excited and motivated workers were the opportunities to achieve, excel, and be recognized for these achievements on the job. Subsequently, these opportunities would lead to increased job satisfaction, responsibilities, and organizational advancement.

David McClelland also addressed the need for achievement but also found that workers found increasing job satisfaction when they were positioned to actually influence the way a job was performed. This need for power and the enjoyment that workers obtained when they could affiliate with like-minded workers also led to increased job satisfaction and improved job performance.

More recent studies, performed by MIT on behalf of the Federal Reserve Board, have made some fascinating, albeit, not so surprising findings. These studies showed that performance actually decreases when paying sizable financial incentives for complicated tasks requiring conceptual creative thinking. Financial incentives are quite effective, though, for relatively simple tasks that have a clear cause and effect, such as completing administrative or routine activities. These studies demonstrated that when workers feel they are paid fairly, they are then free to concentrate on accomplishing the work to the highest standard possible. Daniel Pink, former speech writer for former Vice President Al Gore and now noted author on motivation, noted that team members feel the most comfortable and perform better when positioned under the following three criteria:

- **Autonomy:** the opportunity to self-direct their work. This allows team members to exercise their creativity and problem-solving skills.
- **Mastery:** the opportunity to get better and become subject matter experts in a chosen area of expertise.
- **Purpose:** the opportunity to make a contribution to the betterment of the common good. This sense of purpose supports McGregor's Theory Y management approach, which states that team members want to impact the mission of the organization and provide recognizable value to that mission.

Motivation and Morale Survey Results

To this point, little has been said about the role of rewards and recognition programs. Historically, there is simply little correlation between financial rewards, such as salary and bonus programs, and a real noticeable increase in performance. I decided to undertake my own informal study and take these findings to the next level by asking the question: What do managers and executives need to do to reward team members and encourage the right behaviors that will lead to improved performance, better results, and greater morale? I sent surveys over 1000 managers and team members to address this question and received 118 responses. In addition, I addressed and discussed similar questions to over 300 project managers attending my numerous project management training classes, and the results are very consistent. Let's take a look at the questions, answers, and my conclusions in the following tables.

1. I feel considerable excitement when I receive:				
	Don't Agree	**Somewhat Agree**	**Totally Agree**	**No Answer**
My regular salary pay	44%	45%	8%	3%
My bonus pay	6%	34%	48%	12%
A compliment for a job well done.	2%	19%	79%	1%

Conclusion: Receiving our salary clearly DOES NOT generate the same excitement as that which comes from recognizable success in performing the job. This reaffirms Herzberg's theory that the opportunity to achieve outweighs the financial incentives. Project managers and team members I speak with consider their compensation, including bonuses, an "entitlement" rather than a reward. If the objective is to build morale and improve performance, financial rewards are clearly not the answer.

2. I tend to perform better on the job when:				
	Don't Agree	**Somewhat Agree**	**Totally Agree**	**N/A**
My work related confidence is high.	1%	19%	80%	0%
I'm passionate about my work.	2%	8%	90%	0%
My personal life is going well.	2%	36%	62%	0%
I'm compensated what I feel I'm worth.	6%	42%	52%	0%

Conclusion: Performance is higher when:

(1) We are confident and passionate about our work

(2) Our personal life is going well

(3) We are paid fairly

Again, there is little correlation between higher pay and increased performance. Like Daniel Pink in his book *Drive* stated, "team members simply want to be paid fairly" but to increase performance, they must be confident and passionate about their assignments. It is interesting that perceived performance tends to dip when we feel we are paid more than our worth. This may have more to do with personal expectations rather than the realistic perceptions held by our colleagues.

3. Which type of bonus program excites YOU most?	
Bonus paid against YOUR success.	58%
Bonus paid against TEAM success.	42%

4. Which type of reward/bonus would best help you feel GREAT about yourself and the organization in which you work?	
Total monetary reward.	44%
A personally customized reward/bonus package to include gifts, vacations, college scholarships for your family members, etc.	56%

5. Given the choice, which type of reward/bonus option would you choose?	
Total monetary reward.	53%
A personally customized reward/bonus package to include gifts, vacations, college scholarships for your family members, etc.	47%

Conclusion 1: In project management we stress the importance of the team and the value the team has to effectively deliver the project's product. This importance goes out the window when it comes to our personal compensation. We would prefer to be compensated against our own performance rather than against the performance of our colleagues on our team. This may be due to our entrepreneurial spirit, which encourages us to be rewarded against our own efforts rather than those of our competitors.

Conclusion 2: Over 50% of those who responded to this study admitted that a personally customized reward/bonus package would help them feel great about themselves and the organizations they work for. Again, financial rewards do not consistently lead to higher morale and improved performance; that said, given the choice, we would prefer the cash so we can exercise our independence and choose what **we** would like to do with our reward. Although cash rewards may increase our choices, it may not improve our morale or provide enough incremental motivation to increase performance.

Lessons Learned

Now that we understand the study's findings, let's summarize these findings and make some conclusions:

- We all exist somewhere on Maslow's pyramid. Ideally, we would like our team members to have a high level of self-esteem.
- Our team members typically find satisfaction with achievement, recognition, work itself, affiliation, and the ability to influence (power)

- Excessive financial incentive programs do not deliver exceptional performance. Pay workers fairly and consider other ways to motivate them, such as independent work, training, recognition of expertise, and the opportunity to share in the project's success.

- "Soft rewards" (a pat on the back) can be very effective in maintaining morale.

- Self-rated performance is higher when the team member is confident and passionate about his or her work.

- Self-rated performance is higher when the team member's personal life is in order.

- Team members prefer to be rewarded based on the factors they can directly control.

- Team members would enjoy a mixture of both monetary and "materialistic" reward/bonus programs, but given the option, will typically choose a monetary reward.

Summary

The next step is to apply these principals and take the bold step to implement an approach that for many will seem as innovative yet extremely risky. As leaders we must focus on understanding each individual worker, his or her passions, personal circumstances, and his or her value systems and apply them in a unique way to staff projects with the "right" team members and reward and encourage individuals against the lessons learned above. Here are some recommendations:

- Organizations must resist offering financial incentives, thinking they will result in improved performance.

- Start recognizing and rewarding passion, commitment, independent thinking, and leadership — not just project success!

- Look to hire (or acquire) team members who have demonstrated these traits and are excited to have the opportunity to solve the client/sponsor's problem. Don't jump to acquire the most technical/competent person, but strive to obtain the most passionate team member.

- Seek to understand the whole person, NOT just the team member. Each employee's personal life and personal situation is unique and he or she **does** bring it to work.

- For maximum benefit, rewards and bonus programs must be customized to each individual to include a balance of personal, materialistic, and financial rewards.

- Employees must be willing to allow management to understand them outside the scope of their immediate job.

Organizations have gotten into the habit of handing out cash as part of an effort to retain workers and/or balance compensation. Management is wrong in thinking that these programs actually motivate workers to succeed and improve their morale. True motivation comes from within the individual worker. Enlightened management will work to understand those intrinsic motivators and seek to satisfy those motivators. Especially during difficult economic times, management can't afford big bonus programs and must be more creative in their efforts to retain and motivate their team members.

To this end its important to understand that I am not encouraging reward without merit. Everyone is not entitled to a trophy. When performance is clearly lacking, it must be discussed with the team member and dealt with humbly, honestly, and professionally. Lateral thinking and working to understand the root of the problem may help improve performance. Or, maybe the team member is simply in the wrong job.

About the Author

For over 30 years, Joseph (Joe) D. Launi, PMP, President and CEO of Project Management Experts, has worked tirelessly to develop a solid reputation for delivering successful projects and improving project management processes. Mr. Launi is a proven project management executive with progressive experience, which encompasses project management office (PMO) leadership; development and management of PMO policies, best practices, and methodologies; development and presentation of project management training; implementation of project management software solutions; information technology project and program oversight; research and development into motivation and morale building programs; and, profit and loss management of various consulting practice areas.

Mr. Launi has published numerous works in areas such as software implementation and project planning. Project Management Experts specializes in providing organizations with the skills, knowledge, and experience needed to improve their project management competency.

Understanding Project Stakeholder Psychology: The Path to Effective Stakeholder Management and Engagement

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Effective stakeholder management and engagement is now universally acknowledged by project management practitioners and academics as a prime critical success factor for all projects. However, many projects still encounter serious unaddressed issues and challenges in dealing with their stakeholders, especially external ones. These can have damaging consequences both for the projects and their stakeholders. A major cause for this deficiency is the evident paucity of knowledge about the underlying psychological factors which profoundly influence stakeholders to act as they do towards projects. On many projects, especially in construction and civil infrastructure development, external stakeholders collectively tend to constitute an exceedingly diverse, large and complex community and their actions may range from supportive to neutral to adversarial. These stances can change over time potentially increasing the danger level to the project if not handled properly.

Based on an in-depth analysis of available information on numerous large completed and on-going projects across the globe, mainly in construction and civil infrastructure development, this research attempts to address this serious knowledge gap. It identifies and discusses six key psychological factors – motivation and concern, expectation and perception, and attitude and behavior – which apply universally to all internal and external stakeholders (individual, organizational or otherwise) - on every project. A thorough understanding of these factors and why they influence stakeholders to adopt positions pro or contra projects is essential in order to assist project owners, planners and executors craft effective management and engagement strategies which enable the development of an amicable, ethical, mutually beneficial and sustainable relationship with their stakeholders throughout the project life-cycle. By doing so, they can maximize the opportunities for their projects while concurrently and proactively reducing or minimizing the threats to them, existential or lessor, which typically would ensue from possible stakeholder opposition to their projects.

Introduction

Stakeholders are now acknowledged as the key driving force and most important critical success factor on every project. Even if a project is successful in the narrow conventional sense in that it achieves its goal within its cost, time, scope and quality constraints, modern interpretations of project success hold that the project cannot be considered truly successful if key stakeholders are dissatisfied with the way in which it was undertaken or if significant and unresolved stakeholder conflicts and issues emerged prior to project initiation, during the course of the project life-cycle or subsequent to project completion.

However, although the criticality of effective stakeholder management and engagement is undisputed by project management academics and practitioners, and in recent years has emerged as a major thematic area of research in which a voluminous body of literature now exists, stakeholder conflicts and issues are a given in most projects and are identified in several project performance surveys undertaken over time as constituting a prime reason for ‘project failure’. Long is the list of projects which experienced cost and schedule overruns, unwanted and unanticipated scope modifications, severe reputational damage, or which were doomed to premature termination because of flawed stakeholder management and engagement by the project’s decision-makers. Effective stakeholder management and engagement is hence an imperative for projects and is at least as important as effectively managing their cost, time, scope, quality and other ‘technical’ aspects. It is also a highly complex and challenging task because it requires a good understanding of the discipline of psychology and allied disciplines such as sociology which normally do not apply to the technical aspects.

The prime objective of this research was to develop an analytical value-adding psychological framework for projects. The authors are of the view that through judicious application of this framework projects can, on the one hand, significantly reduce both the opposition and the threats they encounter from stakeholders and, on the other, simultaneously identify and to the maximum possible extent exploit the opportunities which present themselves in their interaction with them. This combination may significantly increase the likelihood of project success and may boost project effectiveness and efficiency. Understanding and managing/engaging all stakeholders fairly is, moreover, the ethical responsibility of every project and this psychological framework, which is based both on simple logic and extensive empirical analysis, provides project owners, managers, planners and executors with significant insight into the reasons why stakeholders adopt positive or negative stances and courses of action towards projects and how these stakeholders, if properly managed and engaged, can be used as a force in favor of rather than against the project.

For their research the authors analyzed information available in the public domain on over fifty high-profile, well-documented and controversial on-going and completed projects across the globe primarily in Construction and Civil Infrastructure Development (CCID). CCID encompasses a broad category of projects which include, inter alia, creation of buildings of all types, industrial facilities, transportation, energy, mining and communication systems, and mines. This research has resulted in the identification of six fundamental and inter-related stakeholder psychological ‘attributes’ which can be grouped into three pairs: motivation and concern, expectation and perception, and attitude and behavior. The authors have also determined that these attributes are common to ALL project stakeholders regardless of whether the stakeholders are internal or primary, i.e., they have contractual relationship with and/or legal obligations to the project and are consequently actively involved in it and normally have a vested interest in its success, or are external or secondary, meaning they lie outside the project’s formal direct control and who may or may not want the project to succeed depending on whether they are positively or negatively affected by the project during its life-cycle or subsequently when it enters its operational phase. Furthermore, the attributes apply to stakeholders of any type – individuals, groups, communities, organizations and even countries – and to projects in all categories, of any duration, size and level of complexity regardless where they are physically undertaken. In other words, these six attributes have universal application.

Understanding these six psychological attributes and systematically collecting data and information on them is an integral part of the complex process of stakeholder analysis which constitutes the third step in the five step iterative process of project stakeholder management and engagement which the authors previously proposed and discussed in their paper on a proposed project stakeholder governance framework which was presented at the University of Maryland's first annual project management symposium in 2014. Sequentially the steps are contextualization, stakeholder identification, stakeholder analysis, and design and implementation of stakeholder management and engagement strategies. As stakeholder analysis is dependent on the preceding steps of stakeholder contextualization and identification, it is crucial that the latter are thoroughly undertaken. Stakeholders obviously must be comprehensively and accurately identified before they can be analyzed. All major project stakeholder identification methods were presented and discussed by the authors in the paper on the subject which they presented at the University of Maryland's second annual project management symposium in 2015. Identification of internal stakeholders is comparatively easier and quicker to undertake than for the external stakeholders. Internal stakeholders on a large urban construction project for instance are typically the project owner, sponsor or client, project manager and team, financiers, consultants, contractors and sub-contractors, vendors, hired labor and various involved public agencies; important external stakeholders usually include the affected community, business community, environmentalists, political entities, the media, academia, and other public agencies which are not involved in the project but have some interest professional interest in it. Failure by the project to initially identify some external stakeholders can lead to complications later.

Projects must be mindful of the practical hurdles and limitations associated with analyzing their stake-holders' psychological attributes. Both the internal and especially the external stakeholder community can be very large and complex in terms of, inter alia, their respective missions, interests, goals, priorities and culture (for organizations), and (for individuals, groups, communities) their social and cultural diversity, economic background, objectives, awareness, education and intelligence, family upbringing, norms, values and personal or shared experiences and so forth. The stakeholder psychological attribute analysis is only as useful as the quality of information it is based on, meaning, the information must at least be accurate, precise, relevant, specific, up-to-date, reliable and actionable. Finding information which satisfies this set of criteria on all stakeholders, especially external ones, can be very difficult, costly and sometimes impossible to do. Powerful or influential stakeholders must be prioritized. The difficulties are compounded when the dynamism of these six attributes over time is taken into consideration. These can change significantly and rapidly in response to project developments and such changes may need to be reflected in a prompt and corresponding change in the project's stakeholder management/engagement strategies. Monitoring and tracking such changes would necessitate a situational or periodic repeat of the information collection task and stakeholder attributes analysis.

The challenge of attempting to devise and implement effective and customized stakeholder management/ engagement strategies on the basis of the stakeholder attributes analysis can be immense, time-consuming and costly and offers no guarantee of success. Without qualified support, for instance in the form of a team of highly skilled, competent, creative and experienced analysts or hired consultants, such activities would excessively burden project managers and teams already heavily burdened with the arduous technical and administrative tasks they typically encounter in the day to day operations of their projects.

Project Stakeholder Attributes: Motivation & Concern

All Stakeholders have needs and wants. Satisfying these needs and wants is a key objective for them, regardless of whether the stakeholders are individuals, groups or associations of individuals, communities, or organizations. In his famous "pyramid of needs" the American psychologist Abraham Maslow identified several universal human needs ranging from very basic and immediate needs (e.g. food, safety, sleep) at the bottom of the pyramid to complex high-level needs such as self-actualization at its top. Wants build upon needs, sometimes constituting a refinement of them and sometimes going way above them. For stakeholders in the form of organizations, it seems reasonable to assume that their needs and wants relate to the achievement of their missions, strategic goals and ambitions they are pursuing and which define the very purpose of their existence and where they ultimately seek to be.

Projects offer stakeholders a potential opportunity to satisfy their general and specific needs and wants and stakeholders are naturally interested in ascertaining if, how and to what extent this is possible. Projects thus constitute a source of *motivation* for stakeholders; this is good for the project because the greater this motivation is the more likely it is that stakeholders will view the project in a positive light, and vice versa. The practical implication in project perspective is that project owners, planners and executors must carefully research stakeholder motivation and seek to align their projects with their stakeholder needs and wants to the maximum extent possible within the given project resource, time and other constraints. Doing so serves the twin objective of reducing actual or potential stakeholder opposition to the project, and the danger this may entail, while concurrently ensuring that the project fulfills its ethical responsibility towards its stakeholders who consequently derive value from it.

Stakeholders are not a homogeneous group; they embody a wide spectrum of, inter alia, economic backgrounds, education and intelligence, norms, values and belief systems, personal goals and interests and (organizational) missions, goals and objectives, and ambitions. For some the project offers greater motivation than for others. Some are closer to the project than others. Internal stakeholders are contractually or legally bound to the project and hence are actively involved in it and normally have a vested interest in its success. For these stakeholders the motivation is especially high given the considerable and multi-dimensional benefits they reap from their direct involvement in the project. During the project life-cycle these include, for example, remuneration from the provision of consultancy services, labour and tangible or intangible inputs, professional and personal networking, acquisition and enhancement of expertise, knowledge and experience, career advancement, image and reputational gain etc., and, after the project completion when it enters its operational phase, the financial, material and other value-adding benefits which are subsequently realized over time for the project owner, client or users and other stakeholders concerned.

For external or secondary stakeholders, which by definition lie outside the project's formal control and are not entitled to the benefits of the internal stakeholders, gaining an understanding of their motivation vis-à-vis the project is more complex and requires a closer and more careful consideration. In their review of CCID-projects the authors have identified several fundamental motivation factors which incline external stakeholders favorably towards projects and which are briefly discussed below:

If the project serves to overcome a problematic condition or situation whose solution is widely regarded as being one of public urgency then the project is likely to be welcomed. For example, the widening of town roads (to relieve traffic congestion), commissioning of new power stations (to eliminate power outages or reduce the pressure on the existing system), initiation of urban regeneration schemes (to overcome dreariness and combat crime), construction of sewage treatment and garbage incinerator facilities (to prevent a public health hazard), opening of new kindergartens, schools and hospitals (to meet growing public demand) and launching of a technical and vocational training initiative (to help reduce chronic youth unemployment) all fall under this.

Employment is a big motivator worldwide and CCID projects usually offer ample opportunities here throughout their life-cycle, especially prior to commencement of and during the execution phase, and after project completion when the project output created becomes operational. Job creation on a large scale for skilled, semi-skilled and unskilled labour is considered a major selling point for projects and actually is frequently used by project advocates as a 'weapon' to generate stakeholder support and counter opposition. In less affluent communities where unemployment is acute and chronically high, the economy is depressed and stagnant, and job opportunities are otherwise hard to come by, such projects can deliver significant financial, material, experiential and other benefits to many people over time besides ensuring a source of sustenance for their families.

Business is another motivating factor for external stakeholders. CCID projects can constitute an important source of business opportunities for the localities where they are undertaken during their life-cycles and often also after their completion. Usually they require large quantities of tangible and intangible inputs sourced commercially. Some inputs are supplied to the project formally through contractual agreement (in which case the supplying entities become internal stakeholders) while the rest are supplied informally. This happens, for example, when project employees avail regular use of the project locality's shopping, eating, entertainment, recreational and other commercial facilities and attend local events. The departure of non-local employees after project completion can also constitute a significant loss of business for the locality, especially if the number of employees concerned is large and departure is sudden.

Completed CCID projects may subsequently prompt follow-on projects resulting in an increase in investment and commercial activity in the project localities and their environs. For example, improvements in transportation infrastructure can result in new factories, warehouses or other industrial/commercial facilities being created or existing ones upgraded with a view to benefitting from the enhanced logistical ease of moving products. The construction of a dam can encourage the development of fisheries and agro-based industries. A newly established university in a small town may prompt companies to set up offices there with a view to undertake collaborative activities with the university or to employ its graduates. Follow-on schemes like-wise can bring about significant job creation, business opportunities and other benefits for stakeholders.

Individuals and organizations actively involved in CCID projects usually require living quarters and office space located in proximity of the project site. These must be rented or purchased if the entities concerned are not from the locality or are out of commuting range. For local landlords the projects hence constitute a potential source of rental income while for local property owners they present an opportunity to sell their property more quickly and at a higher rate than would normally be possible without the projects. Premises for rent or purchase may also be required after project completion for non-locals employed in operating the functional buildings and infrastructure, and likewise for subsequent follow-on projects. Increasing demand for property for rent or purchase causes upward pressure on rents and on residential or commercial property purchase prices which constitutes a wealth gain for landlords and property owners besides giving a feeling of satisfaction to those landlords and owners uninterested in renting out or selling their properties.

Tourism constitutes a pillar of the global economy and is the prime source of income and wealth for many communities, cities and countries. Tourists the world over like to flock to places far and wide offering fun and adventure, sightseeing and recreation, cultural learning experiences and the possibility to meet and forge lasting relationships with people whose outlook on and way of life may be considerably different from their own. For local people, meeting and interacting with tourists proffers an opportunity to learn about other places, people, outlooks on life and life-styles. Tourism thus constitutes an excellent means of inter-cultural relationship building and mutual experiential enrichment and tourism-based projects, such as the construction of resorts and infrastructure, thus tend to attract widespread support.

All stakeholders harbor a keen interest in enhancing their quality of life over time. In the contemporary context quality of life is usually viewed as ensuring access, inter alia, to a broader, superior and cheaper range of goods, services, comforts and experiences, and by providing a safer, cleaner, healthier and more happier and enjoyable environment to live and work in. Consequently, projects which transform these needs and wants into reality stand a high chance of acceptance. Typical examples are shopping malls and supermarkets, restaurants and food courts, cinemas and entertainment centers, theme parks, sport and recreational facilities, libraries, museums and art galleries, music and exhibition halls, urban regeneration schemes, and facilities producing new products and services.

Some stakeholders relish the prospect of change which CCID projects bring about along with the accompanying excitement and distractions – unlike their more conservative peers who are resistant to change and would cringe at the prospect. For them the projects are looked upon as a good idea signifying progress, development and modernism in addition to delivering considerable benefit to the many stakeholders who will utilize the newly created buildings and transportation, energy and communications infrastructure.

In the contemporary age of superlatives, projects which stand out in their class constitute a great source of pride and sense of accomplishment for many of their stakeholders. Whether the project in question is about erecting the tallest skyscraper, the longest bridge, the highest road, the largest airport and dam, the biggest theme park, or the most innovatively designed building and so forth, it usually will generate considerable attention, interest and support among stakeholders which are impressed, inter alia, by the vision, huge financial investment, and the successful overcoming of the enormous technical and managerial challenges which all converge in these projects. The pride effect can also surface in localities where CCID projects undertaken are on a comparatively much less grander scale if the structures subsequently created exceed dimensionally existing ones within the locality or in neighboring ones.

Projects evidently can go a long way towards satisfying stakeholder needs and wants and hence ensuring high stakeholder motivational intensity towards the project. At the same time on-going and completed CCID projects can give rise to serious misgivings, apprehensions, fears or worries which can incline some or many of their stakeholders disfavorably towards them. This counterweight to motivation is called *Concern* and the authors' research clearly reveals that both the internal and external stakeholders may have numerous and diverse general and specific concerns in connection with CCID projects. The nature of concerns are different in each stakeholder each category and addressing them comprehensively and completely may be extremely challenging. Concerns are determined by various factors - personal, social, cultural, environmental and others – and may emerge at any point in time before a project's formal approval and initiation, during its life-cycle or even after its completion. The intensity of the concerns may increase or decrease over time. New concerns may eventually surface. Some concerns are specific to individual stakeholders, others are collective. Some stakeholders may have more concerns than others. Some concerns are prioritized over others. Concerns tend to be context-sensitive. Failure by the project to adequately address and overcome at the very least the more salient stakeholder concerns may prompt stakeholders to adopt courses of action having a serious negative impact on the project or its goals and objectives, in the extreme case possibly even resulting in its premature termination. Hence, it is critical for the project to comprehensively identify, monitor and carefully assess stakeholder concerns and implement (for internal stakeholders) management and (for external stakeholders) engagement strategies which aim to eliminate or, more realistically, to reduce their concerns to the maximum extent feasible. Addressing external stakeholder concerns is thereby comparatively more difficult than addressing those of the internal stakeholders for the project because these stakeholders can be very numerous and heterogeneous and information about them may be considerably more difficult to collect and analyze. Some of the major secondary stakeholder concerns identified by the authors are briefly discussed below.

Perhaps the most important concern identified on the CCID projects reviewed by the authors is the involuntary displacement of people from ancestral lands and resettlement in other, sometimes distant, locations. CCID projects stand out amongst all project categories in that they tend to have the largest people displacement effect. Dam projects in particular are notorious in this regard. According to the World Commission on Dams the number of people affected worldwide since the end of World War II stands at approximately 40 million. The mammoth Three-Gorges-Dam project in China alone resulted in the displacement of around 1.5 million people. For the affected stakeholders forced displacement carries with it heavy psychological, health, emotional, social and economic cost and more often than not the monetary and material compensation they receive by way of return falls far short and often is handed out unwillingly after years-long delays. Even for those not displaced, CCID projects can have a devastating impact on their livelihoods, access to food, and way of life. This has occurred on numerous occasions over time whereby indigenous and tribal people often are compelled to bear the brunt of the change. For this reason these stakeholders are usually fiercely opposed to CCID projects in their areas, their highly-publicized 'David versus Goliath' epic struggles, often violent and dragging on for years, against powerful energy and mining corporations allied with national governments.

Environmental damage is another major priority concern for stakeholders. Large tracts of land need to be cleared in preparation for CCID projects. Factories, power generating stations (especially nuclear and coal-fired ones) and pipelines cause or risk causing extensive soil, air and water pollution with damaging repercussions for the health of stakeholders with consequent high attendant cost. Nature's pristine beauty is degraded and its fauna and flora threatened, sometimes with catastrophic consequences for plant, bird, animal and insect species whose habitats are destroyed by the land clearing.

The past and present occasionally encounter each other on on-going CCID projects. The ensuing damage to or the destruction or demolition of sites of archeological, historical or cultural significance often encounters stakeholder condemnation and stiff resistance. The construction of oil and gas pipeline projects in particular are often opposed by native tribes aghast at the notion of the pipelines traversing land 'sacred' to them.

CCID projects in urban localities usually cause considerable traffic obstruction, congestion and diversion in their execution phase which can extend over months and during which the risk of vehicle accidents and consequent damage, and personal injury and death increases. Commercial activity in the affected locality may be negatively impacted by restricted vehicular and pedestrian access. Most stakeholders dislike the inconvenience, dust and dirt, noise, stress and vibrations caused by construction sites located in close proximity of their residences or office premises.

For some stakeholders building construction projects are a cause for concern because they are deemed unsightly or architecturally disharmonious with the urban landscape in which they are embedded or because they obstruct the stakeholders' view of the natural landscape and surrounding environs. Taller structures constructed in earthquake-prone zones may arouse concern among stakeholders worried about the risk and possibility of their collapse. Stakeholders residing or working in close proximity of newly constructed or under construction buildings may be upset at the unwanted shading and cooling effect stemming from their blockage of the Sun's light and warmth. More historically conscious and sentimentally inclined stakeholders may resent the demolition of decades or centuries old or familiar buildings to make way for modern replacement structures in their place.

Stakeholders may be concerned about the possible economic or financial loss they may incur as a result of some CCID projects. Established businesses may stand to lose out to new incoming competitors, consumers may apprehend a rise in the cost of goods and services, tenants may worry about possible rent hikes and the prospect at being forced to relocate to more affordable accommodation in outlying areas, and potential property buyers may anticipate an increase in residential or commercial property prices. Landlords and property owners may oppose certain CCID projects because of the anticipated downward pressure these may have on their property rental and sale values. Other stakeholders are simply opposed to the phenomenon of change and consequently oppose CCID projects because these are admittedly the main vehicle of effecting visible change. Gentrification projects are encountering increasing opposition for this reason.

In many places water and energy resources are scarce commodities and public access to them may be severely limited. CCID projects typically require large amounts of these resources, both while on-going and subsequently after completion when they enter their operational phase. Due to the intensified resource competition in future, stakeholders access to water and energy may be further curtailed and apprehension about this can generate considerable opposition among them to such projects.

Stakeholders frequently question the necessity of CCID projects, especially those pursued by the public sector, considering them a squander of resources which could be utilized as or more effectively on less costly alternatives. Sometimes stakeholder opposition to projects stems from their conviction that the project cannot realistically deliver on its tall promises and assurances, at other times because the stakeholders believe the project owners stand to derive enormous benefits while they (the stakeholders) are the ones who will ultimately have to live with the risks and other negative consequences which inevitably accompany such projects.

Social, cultural, ideological and religious considerations appear to play an important and evidently increasing role in how stakeholders regard projects. Some stakeholders oppose certain projects because they deem them to be morally offensive or conflicting with their personal values and beliefs, others oppose projects simply because their owners or main beneficiaries are foreign or hail from an ethnic or religious minority community whose alien beliefs, norms and rituals are considered offensive and abhorrent by the majority and whose intent in undertaking the project is looked upon with suspicion.

A major irritant for stakeholders is the lack or total absence of consultation with them by project owners, planners and designers, and executors prior to initiation of the projects and during the project life-cycles. Consultation and information inadequacies breed a feeling of resentment towards the projects by their stakeholders which come to regard them as arrogant and inconsiderate, prompting them to look upon the projects in a less favorable light than they may have done otherwise. Non-conformance to established rules and procedures by project owners, for example, failure to undertake proper environmental and social impact assessments or a thorough feasibility study, lack of transparency, irregularities in the tender or procurement processes of public sector projects and rampant cronyism and patronage in them, all serve to arouse suspicion and generate hostility and opposition among many stakeholders.

Stakeholder opposition may also surface because of the negative image, reputation and undesirable policies and practices, past and present, of the organizations and individuals owning or undertaking the projects. They may also be concerned at the projects' inadequate or non-existent engagement towards them or harbor suspicion and skepticism about their ability or intent to follow up on their assurances and specific commitments given to the stakeholders. This is especially true for the projects of mining and energy companies in developing countries where environmental and human rights standards are lower than in developed countries, where unethical practices are rife and corruption and bribery in the political and public administrative spheres is high and often unchecked. Projects in such places are often associated with reports of strong-arm tactics and brutal harassment and intimidation methods by the project which not infrequently involves incidents of brutalization, forced disappearances and the assassination of project opponents. The influx of outsiders employed on on-going projects can also give rise to concern at the possibility that some of the newcomers are criminally inclined or that the completed project when it enters its operational phase will serve as a magnet attracting criminals into the locality.

In the post 9/11 age security has emerged as a major stakeholder concern. Stakeholders have voiced fears over the possibility of terrorists launching attacks on nuclear power stations, chemical, explosives and weapon factories, and other strategic facilities, with potentially disastrous consequences, and oppose the pursuit of such projects in their localities.

In many countries which are afflicted by civil upheaval and years-long insurgencies, many stakeholders oppose CCID projects simply because they view them as symbolizing the state and government they detest and have resorted to drastic, often violent means to prevent or disrupt these projects.

Project Stakeholder Attributes: Expectation & Perception

Expectation is the belief a stakeholder has that general or specific project-related conditions, situations, events, targets, objectives or other developments considered of interest or substantive importance to the stakeholder will or will not happen or be realized during the project's life-cycle or after project completion. It is futuristic. Most stakeholders can at some future time expect to experience benefit and/or incur cost in consequence of a project. Benefit reflects the degree to which the project satisfies stakeholder needs and wants while cost reflects the problems, issues and other disadvantages the stakeholder will inevitably encounter because of it. Benefit and cost can be monetary and/or non-monetary and their occurrence spread over different time horizons in which they can manifest themselves synchronously (i.e., they both occur at or approximately at the same time) or asynchronously (i.e., cost first, benefit later, or vice versa). For some stakeholders the benefit and cost may extend throughout the project life-cycle, even for years after the project enters its operational phase, while for others these may be confined to just a single phase or sub-phase of the on-going project. Stakeholder expectation is hence basically derived from motivation and concern and is determined in large measure by the information the stakeholder acquires about the project and which can stem from its own direct and indirect observations and information gathering, its interaction with other stakeholders, its information processing ability, and its intuition and personal experience.

Expectation is evidently very important because of its role in shaping the attitude and behavior – the last pair of remaining attributes - that stakeholders form and adopt towards projects. Assuming stakeholders think and act rationally then it is reasonable to assume that if their expected benefit from the project per se or from its constituent phases, activities etc. exceeds their expected cost - i.e., condition of expected net gain - the stakeholders will feel positively about the project and consequently develop 'positive expectation' about it, or vice versa, if their expected cost is larger than their expected benefit - i.e., condition of expected net loss - they will think negatively about it and develop 'negative expectation'. Higher positive or negative benefit-cost differentials translate into correspondingly higher degrees of positive or negative sentiment towards the project. The certainty factor also plays a crucial role in the determination of stakeholder expectation. Stakeholders expecting a net gain from the project with a high likelihood will presumably be more favorably inclined towards it and develop higher positive expectations than other stakeholders which attach a lower likelihood. Conversely, stakeholders expecting a net loss with a high likelihood will presumably develop a higher negative expectation about the project and will tend to oppose it more than stakeholders which attach a lower likelihood to this happening. Many combinations of expected benefit and cost, and their likelihood of occurrence, are possible and this will determine the stances stakeholders respectively adopt towards the project.

Failure to satisfy a stakeholder's positive expectation or showing stakeholders that their negative expectation is unfounded can have important consequences for the project. If, for example, a stakeholder develops a positive expectation that a mall construction project soon will offer him an excellent technical employment opportunity close to his home but then realizes that no such opportunity is or will be forthcoming, disillusionment with the project may set in. Any project-specific concerns he has may now start to preponderate in the absence of any other expected benefit from the project and henceforth he may oppose the project. On the other hand, a stakeholder having to commute daily past the mall construction site may develop a negative expectation that the project will cause considerable traffic nuisance while under execution resulting in inconvenience and delay for the stakeholder but then experiences the contrary because an alternative and better route is opened for traffic. In this case the stakeholder may curtail or cease its opposition altogether towards the project.

A stakeholder may develop a chain of expectations relating to different future points in time spread across the project life-cycle and beyond when the project enters its operational phase, and these expectations may change over time depending on the level of fulfillment of preceding expectations as well as on other influences. Expectation's sister attribute *Perception* plays a crucial role in this regard. All stakeholders have the ability in varying degree to perceive the project reality as it affects them at any point in time and any observed disequilibrium which manifests itself between their expectations and perceptions – the 'expectation-perception gap' – will determine how their subsequent expectations develop. Stakeholders can expect either a net gain (i.e., expected benefit is greater than expected cost: Situation A) or expect a net loss (i.e., expected cost is greater than expected benefit: Situation B). For both situations there are four possible expectation-perception combination scenarios, namely, (1) perceived benefit and perceived cost both exceed expected benefit and expected cost, (2) perceived benefit and perceived cost both fall short of expected benefit and expected cost, (3) perceived benefit is less than expected benefit while perceived cost exceeds expected cost, and (4) perceived benefit exceeds expected benefit while perceived cost is less than expected cost. For Situation A (expected net gain) the fourth scenario is obviously the best from stakeholder perspective because it normally offers the possibility of attaining the highest net gain and the stakeholder will consequently tend to view the project favorably which it would not do if it felt that the project is causing, or in future will cause it, either a net loss or yield no net gain. For Situation B (expected net loss) the fourth scenario offers the lowest incurred net loss which may serve to dampen its opposition towards the project.

Stakeholders who perceive they are receiving a net gain from the project will probably have confidence in its ability to fulfill their subsequent expectations, assuming they have any, and will become or remain favorably inclined towards it – provided that their subsequent expectations too are also fully, or at least in large measure, fulfilled and they have as no reason to fear experiencing a net loss in future. The same applies vice versa. Hence, stakeholders must enduringly perceive that they have received a net gain from the project so that their support for it is ensured and sustained. The implications and challenges for the project's stakeholder engagement are thus two-fold, namely, to ensure that stakeholders develop positive expectations with a high degree of certainty towards the project, and which extend throughout its life-cycle, and that stakeholders recognize and appreciate that the project is consistently fulfilling, largely fulfilling or exceeding their expectations. Care must be taken to ensure that stakeholders do not develop unrealistic positive expectations as these will be difficult, if not impossible, for the project to satisfy and the consequence therefrom could be a large number of disenchanted and annoyed stakeholders who could pose a serious headache for it.

Project Stakeholder Attributes: Attitude & Behavior

Attitude is the feeling of affinity, indifference or dislike a stakeholder has about a project while it is on-going or after it enters its operational phase. Stakeholder attitudes are not static and can change over time, sometimes significantly from affinity to dislike or vice versa. Attitude formation is complex and is a function of the stakeholder attributes motivation, concern, expectation and perception in relation to the project. Understanding and appreciating these is essential for the project in order for it to design and execute management and engagement strategies which influence stakeholders in favor of the project. Internal stakeholders are usually voluntary and active project participants and it can be assumed that they have an automatic affinity with the project which they are contractually or legally bound to pursue professionally and responsibly. However, this may not be the case if some internal stakeholders come to perceive that the project will not bring them the net gain they anticipated when they joined it or when an irreconcilable major conflict of interest with the project surfaces.

Behavior is the stakeholder's conduct towards the project. It is the outward manifestation of stakeholder attitude and is normally, but not always, the mirror reflection of attitude. Behavior spans three categories - supportive, neutral, and adversarial - which directly correspond to the stakeholder attitude categories affinity, indifference, and dislike. Both supportive and adversarial behavior can be further subcategorized into strongly, moderately or marginally supportive or adversarial. Furthermore, supportive and adversarial behavior can be either passive or active whereby the degree of activeness may vary greatly in intensity ranging from almost negligible on the one extreme to very intense on the other. Analogous to attitude, stakeholder behavior may change over time, moving within and between categories, and going up and down the intensity scale. It is reasonable to assume though that the more strongly a stakeholder feels about a project, regardless of whether the feeling is supportive or adversarial, the more likely it will behave more intensely towards it. For instance, some intensely adversarial stakeholders may behave very aggressively - even violently confrontational - towards the project while their marginally adversarial peers may register their opposition to it with a vigil or by publishing a negative newspaper editorial about the project. The positive or negative impact a stakeholder has on a project is a reflection of the power and influence it possesses and which it excercises through the options available to it. These options are discussed in detail by the authors in their second paper for this symposium.

Stakeholder behavior is hence a crucial performance indicator of the effectiveness of a project's stakeholder management and engagement strategies and must be carefully monitored throughout the project. If opposition to the project decreases this implies its strategies are effective but if opposition persists or increases over time this signifies strategy ineffectiveness and the project must redesign or modify its strategies until they have the intended effect. Unlike the internal stakeholders whose behavior is generally predictable, dealing with external stakeholders is more challenging and risky because they lie outside the project's formal control and generally less is known about them. External supportive stakeholders may have much to offer the project by way of moral support and other forms of formal and informal cooperation. These constitute potential opportunities for the project. On the other hand, external adversarial stakeholders can cause serious complications for the project or even endanger its very existence depending on the spectrum and potency of options available to it and the extent to which they are willing to exercise these options against the project. Prudent and effective engagement of external supportive stakeholders means that the project will on the one hand seek to mobilize, bolster and sustain their support for it which they can do through good expectations and perception management. Powerful or influential secondary supportive stakeholders must thereby be prioritized in order to prevent them from turning into indifferent or adversarial stakeholders which could harm the project. On the other hand, engagement must attempt to eliminate or minimize the danger external adversarial stakeholders present to the project through exercise of their options. It can do this through a careful and thorough analysis of these stakeholders which seeks to ascertain the causes of their adversity and then attempt to address all the causes fairly. Project interest is especially well served by attempting to convert powerful or influential adversarial stakeholders into supportive or at least into neutral ones. The engagement strategies which can achieve all these objectives will be discussed by the authors in a future symposium paper.

Concluding Remarks

The authors' research shows that six psychological 'attributes' – motivation and concern, expectation and perception, and attitude and behavior - can explain the nature and intensity of relationship between any project and its internal and external stakeholders. By acquiring deep insight into these six attributes, which can only be undertaken through a systematic and rigorous stakeholder analysis, the project can reduce its major risks, existential and other, and at the same time fulfill its ethical responsibility towards its stakeholders ensuring that for both a win-win solution is attained.

2017 UMD Project Symposium

Use of Project Simulation in a Masters in Engineering Project Management

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Introduction

Typical of many reports on "un-satisfactory" Project Management practice, the *Lessons Learned from UKCS Oil and Gas Projects 2011-2016* reports:

"Since 2011 fewer than 25% of oil and gas projects have been delivered on time; with projects averaging 10 months' delay and coming in around 35% over budget"

"Over and above specific technical issues, it was also clear that there is a common necessity for:

- More clearly defining the project scope prior to project sanction
- Keeping the project as simple as possible
- Increasing the accountability of project delivery
- Improving the co-operation between companies/stakeholders"

It is fair to say that these supporting statement are not uncommon and yet of interest to those with a purpose of moving forward practice and where academic teaching has a role to play.

This paper looks at an approach will may assist this position and the findings are derived from a delegate stream from a CPD Masters Programme.

The author was responsible for the design & development of the MSc Engineering Project Management at the University of Strathclyde, Glasgow, UK, which has an emphasis on management techniques and application within sponsors' organizations. As a result, Year 1 has an heavy focus on management techniques and years 2 & 3 linking these into project practice with two pieces of project work designed in conjunction with sponsors. (The Group Project and the Individual project). See Table 1 below for the programme structure.

PGCert	CD901 PROJECT MANAGEMENT
	M9851 COMMERCIAL
	CP941 FINANCE
	EF938 RISK
	EF939 QUALITY
	EF937 DESIGN
PGDip	DM936 Project Control and Change Management
	DM918 People, Organizations & Business
	CD902 Group Project
	DM945 Introduction to Optimization &
MSc	CP961 Individual Project

Table 1: MSc Engineering Project Management syllabus

They are delivered as multi-company CPD programme by the University of Strathclyde, Glasgow, UK, as part a cross disciplinary programme leading to the award of MSc in Engineering Project Management. The cohort here is now totaling around 400, and the discussion here centers around an introductory class from the eight specialist classes in Project Management.

What is interesting about these cohorts are that they are either graduate students with limited industrial experience, or project managers of some 4-10 years of experience who have been identified as members of a tracked development programme into more senior roles.

The contention here is that the numbers and diversity of individuals are sufficient that lessons can be drawn and passed on to a wider community, and suggest that individual discipline activity has no difference from the engineering student population in project management skills.

Class Rational

A substantial number of Project Managers control projects based on financial constraints generated from the "estimating/approval stages/construction" process, and as a result are responsible for the cash they request and spend. Alternatively, at the other extreme position, they are given a budget and then attempt to operate within that constraint.

Experiences of teaching on an in-house programme to a large group of Project Managers, who display a wide range of experience & responsibilities, has shown that the deep understanding of how money flows through projects, the cost of funding capital and the return on investment is very limited.

This paper will present the use of a project Simulation package designed to integrate Project Planning, Project Team effectiveness, Contract Management and Financial management, designed overcome that knowledge deficiencies.

To begin this process the programme commences with the teaching of a class in Project Management Principles class, which uses interactive simulation to test out student skills in project management. The class is set around a general review of tools and techniques, a use of case studies to develop the principles of:

• Defining the project

• Accountability of project delivery

• Co-operation between companies/stakeholders"

There is a particular focus on the relationship between project delay and coming in over budget and how that has a major business impact to client/project team/contractor etc. (Note the relevance here to the opening statements quoted from UKCS Oil and Gas Projects 2011-2016)

The class begins with a general review of project management principles in:

Introduction to Project management techniques and project control.
Basic aspects of project teams; project scope of work; network related management techniques; project features; project constraints and resources; quality assurance and document control.
Project networks: definition of events; activities and nodes; precedence networks and "activity on node" method; analysis of critical path.
Procedural and Graphical presentation techniques that are used as industry standard planning packages.
Introduction to Contract Law: formation of contract; validity; terms of the contract; breach of contract; agency; company contracts.
Project Budgetary control including cash flow, financial borrowing and investment

It then focusses on the task of running a defined project against standard parameters of completion, and the project value to the contractor with a interactive simulation that matches this last class topic of "Project Budgetary control including cash flow, financial borrowing and investment" which defines project management success in the author's view.

Project Simulation Scope

The project has to be completed within a measureable project timescale, quality and cost – meeting the theoretical units of project success. In any one class, there will be typically 6-10 groups and the class has been delivered on 12 occasions over the past six years. These groups are typically amorphous since they are mostly multi-disciplinary engineering graduates with some project management experience in a range of 3-8 years.

All groups complete a project where the individual resource and task values have a defined monetary value and with good project planning a profit is achieved over the project. The group is charged for resources and make claims for tasks completed. Variability in performance of individual groups is therefore as a result of the efficiency of resources use, including borrowing finances to fund the work. The measureable output will be the profit made in completing the project. This providing the common parameter of success of any project, whether it is measured at profit, ROR, ROI etc.

The project itself is not complex with a short critical path, and has a series of built-in penalties for delays. These only each representing 1.5% of the project value and 5-10% of project profit, yet it is surprising the exaggerated focus that project teams place on incurring these penalties.

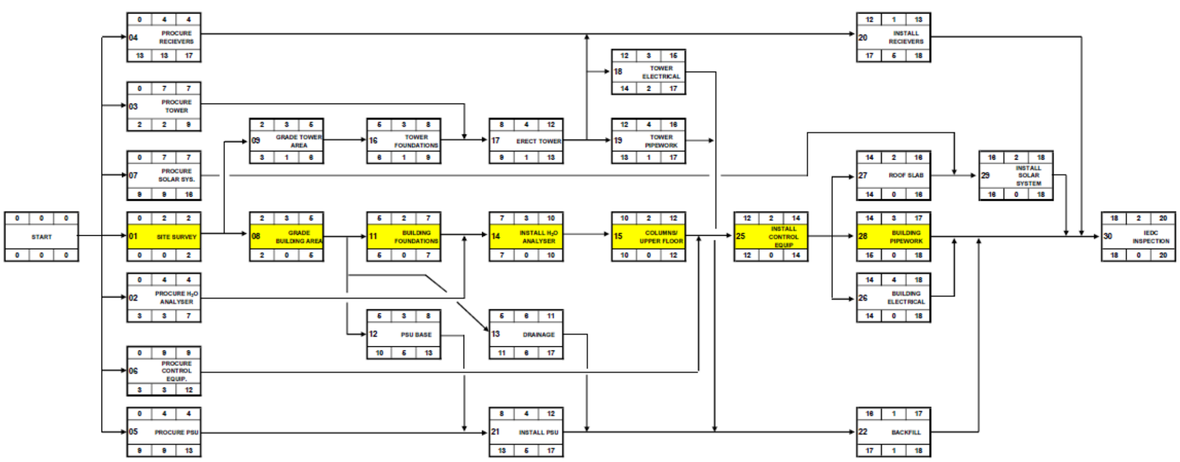

Fig 1: Project Network Analysis

Further variability that exercise project management skills and project costs are:

- 1/3 of tasks have "hidden duration fluctuations"
- If resources are not available when called for, they are provided automatically at a premium cost
- Terminated workers remain on-site longer than their notice period creating accommodation jams.
- Bank borrowing at favourable rates require fixed repayment schedules and if not in surplus, the project account is charged significant overdraft costs.

To add a greater challenge to the task, the real-time project week is of a 30-minute duration, with 5 minutes and the beginning and end of each period as processing time, this then require quick and "first-time correct decision making.

The real risk of failure is hidden in a large overhead cost, which over a 24-week programme will be 15 % of the project cost and the cost of finance, which could add 15-25 % of the project cost. These two factors need to be managed by the team and it is surprising how little focus is attached to it by them and on reflection at after-event reviews, the most often quoted excuse in their real time experience is that because that is all dealt with at Head Office"

Measures of success is based on the projects teams estimating abilities and the report:

1. At week 0: Projected Final Project Profit
2. At week 8, Revision 1: Final Project Profit
3. At week 16, Revision 2: Final Project Profit

The range of actual outcomes is shown in Table 2 below, with the highlighted detail being an estimate range that will carry "reward assessment marks". To add some "realism" to the task, additional reward marks are allocated on a competitive basis for "best profit"

This reward mechanism places an interesting effect on performance since the review process establishes that the student main drivers are:

1. Completion on time
2. Achieving the best profit over all other groups

The Actual Result should be in the range of $600- 800k and here four groups from fourteen achieve that level of success and there are four real failures at ~<$200k

Estimate & Final Value Report

TEAM	Estimate	Rev 1 @wk8	Rev 2 @wk16	Final Value ($k)
1	400	500	700	£526
2	589	310	323	£33
3	308	287	-705	-£484
4	930	400	250	-£453
5	480	290	400	£444
6	701	425	324	£661
7	560	180	215	£195
8	600	600	600	£681
9	550	200	170	£521
10	605	647	651	£644
11	350	730	635	£692
12	295	336	108	£162
13	350	550	150	£308
14	229	560	380	£206

(Highlighted:) Where estimate value with in ~15% of Final Value

Table 2: Typical Team performance metrics

Review of the performance of the simulation vs Original Learning Objectives

The classes formal teaching objectives are as follows:

Learning Objective 1

a) Be able to interpret a project specification
b) Prepare a bid document that demonstrates the effect & efficient use of project resources
c) Be able to understand the dynamics of managing specialists in a multi-disciplinary project team

Learning Objective 2

a) Complete a project work schedule and network analysis
b) Plan the allocation of resources

Learning Objective 3

a) Be able to modify an original project plan to cope with changing circumstances
b) Reallocate resources efficiently in the light of project variations
c) Understand the effect project variations will have on the project contract and the client/contractor relationship

It would be fair to claim that both the instructional, and then the practice parts with this simulation exercise meet all these objectives.

At the end of the exercise, we complete a feedback lessons-learnt session and some of the most common comments reasons for failure proposed are:

1. Those built into the system that require project team reaction and where not managed
2. Failure to adjust estimate revisions when information suggests significant variation is taking place
3. Group dynamic failure where the group sub-divides and do not share decision-making
4. Fundamental misunderstanding of the cost of money to finance a project and the impact of delay on ROI
5. Not understanding the effect on project cash flow of delays in progress payments vs outstanding expenditure costs vs bank interest charges
6. The drive to finish “first”

Conclusion

Since this class leads onto more detailed classes, covering Project Finance, Contract Law, and Risk, it achieves further objectives of being:

- A precursor to further studies
- Brings all students to the same base knowledge level
- Demonstrates that project management is a multi-skilled activity of planning, communications and cost controls.
- Reinforces that financial returns are the ultimate measure of project success.

In addition, much is this is more than adequately summarised in the following quotation:

Integrated project teams guide for use with DOE O 413.3A U.S. Department of Energy

“Federal Project Director Leadership: The act of assigning people to a cross-functional/cross-organizational group does not automatically create an IPT. Each IPT member comes with his or her own values, biases, and priorities. The FPD should not wait passively for collaboration to occur, but should be diligent in making the members aware of their inter-dependencies and collective interests:

- showing how each member contributes to the projects mission;
- communicating the importance of that mission;

and,

- rotating lead responsibility within the IPT based upon which member has the most knowledge and capability of the subject being addressed.”

References

U.S. Department of Energy: Integrated project teams guide for use with DOE O 413.3A https://www.directives.doe.gov/directives/0413.3-EGuide-18/view accessed 3/11/17

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What to Expect When You're Expecting
(A Major Organizational Change)

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ABSTRACT

When new parents are about to have their first child, they do a significant amount of research in order to understand all of the changes that will be coming. There will be changes to them personally, to their home, and of course, to their family.

The same principles are true when an organization is about to undergo a major change. The organization may be nervous about what will happen and what the impact will be for the future.

Much like a parent expecting a baby, being aware of what will happen throughout the major organizational change will help to provide a level of comfort and understanding. Information reduces uncertainty, and this translates into buy-in within the organization.

WHAT TO EXPECT WHEN YOU'RE EXPECTING

The book, What to Expect When You're Expecting is the longest running New York Times bestseller, with over 18.5 million copies in print. Why is this? Well it may be because it describes every conceivable issue that new parents would want to know about in order to be fully prepared for the pregnancy, and during childbirth.

For some parents, the book is overkill and a scary game of "What Could Go Wrong?" For others, it helps to ensure proper planning and provides strategies for mitigating the various risks. The book is organized into trimesters and thoughtfully articulates an answer for every question you may have.

WHAT TO EXPECT WHEN YOURE EXPECTING A MAJOR ORGANIZATIONAL CHANGE

Unfortunately, there is no corresponding book for what to expect during a major organizational change. You may think that if the CEO of your organization requests the change, the change will magically happen and all will be well. But this is not true. Organizational change needs nurturing and constant support, just like an expectant mother.

Every organizational change is different, and will be handled differently based on the change and the organization. However, the change life cycle of: identifying the change, getting buy in, implementing the change and then reviewing the impact of the should be constant.

Twinkle in Your Eye – Identifying the Need for Change

When someone in your organization gets the hint of an idea that they would like to implement that is different from the current standard, this is similar to prospective parents determining if they are ready to start a family. During this phase, there are idealistic visions of what the change will be like, once realized. When people say "this change will revolutionize the company", this is similar to parents talking about how their hypothetical child will win the Nobel Prize, or find a cure for cancer.

And just like not every child grows up to win the Nobel Prize, not every change will have the sweeping benefits that were originally anticipated. What can be anticipated, however, are the reactions that may result from the change. If the change includes a reorganization or a shift in workload or work product, those issues should be addressed and discussed openly and frequently with the staff impacted by those issues.

Researching what to expect, who can help, and identifying information sources that provide insightful strategies and tactics increase the opportunity for a successful change process.

Getting Ready for Change – Getting Buy In

Change is hard. Two key things to making the change more tolerable are: thoughtful and constant communication of the change, and identifying your change agents.

Communication

Communication is important for socialization of the change. If the change you are considering will have a major impact on your staff, you need to discuss the change early and often. And as part of this process, you should be transparent and discuss both the benefits and the drawbacks to the change. You should also identify multiple strategies for communication such as "townhalls", change bulletins, vlogs, email updates, etc. The key is to target everyone that will be impacted in a method that will engage the stakeholder.

When you bring a new sibling into a family, you have discussions with the current family members. You may have to have a conversation where you explain "Yes, you will have to share a room, but you are gaining a sidekick that will always look up to you."

If the change is going to have a perceived negative impact, you should discuss that openly as well. To some, all change is negative. So, you should explain the total impact in order to lessen any potential surprises.   If the system is going to look different and require training to use, but replaces something antiquated that the organization needs, then make that case again and again.

Change Agents

To help in implementing the change, your organization should identify your change agents. These change agents will be the biggest advocates for the organizational change. They will likely also be the implementers of that change, helping to provide training and constant reinforcement about the need for change.

Your change agents can come from within your organization, or can be external, depending on the will of the organization. Some organizations choose to bring in external parties to identify the need for the change and then share that with the rest of the organization. This is typically done so that those change agents can be the "bad guys" and then leave once the change has been implemented. Other organizations find their change agents internally, as they know that the change does not end at implementation, but rather remains ongoing and it can be more successfully implemented with known, trusted agents. Essentially, you need people who will advocate for the change and influence the opinions of those individuals that are opposed to or unsure about the change.

Response Plan

The vast majority, about 70%, of organizational changes fail. In addition to improved communication, another method for mitigating impediments to change is to leverage input from change agents and stakeholders to identify a response plan. This plan will identify the actions to take in the event certain issues start to arise and typically involve your communication strategy and change agents.

The Due Date Has Arrived – Implementing the Change

The time has come to implement the change. The timing of your implementation may be based on external factors, like the system you are using is out of date and going to be discontinued. Or it can be based on internal factors, like the best time for your organizational change aligns to a new fiscal year.

In either case, your organization needs to plan for the day the change is kicked off. Expecting parents likely have a travel bag ready and the best route to the hospital identified at various times of day. The change agents of an organization need to have announcements ready for the day of the change that can be sent at intervals as reminders that the change has occurred and why.

And though everything has been planned out, there still may be hiccups. People may have forgotten the change was occurring. Or maybe they are still in denial. In any case, your change agents should kick in to gear with reassuring words for those employees, and a reminder that, though change is difficult, everything is going to be ok.

Post Change Depression – Reviewing the Impact

Sometimes, though precise plans were made, and the change is having the desired impact, people may still not be happy. Think about how your eldest child reacts to a new sibling, and you will understand this phenomenon.

After the change has been implemented, both sets of staff need support: the change agents and those impacted by the change. The change agents will take the brunt of the response regarding change, and will likely be blamed for the reason the change took place. They may hear things like "everything was just fine until you came along". And though your change agents have been prepared to be the lead communicators, too much pushback can be trying. Executive management needs to be prepared to publicly support the change, and the change agents throughout the process. This is particularly important if the change agent was internal to the organization, since employees will likely always remember the day that change agent disrupted their processes with new ideas.

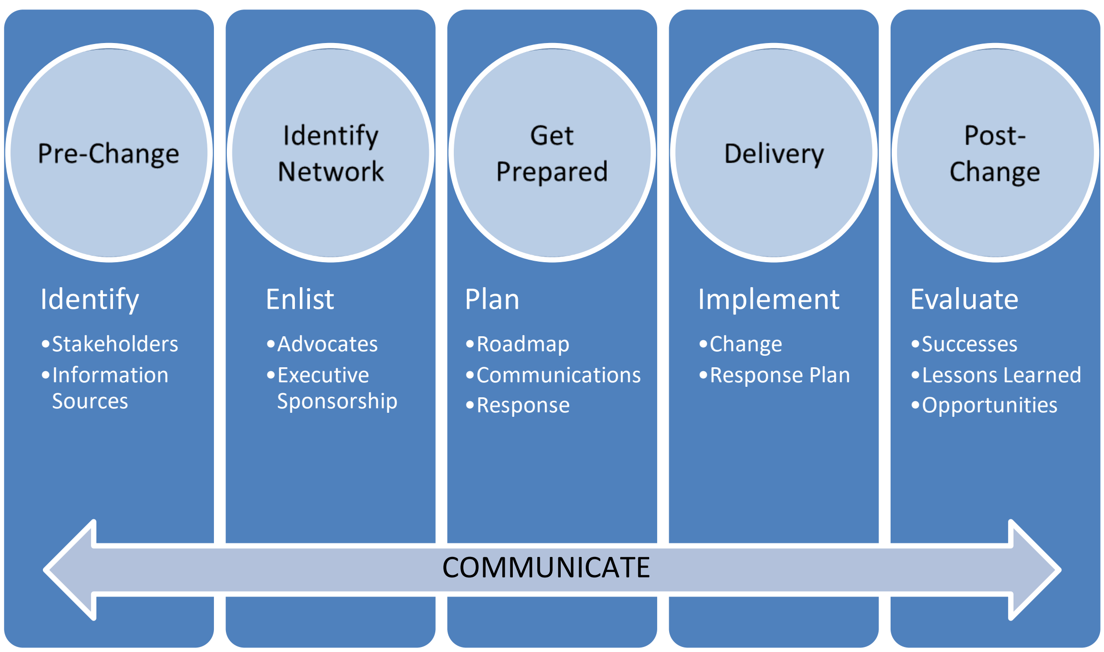
Even while supporting the change agents, there needs to be a continual acknowledgement for those impacted by the change. The acknowledgement shouldn't be "those darned change agents", but instead needs to be reassurance about why the change was needed, and why the benefits outweigh the costs.

Transparency and communication should continue post implementation. Stakeholders should be engaged by providing them with information and allowing them to contribute towards identifying the successes, mistakes, opportunities, and other lessons learned resulting from the change.

CONCLUSION

Much like expectant parents benefit from a roadmap of what will occur throughout pregnancy and during childbirth, so too would organizations benefit from a roadmap explaining what to expect when implementing a major change.

Every organizational change is different, and will be handled differently based on the change and the organization. However, the change life cycle of: identifying the change, getting buy in, implementing the change and then reviewing the impact of the change should always be considered.



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