Addressing Inadequate Investment in School Facility Maintenance

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Abstract

School facilities where both students and teachers struggle with such issues as noise, poor indoor air quality, poor lighting and even physical security concerns is unlikely to be conducive for learning and teaching. The total deferred maintenance of schools in the United States was estimated at $254.6 billion in 2008. With over 94,000 public elementary, middle and high schools being attended by more than 50 million students, there is need to implement an effective method for estimating the adequate amount of investment for facility maintenance. Earlier methodologies were evaluated and a new plant value model was developed. The model also introduces a commensurate increase in annual budgets to address maintenance backlog, as well as strategies for setting maintenance priorities. Finally, to effectively maintain building conditions, appropriate custodial and maintenance staffing is analyzed for school facilities. Establishing appropriate annual maintenance budgets for school buildings, including the resources necessary to address accumulated maintenance backlog is critical for upgrading school facilities to adequate conditions for ensuring the health and performance of US teachers and students.

1.0 __Introduction__

Inadequate investment in school facility maintenance in the United States has led to a scenario where there are a significant number of facilities with need for major repair and renovation. The American Society of Civil Engineers (ASCE) in their "Report Card for America's Infrastructure" gave school infrastructure a D grade in the 2005 and the most recent 2009 editions. This was an improvement from the D- grade given in 2001 and 2003, and the F grade of 1998. While the trend is positive, the need to more adequately invest in school facility maintenance remains critical for a number of reasons.

Schools are centralized locations where learning is encouraged and both subjects and values are taught. As educating the next generation is a critical need for every society, it is imperative the school environment is conducive for learning. A school facility where both teachers and students struggle with such issues as noise, poor indoor air quality, poor lighting and even physical security concerns is unlikely to be conducive.

Lawrence (2003) pointed out that poorly maintained school facilities may have adverse health and safety impacts in causing asthma attacks, drowsiness, lethargy and a resulting inability to concentrate. The study also expressed that poor school facility conditions negatively impact staff and student morale. Another study (Cash, 1993) found schools with better facility conditions had higher student achievement scores.

With over 94,000 public elementary, middle and high schools being attended by more than 50 million students (U.S. Census Bureau, 2006), there is need to determine and/or implement an effective method for determining the adequate amount of investment for facility maintenance. The National Research Council (NRC) of the National Academy of Sciences (NAS) in a 1990 report determined an appropriate budget allocation for routine maintenance and repair should be in the range of 2 to 4 percent of the current replacement value of a facility. Ottoman et al (1999) summarized numerous models that have been developed and evaluated their estimating approaches. They included plant value, lifecycle, condition assessment and other methodologies. This paper presents a new model that attempts to better factor the critical parameters that should be considered in determining facility maintenance investment needs. Such parameters include the age, complexity, material and the functional spaces of a facility among others. Also, considering school facilities in the United States have accumulated a significant maintenance backlog, there is a need to prioritize building system renovations and improvements based on criticality.

Additionally, while it is important to adequately invest in school facility maintenance, it is also necessary to appropriately staff the school facilities with custodians and maintenance workers. This is in order to effectively maintain and monitor building conditions. This issue along with other developments such as, the outsourcing of facility maintenance, need to be investigated to better identify the path towards improved conditions in the nation's school facilities.

2.0   The Scale of the Challenge

2.1   The Current State of America's Public School Facilities

There are more than 94,000 public elementary, middle and high schools in the United States, a significant percentage of which are in a condition requiring major repair and renovation. A 2006 research report from Healthy Schools Network, Inc. assessed the conditions of American public school facilities on a state by state basis. They found the percentage of schools with at least one inadequate building feature ranged between 37 percent in Georgia to 91 percent in the District of Columbia. The average range was 50 to 59 percent. This report alludes to the poor state of public school facilities nationwide. Many states have conducted condition assessments of their school buildings. In 2003, the State of Maryland determined $3.85 billion in local and state funds will be required to bring their public schools to the minimum building and education standards that would be in place if they were constructed in the present day. North Carolina (2006), through a five year facility needs survey of their over 2,600 schools estimated $2.27 billion was needed in renovations cost. Arkansas (2004) also estimated $2.28 billion in renovation cost for their public school facilities. This is represented in *Figure 1*.
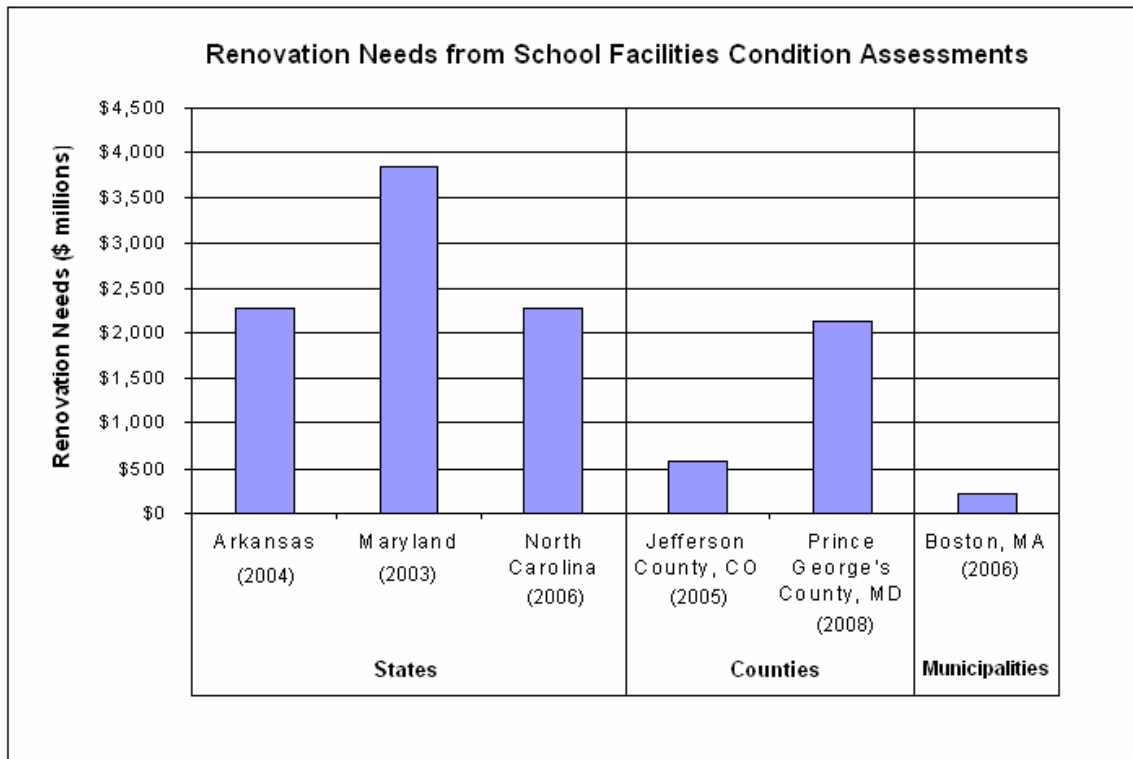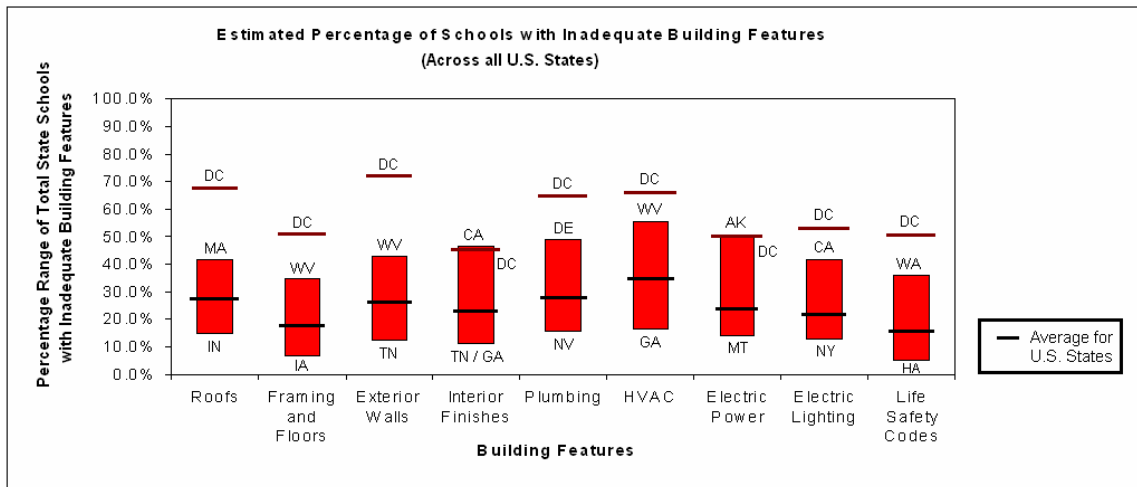

Figure 1

Many counties and cities have also conducted condition assessments of their schools. Prince George's County of Maryland (2008) alone estimated $2.13 billion would be required to repair and renovate its 184 elementary, middle and high schools. Another county, Jefferson County of Colorado (2005), documented $577 million to meet the renovation needs of its school districts. On the city level, a study of Boston public

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schools (2006) estimated $200 million would be required to renovate 83 percent of the city's schools, which all have repair needs.

A 1996 study by the U.S. General Accounting Office (GAO) estimated the percentage of schools in each state with less than adequate building features. For exterior walls, finishes, windows and doors, the range was between 13 percent for Tennessee and 72 percent for the District of Columbia with an average of around 25 percent. For Heating, Ventilation and Air Conditioning (HVAC) systems, the range was between 19 percent for Arkansas and 66 percent for the District of Columbia with an average around 40 percent. The ranges for other inadequate school facility features are also very indicative of substantial renovation needs. The District of Columbia stands out with the highest percentage of most types of inadequate building features. This is as seen in *Figure 2*.

[Source: GAO (1996)] **Figure 2**

Conclusively and collectively, the assessments and studies allude to the poor conditions of the nation's school facilities.

2.2   Importance of Addressing Poor School Facility Conditions

There are ramifications to the utilization of school facilities in inadequate conditions. Firstly, there is the ramification associated with the very function of schools, the learning of subjects and values. A school facility where both teachers and students struggle with such issues as noise, poor indoor air quality, poor lighting and even physical security concerns is unlikely to be conducive for this very function. Student achievement could thus be impacted. Cash (1993) found schools with better facility conditions had higher student achievement scores. A study by Edwards (1991) found students attending schools in poor condition in Washington, DC had achievement that was 11 percent below schools in excellent condition and 6 percent below schools in fair condition. Additionally, Earthman (2002) stated a difference of between 5 and 17 percentile points has been repeatedly found between achievement of students in substandard buildings and those in standard buildings even after the socioeconomic status of the students is statistically controlled.

A related ramification to the first is a negative impact on school attendance. In a 2008 study of New York City public schools, Duran-Narucki (2008) found attendance was a mediator for student achievement. Students in run-down school facilities were found to have attended school fewer days on average and had lower grades in standardized tests. Bosch (2003) also alluded to the adverse effect of poor school conditions on student attendance and achievement.

Ethnographic and perception studies have also indicated inadequate school facilities adversely impacting teacher effectiveness and performance thereby negatively impacting student performance (Earthman, 2002). In the same vein, Lawrence (2003) expressed that poor school facility conditions negatively impact staff and student morale.

Another ramification is the adverse effect on teacher retention and recruitment. Buckley et al (2004) determined school facility quality affects the likelihood that teachers will leave a school. Furthermore, the results from a survey of 456 New Jersey principals (2004) indicated only half reported their school as very adequate for recruiting and retaining teachers. Buckley et al (2004) also expressed improving school facility quality could be a more cost-effective teacher retention strategy than a permanent salary increase for teachers on the medium to long term.

Negative health and safety impacts constitute perhaps the most significant ramification of inadequate school facilities. Lawrence (2003) pointed out that poorly maintained school facilities may have the effect of causing asthma attacks, drowsiness, lethargy and a resulting inability to concentrate for both students and teachers. Graham et al (2006) also reported schools with highest rates of leaks, mold and pest infestations were found to have higher than average asthma rates for students in Boston public schools. The report also stated poor indoor air quality in school buildings could lead to problems ranging from allergies to sinus infections which can adversely affect the teaching effectiveness of teachers and the academic performance of students.

These ramifications collectively highlight the importance of addressing the poor conditions of the nation's school facilities. With more than 50 million students attending the 94,000 elementary, middle and high schools in the U.S. (U.S. Census Bureau, 2006), it is critical to identify the cause and define measures to improve the situation.

2.3   Inadequate Investment in School Facility Maintenance

Expenditure by school systems and districts must stay within the limit of their available funding. As such, there is a budget constraint. When there are needs deemed to be more important, those needs take priority in funding. Furthermore, where a cost item is deferrable, it may be deferred in favor of a more "immediate and important" need. School facility maintenance has been subject to deferral by school systems in favor of building new schools and making additions to existing schools. Throughout the lifecycle of the school facilities, portions of funding intended for maintenance have tended to be deferred or reassigned. This continuously accumulates the total amount of deferred maintenance

thereby resulting in poorly maintained school facilities. This circumstance is applicable to most school systems throughout the United States. As such, the poor conditions of the nation's schools are in large part due to inadequate investment in facility maintenance.

As discussed earlier, the amount of deferred maintenance of the nation's schools is substantial. Crampton and Thompson (2008) estimated the total need across the United States at $254.6 billion. The study found the funding need ranged from $326 million in Vermont to $25.4 billion in California with the average state funding need at approximately $5.1 billion.

It has already been highlighted that utilizing school facilities in poor conditions has adverse effects on student achievement, student attendance, teacher effectiveness, teacher retention and recruitment and, occupant health and safety. Accumulated deferred maintenance tends to have a significant undesired outcome, the disposal of a facility. This tends to be the decision at the point where maintenance needs seem too substantial to justify renovation over replacement. A very common metric used in determining this stage is the Facility Condition Index (FCI) as expressed in *Equation 1*.

$$\text{Facility Condition Index (FCI)} = \frac{\text{Deferred Maintenance (Current Cost of Repairs)}}{\text{Replacement Value}}$$

Equation 1

The School Facilities Condition Assessment (SFCA) of different states and counties set different FCI scores for determining the school facilities that should be replaced and not renovated. This is as seen in *Figure 3*. The State of Montana's SFCA (2008) specified buildings with an FCI that exceeds 50 percent were to be considered to be experiencing such levels of failure that the merits of reinvestment in the existing structure be carefully considered. The State of Arkansas's SFCA (2004) meanwhile recommended an FCI of 65 percent to determine replacement over renovation. Over 7 percent of Arkansas elementary, middle and high schools were determined to fall into this category. The SFCA (2008) of Prince George's County of Maryland expresses to consider replacing and not repairing a school when its FCI approaches or exceeds 75 percent. Most of the county's schools lie between an FCI range between 40 and 75 percent.

Additionally, the SFCA also estimated the current average FCI of all schools to deteriorate by 16 to 24 percent over the next 10 years if no funding is applied to renew expiring facility systems. It is evident the lack of adequate annual investment in school facility maintenance is leading to earlier facility disposal. In effect, facility maintenance investment is being deferred in the interest of investing in new facilities and additions to account for increased enrollment and the result, is the disposal of existing facilities. This is clearly counterproductive. And since new facilities and additions already account for a more significant percentage of the annual budget of many school systems, it is not justifiable to defer facility maintenance in that interest. Even when North Carolina's SFCA (2006) estimated the state's five year school facility needs, only 23 percent was determined for renovations while 44 percent and 23 percent were determined for new schools and additions respectively.
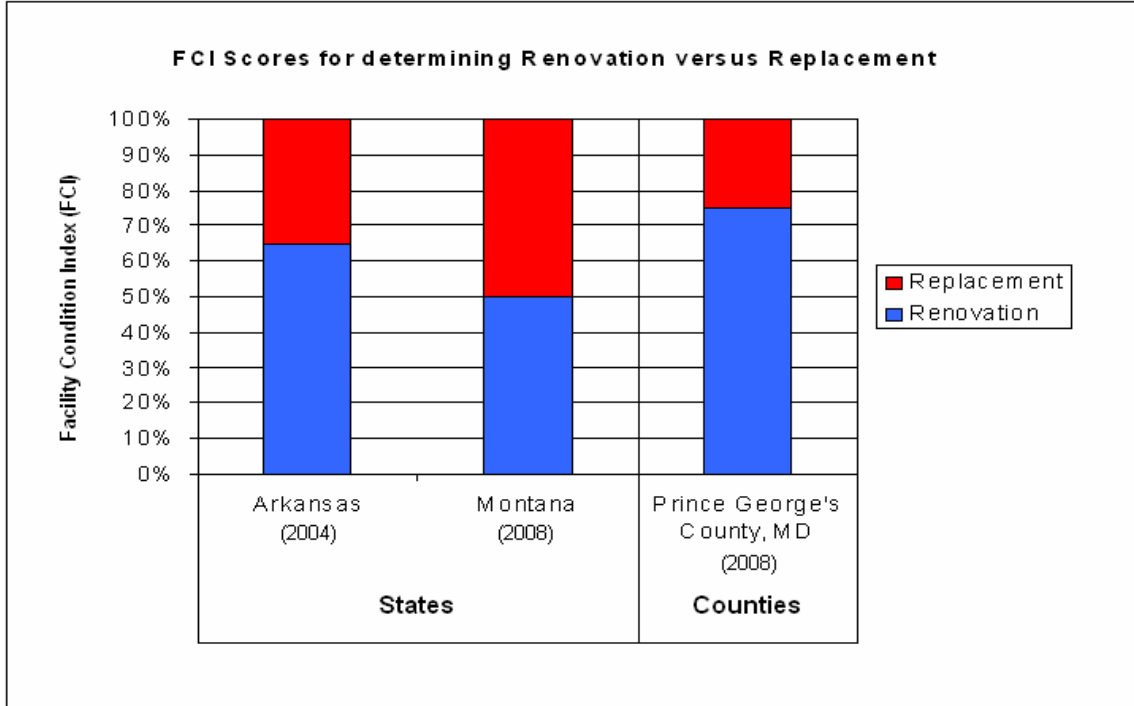
Also, different school facility condition assessments set different FCI scores for schools considered to be in poor condition. The State of Montana's SFCA considered those schools with an FCI greater than 20 percent as being in poor condition. Tolk (2007), Hirai et al (2004) and, Edgar and Telcholz (2001) meanwhile expressed an FCI greater than 10 percent to indicate a facility in poor condition. Using these scales mean a substantial percentage of school facilities are in poor condition and are therefore subject to possible negative effects on student achievement, student attendance, teacher performance, occupant health and safety, teacher retention and recruitment.

Though school facility conditions will deteriorate due to normal wear and tear and also functional and technical obsolescence, the degradation would be faster without adequate investment in facility maintenance. This is lost facility service life. According to NRC (1998), once this service life is lost due to deferred maintenance, the loss is irreversible, performance is sub-optimized, and capital renewal becomes necessary to restore the facility to a minimum level of acceptable performance. An illustration of this scenario is seen in *Figure 4*. This is a modification of the graph by Tolk (2007). The graph illustrates the fact that adequate facility maintenance may substantially extend the service life of a facility. It also illustrates optimum performance as unlikely to be sustained if ever attained.

Considering the negative impacts associated with inadequate facility maintenance investment and deferred maintenance, it is important to ensure allocations slated for maintenance actually serve that purpose despite other priorities. Even a single deferral may prove to have as far reaching and as numerous adverse effects as those earlier discussed. Accordingly, the damage due to facility maintenance deferral very likely exceeds the initial benefits.

Service Life with and without Normal Maintenance
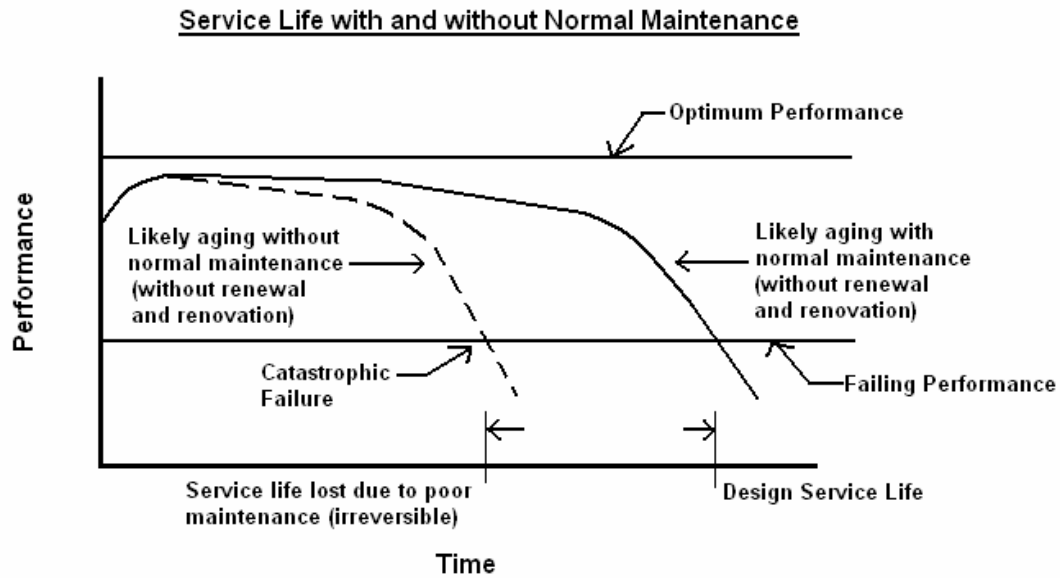
[Source: Modification of Tolk (2007)] **Figure 4**

Over the past decade, the attention of many governments and agencies has been drawn to the poor condition of the nation's elementary, middle and high schools. There appears to have been a positive effect. The American Society of Civil Engineers (ASCE) in their "Report Card for America's Infrastructure" gave school infrastructure a D grade in the two previous editions, 2005 and 2009. This was an improvement from the D- grade given in 2001 and 2003 and, from the F grade of 1998. Furthermore, the American School and University Magazine in its annual maintenance and operation cost studies has indicated a general increase in total facility maintenance and operation budget from 2001 to 2009 for the nation's public school districts. This increase is however inadequate to address the accumulated maintenance backlog over the lifecycle of the school facilities. Deferred maintenance is after all, more prevalent during the earlier years of a facility's service life when the facility is in good functional condition. In 2000, the average age of school buildings was determined to be 40 years (NCES, 2000). Since the condition of school facilities is still assessed as poor, it is apparent the increase in maintenance investment over more recent years has not accounted for the maintenance backlog. As such, there is a need for more adequate investment to address both maintenance and backlog, to avoid the catastrophic failure of the nation's school facilities and their components. In the interest of increasing the longevity of all school facilities, it is imperative to establish a method that differentially considers the key features of any school building.

Adequate staffing for maintenance is another necessary component of facility maintenance. Maintenance workers and custodians are required to monitor the conditions of the school facilities and, to conduct the maintenance and repairs. The amount of staffing for maintenance may thus have a significant impact on the effectiveness of the school facility maintenance investment. Thus, the adequate staffing for school facility maintenance must be specified and the skill needs accounted for.

Some school systems have opted to invest in school facility maintenance through outsourcing. This approach has its advantages and disadvantages which must be evaluated on a facility by facility basis to determine its effectiveness as a strategy for maintaining the conditions of the specific school facilities.
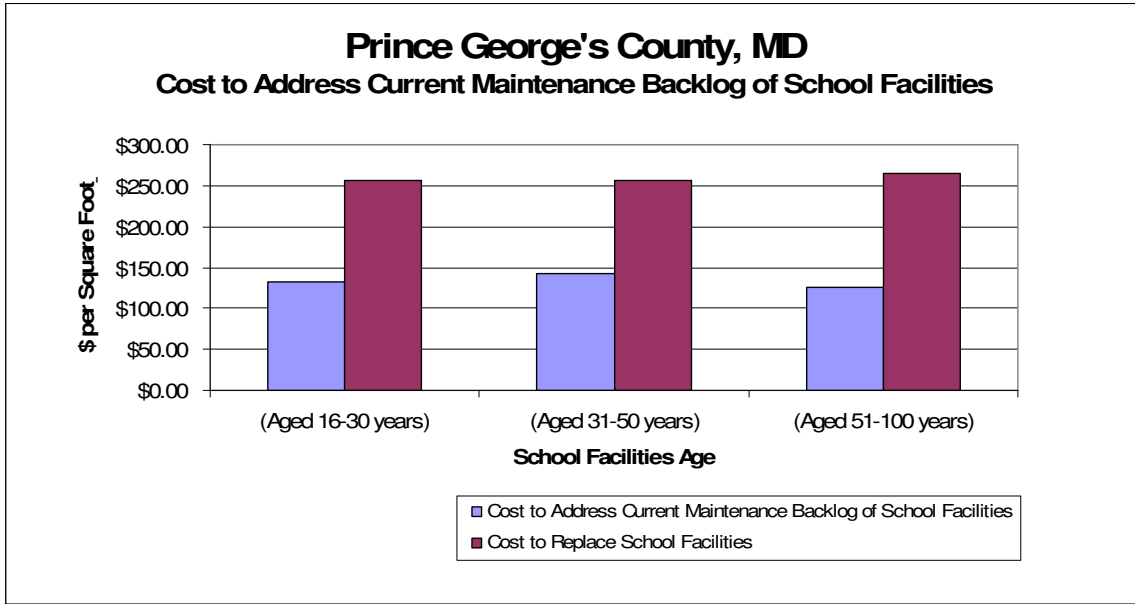
2.4   Renovation versus Replacement

As earlier expressed, facility administrators and owners have different specifications for when to replace their facilities as opposed to renovating them. This is also the case when it comes to school facilities. States and counties have set different FCI scores for determining when school facilities should be replaced. The State of Montana school facilities condition assessment (2008) recommended that when the current cost of repairs or deferred maintenance is more than 50 percent the cost of replacement, the school facility should be considered for replacement. Meanwhile, the SFCA of Prince George's County of Maryland (2008) recommends replacement when repair cost exceeds 75 percent of replacement cost. There are however some important issues that must be considered before deciding to proceed with facility replacement. These issues are the arguments for renovation.

The first argument is replacement results in lost historical value. This is especially true for buildings with distinct features or high levels of craftsmanship. Schenley High School of Pittsburgh, PA fell into this category. The main school building was built in 1916 and was the first high school to cost more than $1 million in the United States. Designed with a triangular footprint, it was constructed of Indiana limestone and with a high level of detail. The school building was listed on the National Registry of Historic Places in 1986. Over time, there had been additions to the school building. However, by 2006, there was substantial maintenance backlog that had been accumulated over its nine decades of service. It experienced severe structural maintenance problems and the Pittsburgh school board found it too costly to renovate the school building to adequate service conditions and voted to close it down. Schenley High School was closed down in 2008 and the students were moved to a previously shut down school facility which had been found more financially feasible to renovate, the Pittsburgh Reizenstein Middle School facility.

Among the SFCA of the different states and counties considered, only that of Arkansas (2004) expresses that exceptions should be considered when it comes to facilities of historical significance. After all, historical value cannot be replaced. This condition assessment further mentions another factor to consider before the replacement or decommissioning of a facility, the potential for other functions.
Arkansas's SFCA (2004) determined that over 7 percent of its elementary, middle and high schools were to be considered for replacement. With 1,205 schools and 5,766 school-related permanent buildings, this would be a substantial investment that has to be spread over a number of years to make financially viable. It is more economical to renovate school facilities than to replace them especially when it comes to large portfolios of facilities. The SFCA of Prince George's County of Maryland (2008) determined it would cost roughly twice as much to replace than to renovate a school facility. This is seen in *Figure 5*.

The replacement of a school facility can also impact other school facilities in the portfolio. Replacing one school facility would increase budget constraints for a school district. These budget constraints create a condition more likely to cause deferred maintenance. Ultimately, a new school is built providing its students and teachers with adequate conditions while the students and teachers of the other schools endure even poorer conditions. The greatest good would be to improve conditions for all schools rather than to provide one new school with adequate conditions.

Given that replacing all the nation's school facilities is neither a feasible nor an effective measure, it now becomes important to identify methodologies that can be used in determining the annual investment needed to not only maintain but to improve their conditions.

3.0   Determination of Adequate Investment for Facility Maintenance and Backlog

Investment for addressing facility conditions is in 3 tiers. These include maintenance, renewal and repair. Maintenance refers to the continual upkeep of a facility in its current condition. It constitutes all actions required to sustain effective operations of facility systems as installed. Renewal refers to the scheduled replacement or restoration of facility components that have exceeded their service life. Repair meanwhile refers to the restoration of facility components to operational conditions after an unpredicted or unforeseen failure.

In this paper, facility maintenance investment refers to regular maintenance, renewal and repair funding. This is not inclusive of operational utility bills and staffing costs. Backlog

meanwhile refers to under funded maintenance, renewal and repair budget. Investment in backlog therefore refers to funding to account for inadequate, deferred or reassigned maintenance, repair and renewal funding. The elimination of backlog is expected to renovate facilities to design service conditions.

Models and methodologies have been developed to determine investment needs for facility maintenance, renewal and backlog. Each addresses different facility attributes and has different characteristics. These earlier models must be investigated to either determine or develop an effective method of estimating the appropriate investment level for addressing facility maintenance and backlog.

3.1   Features for Determining Facility Maintenance and Backlog Investment Needs

Montecrecy (1985) and Tolk (2007) determined various models yielded substantially different results. The facility features they factor and the extent to which they factor them play a role in this. It is imperative to account for certain facility attributes in determining the maintenance and backlog investment needs for individual and portfolios of facilities.

NRC (1990) determined factors that can have a major influence on the appropriate level of maintenance and repair expenditures to include: building size and complexity; types of finishes; current age and condition; mechanical and electrical system technologies; telecommunication and security technologies; historic or community value; type of occupants or users; climatic severity; churn (tenancy turnover rates); criticality of role or function; ownership time horizon; labor prices; energy prices; materials prices and; distance between buildings in facility inventory. Another study (Ottoman et al, 1999) identified facility maintenance and repair cost estimating criteria utilizing substantial literature review. The determined criteria included: facility replacement value; age; size; type; location; type of construction; condition; lifecycle; climate and; deferral penalty cost.

Evident by the facility features included in numerous studies, certain factors are generally considered to be important and among them, some are considered to be most critical. Tolk (2007) compiled a summary of facility attribute data arranged in order of times mentioned in relevant literature. The study documented the most commonly cited attributes in order of frequency. They included: facility age; type; size; system technologies; use; current replacement value; current condition; location; system lifecycle cost and; facility system costs.

To determine attributes of a facility portfolio that directly affect maintenance and repair costs, Monterecy (1985) first documented the eight most often cited reasons by facility portfolio managers as being the cause for having a deferred maintenance backlog. The reasons included age of physical plant, high energy cost, ability to pay, poor construction quality, lack of facility planning, demographic changes, compliance with federally mandated improvements, and lack of maintenance staff. After performing a multiple

regression analysis using the reasons as predictor variables, Monterecy (1985) found only three of the eight variables were related to actual accrual of deferred maintenance namely; facility age, facility planning, and construction quality. He also found age, size, and CRV had the highest correlation to maintenance and repair funding.

Facility features considered important in all these studies could be influential in determining the appropriate expenditure for addressing facility maintenance and backlog. A model or methodology that appropriately factors all features impacting the determination of the actual facility maintenance and backlog investment need is most likely to obtain an accurate estimate. It is therefore imperative the most critical features are accounted for in order for a methodology to be effective. Furthermore, issues relating to feasibility of use must be taken into consideration.

3.2   The Need for a New Model

The need for a new model stems from the need for a model to not only serve the purpose of determining the adequate amount of investment for addressing facility maintenance and backlog but to meet certain attributes that would encourage its use.

With regards to how the earlier developed models meet the functional requirements, a comparative assessment was conducted. The most cited facility attributes as determined by Tolk (2007) were used as part of the assessment criteria. This set of facility attributes were selected because the conducted literature review was very broad, recent and included evaluations of multiple highly cited papers that had listed facility features considered to be critical in determining maintenance budgets. The literature reviewed included the NRC (1990) and Ottoman et al (1999) studies.

Also included as assessment criteria are facility planning and construction quality, they were found to be related to actual accrual of deferred maintenance by Monterecy (1985). Budget constraint was also included as an assessment criterion due to the Monterecy (1985) and NRC (1990) studies. The first study found ability to pay and high energy cost to be among the most cited reasons for the accumulation of maintenance and repair backlog. Both reasons allude to budget constraint. The latter study also determined energy prices can have a major influence on the appropriate level of maintenance and repair expenditures. Lastly, the current plant value was included as an assessment criterion. This was because of the multiple inclusions of cost of construction in different literature. Furthermore, the original cost of a facility serves as an indicator of the quality of construction. Typically, the original cost of a facility is time adjusted to be applicable.

	Model Categories	Models	Age of Facility	System Technologies Complexities	Construction Quality	Use / Functional Demand	Type of Facility	Size of Facility	Location of Facility	Current Condition / Deferred Maintenance	Current / Plant Replacement Value	Current Plant Value / Initial Acquisition Cost	System Replacement Cost	System Lifecycle Cost	Facility Maintenance Planning	Budget Constraint
		Important Facility Attributes for Determining Facility Maintenance Budgets														
	Facility Maintenance with Backlog Investment															
1.	Plant Value Methodologies	PRV Model				●	●	●	●		●		●			
2.		CPV Model	●	●	●		●	●	●			●	●			
3.		Coast Guard Methodology				●	●	●	●	●	●		●		●	●
4.	Life Cycle Cost Methodologies	Phillips Model	●	●							●		●	●		
5.		Dergis-Sherman Model	●	●	●		●	●	●	●		●	●	●		
6.	Condition Assessment Methodologies	Army ISR Methodology	●	●		●	●	●		●	●		●	●	●	
7.		Beach et al (1998)			●					●			●	●	●	●
8.		BUILDER Model			●	●	●	●		●			●		●	●
9.		IMPACT Model						●		●			●		●	●
10.		NASA BMAR Model				●	●	●	●	●	●		●			
11.		University of Virginia Model				●	●	●	●	●	●		●		●	
12.	Other Maintenance with Backlog Models	Incremental Budget Model													●	●
13.		AME Methodology	●			●	●	●	●	●	●		●	●	●	●
14.		Square Foot Model				●	●	●	●							
15.		FISC Model	●			●	●			●			●			
16.		NRC Model (2004)		●		●	●	●	●	●	●		●			
17.		Navy LRMP System	●			●					●		●	●	●	
18.	Summation Methodology	Bello Summation Model	●	●	●	●	●	●	●	●	●	●	●	●	●	●
	Facility Maintenance without Backlog Investment															
19.	Life Cycle Cost Methodologies	DOD Sustainment Model	●	●		●	●		●				●	●	●	
20.		Leslie-Minkarah (1997)	●	●	●	●	●			●			●	●		
21.		UNIFORMAT Model		●		●	●	●	●	●	●		●	●		
22.		Stanford Model	●	●		●	●						●	●	●	
23.		Turner (1996)	●	●		●	●	●					●	●	●	●
24.		MRPM Model	●	●		●	●	●					●	●	●	
25.		Christian-Pandeya (1997)	●	●	●	●	●	●	●			●	●	●		●
26.	Other Maintenance without Backlog Models	Tolk (2007)	●					●								

Table 1

The earlier developed models and methodologies were assessed to determine whether they directly or indirectly account for the selected assessment criteria. The assessment, seen in *Table 1*, found only one methodology met all critical facility attributes, the Summation methodology. It is however important to note this methodology does not provide for a fixed guideline. This is because a key component of the model, the

estimated annual facility maintenance need (EAFMN) is determined by the predictive model utilized. As such, any methodology may be used in producing this value. Thus, the facility features it accounts for in the assessment are actually the facility attributes it could account for depending on which model is used in determining the EAFMN.

To determine the feasibility of effectively utilizing the models to determine adequate annual facility maintenance and backlog investment for schools and other facility types, another assessment was conducted. This was to determine whether each model possessed the attributes of an effective model. Dergis and Sherman (1981) and Monterecy (1985) developed such sets of attributes. The first study listed five attributes while the latter listed ten. Some of the attributes highlighted in both lists were identical or very similar. The attributes from both lists were consolidated to derive a set of attributes to define a model that can be effectively and feasibly used. The most critical of the attributes was identified as easily obtainable model data. This is because data that is difficult to obtain is a major obstacle to implementing more accurate estimation methods. Many organizations do not find obtaining the model data worthwhile and as such resort to estimation based on the previous year's maintenance and repair expenses which if inadequate; causes continued inadequacy. The consolidated set of attributes used as the assessment criteria for earlier models and methodologies is seen.

1. It must utilize quantifiable input data which are easily obtained.
2. It must be simple to apply.
3. It should be generally applicable and promote equitable treatment of all institutions using the formula. It must also be objective.
4. It must be easy or simple to understand.
5. It must be self-adjusting. It must therefore be flexible to meet a changing budget environment.
6. It must be reliable. It must thus allow comparison of results to other users.
7. It must provide an adequate, but economical budget level.
8. Input should bear an acceptable and logical relationship to physical plant function.
9. It must define precisely the functions and costs of resource allocation. It must preserve management flexibility.

Seen in *Table 2*, the assessment depicted none of the models possessing all the attributes of an effective model. A model that not only possesses all the attributes of an effective model but accounts for all the important facility attributes for predicting maintenance budgets would be the adequate model. Since this was not achieved by any of the models, there remains a need to develop one definitive model that would meet more, if not all the attributes.

	Model Categories	Models	Easily Obtained Data	Simple to Apply	Generally Applicable	Simple to Understand	Self-Adjusting	Reliable	Economical Budget Level	Logical Functional Relationship	Define Function of Resource Allocation
	Facility Maintenance with Backlog Investment										
1.	Plant Value Methodologies	PRV Model	●	●	●	●	●	●	●	●	
2.		CPV Model	●	●	●	●	●	●	●	●	
3.		Coast Guard Methodology		●		●	●			●	●
4.	Life Cycle Cost Methodologies	Phillips Model		●	●	●	●		●	●	
5.		Dergis-Sherman Model	●	●	●	●	●	●	●	●	
6.	Condition Assessment Methodologies	Army ISR Methodology				●	●	●	●	●	●
7.		Beach et al (1998)		●	●	●	●	●		●	●
8.		BUILDER Model				●	●	●	●	●	●
9.		IMPACT Model				●	●	●	●	●	●
10.		NASA BMAR Model		●	●	●	●	●	●	●	●
11.		University of Virginia Model		●	●	●	●	●	●	●	
12.	Other Maintenance with Backlog Models	Incremental Budget Model	●	●	●	●	●		●		●
13.		AME Methodology			●		●	●	●	●	
14.		Square Foot Model	●	●	●	●			●	●	
15.		FISC Model		●	●		●	●	●	●	
16.		NRC Model (2004)					●	●	●	●	●
17.		Navy LRMP System					●	●	●	●	●
18.	Summation Methodology	Bello Summation Model		●	●	●	●	●	●	●	●
	Facility Maintenance without Backlog Investment										
19.	Life Cycle Cost Methodologies	DOD Sustainment Model		●		●	●	●	●	●	
20.		Leslie-Minkarah (1997)			●	●	●		●	●	
21.		UNIFORMAT Model			●		●	●	●	●	●
22.		Stanford Model					●	●	●	●	●
23.		Turner (1996)					●	●	●	●	●
24.		MRPM Model				●	●	●	●	●	●
25.		Christian-Pandeya (1997)				●	●	●	●	●	●
26.	Other Maintenance without Backlog Models	Tolk (2007)	●	●	●	●	●	●	●	●	

Table 2

3.3   Earlier Models and Methodologies

In developing a more effective model for determining the adequate amount of financial investment for addressing facility maintenance and backlog, the earlier models and methodologies were investigated in detail. As highlighted earlier, some of the methodologies estimate annual investment levels for maintenance with backlog while

others estimate for maintenance alone. Models and methodologies in both categories were investigated.

3.3.1   Addressing Facility Maintenance with Backlog Investment

These earlier models and methodologies determine the annual investment required to address both facility maintenance and backlog. They determine the annual investment requirement to maintain and to repair a facility to adequate conditions. They may also be used to determine either the maintenance or the backlog needs specifically.

3.3.1.1 Plant Value Methodologies

Plant Value Methodologies determine the annual investment needs for facility maintenance as a percentage of the facility value. The two main methodologies include the Plant Replacement Value and Current Plant Value models which utilize different approaches to determine facility value. Another model, the Coast Guard methodology also utilizes the replacement value of a facility in estimating its maintenance and backlog investment needs.

Plant Replacement Value (PRV) Model

Plant Replacement Value (PRV), also referred to as Current Replacement Value (CRV) is the current cost of replacing a facility with one of similar capacity and function (Barco, 1994). This accounts for the type, size and location of the facility being considered. The formula for the model is seen in *Equation 2*.

Annual Facility Maintenance Budget = X% x PRV of Facility
The value of X is to be determined by the decision maker.

<div align="right">**Equation 2**</div>

The PRV model is one of the earlier cited models for estimating the adequate amount of facility maintenance (Kraft, 1950). Many studies and organizations determined different values for X in *Equation 2*. Some of such specifications can be seen in *Table 3*.

For estimating both facility maintenance and backlog funding needs, one can assign a certain percentage of PRV that also enables the depletion of a facility's maintenance backlog and a general improvement of its conditions. Also, a period of time may be specified for the applicability of the estimating model.

The PRV model is more effective when used on a facility by facility basis and not on an inventory of facilities. Replacement cost is the cost of replacing the functionality and capacity of a facility. As such, the full function of each facility must be considered separately. The PRV model is the most widely used methodology for determining annual facility maintenance budgets.

Sources	Specifications for Annual Facility Maintenance and Renewal Budgeting
Kraft, 1950	MCF x PRV MCF is the maintenance cost factor which is defined by this classification: Wood frame construction: 1.75% Masonry-wood construction: 1.30% Masonry-concrete or masonry-steel construction with concrete floors: 1.10%
EFL, 1982 (Badgett)	K x PRV K is the maintenance cost factor which is defined by this classification: Air-conditioned wood frame construction: 1.90% Non-air-conditioned wood frame construction: 1.75% Air-conditioned masonry-wood frame construction: 1.45% Non-air-conditioned masonry-wood frame construction: 1.30% Air-conditioned masonry-concrete construction: 1.25% Non-air-conditioned masonry-concrete construction: 1.10%
Dunn, 1989	2 - 4% x PRV
NRC, 1990	2 - 4% x PRV
NACUBO, 1991	1.5 - 3.5% x PRV
Kaiser, 1997	2.5 - 4.7% x PRV
GAO, 1999	1% x PRV (U.S. Air Force)
DOD, 1989	1.75% x PRV (U.S. Department of Defense)
GAO, 1999	1.8% x PRV (U.S. Marine Corps)
GAO, 1999	2.1% x PRV (U.S. Navy)
GAO, 1999	2 - 4% x PRV (U.S. NASA)
Kennedy, 2003	1.5% x PRV (University of Nebraska System)

Table 3

Current Plant Value (CPV) Model

Current Plant Value (CPV) is the original cost of a facility time-adjusted to the current year (Barco, 1994). This should also include the time-adjusted values of additions and demolitions. CPV indirectly accounts for facility age. The formula for the model is seen in *Equation 3*.

Annual Facility Maintenance Budget = X% x CPV of Facility
The value of X is to be determined by the decision maker.

Equation 3

Many federal agencies currently use the CPV model for determining their annual facility maintenance budgets (FFC, 1996). One of such agencies is Naval Facilities Engineering Command (NAVFAC) which determined 2.3 percent of CPV would be adequate to maintain their facilities in their current conditions. They also found they were expending approximately 1.85 percent of CPV on maintenance and repair (FFC, 1996).

In determining facility maintenance and backlog funding needs, a certain percentage of the CPV is assigned to both maintain and enable the depletion of a facility's maintenance backlog. This approach is identical to that of the PRV model. Here too, a period of time may be specified for the applicability of the estimating model. However, unlike the PRV

model, the CPV model is effective when used on an inventory of facilities. The model is also widely used for determining annual facility maintenance budgets.

3.3.1.2 Life Cycle Cost Methodologies

The life cycle methodology estimates facility maintenance investment needs by factoring the service life expectancy and resulting maintenance need of facility systems and components. With the frequency of maintenance tasks specified, cost data from cost guides are then used to predict the annual funding needs (Ottoman et al, 1999). Here, two life cycle cost methodologies that determine annual investment to address both facility maintenance and backlog are discussed. They include the Phillips and Dergis-Sherman models.

Phillips (1989) presented a model for determining the annual facility renewal allowance based on the expected lifecycles of facility systems and utilizing the sum-of-the-years digits to account for facility age. Phillips (1989) also presented an equation for determining the annual facility renewal backlog based on the expected lifecycles of facility systems. For both equations, the building age can be adjusted to account for earlier renovations.

Dergis and Sherman (1981) developed a model to estimate facility renewal funding needs at the University of Michigan. This formula-based model assumes a facility lifecycle of 50 years. It also assumes building renewal costs on average, no more than two-thirds of the cost of new construction. The model recognizes older facilities require more maintenance investment by factoring the building age. The sum-of-years digits approach also serves this purpose by increasing maintenance investment needs as the facility ages. Also, adjusting building age for renovations indirectly addresses facility condition. The formula also accounts for the original cost of the facility. This model is found to be more appropriately applied to a portfolio of facilities as opposed to a single building.

3.3.1.3 Condition Assessment Methodologies

Condition assessment methodologies assess deficiencies in a facility or a portfolio of facilities and then generate an estimate of the total cost to renovate and repair to an acceptable or adequate condition. These methodologies may also calculate future maintenance and backlog investment needs by assessing the remaining service life of a facility and its systems. The methodologies in this category include the Army Installation Status Report (ISR) methodology, Beach, Carson & Keating's (1998) model, the BUILDER model, the IMPACT model, the NASA BMAR model and, the University of Virginia model. In addition to utilizing condition assessments to identify facility deficiencies, some of the methodologies utilize other models such as the PRV model along with cost factors to determine maintenance, renewal and repair investment needs.

3.3.1.4 Other Maintenance with Backlog Models

There are other models with distinct approaches to determining investment levels for maintenance with backlog. They include the facility infrastructure sustainment cost

(FISC) model, the National Research Council (2004) model, the Navy Long-Range Maintenance Planning (LRMP) system, the Applied Management Engineering (AME) methodology, the Incremental Budget Model and, the Square Foot model.

The FISC model utilizes a predictive risk-based algorithm and database (INEEL, 2004). The National Research Council (2004) meanwhile assesses systems and subsystems based on a developed Facility Deterioration Curve (FDC). Another model, the Navy LRMP system provides an in-depth documentation of maintenance and repair requirements using a five year cost-estimating system. The AME methodology also known as the NACUBO or Rush model estimates levels of maintenance and backlog requirements based on projected investment (NACUBO, 1991). It may also be used to estimate required funding needs to achieve a certain level of maintenance backlog.

The Incremental Budget model is a very common financial management tool (Ottoman et. al, 1999). This is essentially historical budgeting which presumes the last period's budget is adequate and makes only adjustments for specific requirement changes and for inflation. This simple model does not consider specific facility characteristics. With this model, if the maintenance budget used as the baseline is inadequate, the correlation with actual maintenance and backlog needs is typically lost (Barco, 1994). Lastly, the Square Foot model uses the area of the facility inventory and a cost factor to determine maintenance and repair requirements. The cost factor may be determined from historical data and from RS Means and BOMA (Building Owners and Managers Association) cost guides. This is one of the simpler maintenance and repair funding cost estimation approaches and it is most appropriately applied to an inventory of facilities.

3.3.1.5 Summation Methodology

This methodology involves the summation of the estimated maintenance needs for all the years in a facility's lifecycle deducted by actual maintenance spending over each of those years. The resulting values are maintenance backlog estimates for each of those years. These values can then be time-adjusted and summed to arrive at an estimate of total maintenance backlog for the facility. This can then be distributed over a determined number of years based on feasibility and then, added to the estimated annual facility maintenance investment needs for each of those years. The annual facility maintenance investment requirements are to be determined using any predictive model. Although the approach or concept of this methodology may have been applied before, an equation was not found to express its application. As such, one was developed, the Bello Summation equation as seen in *Equation 4*.

$$\text{Annual Facility Maintenance and Backlog Investment} = \text{EAFMN} + \frac{\Sigma \left(\text{EAFMN} - \text{Actual Maintenance Spending}\right)^{\text{Year 0 to Current Year}}}{N}$$

EAFMN: Estimated Annual Facility Maintenance Need
N: Number of years over which to eliminate facility maintenance backlog (to be determined by facility administrators or managers)

Equation 4

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3.3.2   Addressing Facility Maintenance without Backlog Investment

These earlier models and methodologies were developed to determine only the annual investment required to maintain a facility in its current conditions. Therefore, the annual facility maintenance investment need without backlog or repair is addressed by these models.

3.3.2.1 Life Cycle Cost Methodologies

As earlier stated, the life cycle methodology estimates facility maintenance investment needs by factoring the service life expectancy and resulting maintenance need of facility systems and components. With the frequency of maintenance tasks specified, cost data from cost guides are then used to predict the annual funding needs (Ottoman et al, 1999). Here, only the life cycle cost methodologies that determine annual investment for facility maintenance and renewal without backlog are discussed.

The DOD Facility Sustainment model estimates facility maintenance funding needs over a 50 year service lifecycle utilizing area cost factors and inflation data. The model by Leslie and Minkarah (1997) utilized a construction estimating technique for preparing long term cost and timing forecasts of renewal funding needs for facilities. The Uniform Building Component Format (UNIFORMAT) model meanwhile utilizes a standard framework for organizing lifecycle and repair or replacement cost data.

Another model was developed by Beidenweg and Hutson (1989) for programmatically addressing the short and long term needs of Stanford University's physical plant. The model calculates the expected annual maintenance and repair costs using projections given for the performance of the plant and renewal costs over time. A similar funding model was developed by Turner (1996) for the University of Nevada, Reno.

Neathammer and Neely (1991) designed the Maintenance Resource Prediction Model (MRPM) to estimate annual maintenance costs over a 120 year facility lifecycle using different levels of facility data. This model was developed in an effort to create a cost database for U.S. Army facilities. Lastly, using regression analysis, neural networks and random deviation detection, Christian and Pandeya (1997) developed a decision support system for estimating the per square foot annual operating and maintenance costs for facilities

3.3.2.2 Other Maintenance without Backlog Models

Tolk Model

Tolk (2007) developed a prediction equation using multiple regression analysis to estimate the required maintenance and repair budget for a facility portfolio. Tolk (2007) found the best equation for the substantive portfolio of facilities she assessed to include facility age, size, type and use as predictor variables. Tolk however determined an

adequate result could be obtained using only facility age and size as the variables. The derived equation is seen in *Equation 5*.

Annual Estimated Required Maintenance (ERM) = (185 + 0.0143 Size – 2.06 Age) ²

<div align="right">**Equation 5**</div>

3.4   The Bello-Loftness Model

A new model, the Bello-Loftness model, was developed to provide a more appropriate estimation of facility maintenance and backlog investment needs. Firstly, an equation was developed for determining the adequate annual facility maintenance investment level. An equal add-on was then included to account for backlog investment needs.

The yielded annual facility investment level is inclusive of maintenance, renewal and repair funding requirements. As earlier defined, maintenance refers to all actions required to sustain effective operations of facility systems as installed. Renewal refers to the scheduled replacement or restoration of facility components that have exceeded their service life. And, repair refers to the restoration of facility components to operational conditions after an unpredicted or unforeseen failure.

As in the case of the NRC (1990) recommendation of 2 to 4 percent of PRV for maintenance, the investment level determined by the Bello-Loftness model is exclusive of staffing costs, custodial work, operational utility bills, security services, fire protection services, snow removal, pest control, refuse collection and disposal, grounds care, landscaping, environmental operations and, recordkeeping. It is also not inclusive of such non-maintenance activities as alterations, service requests, support for special events or activities and, standby services by mechanics required by mission activities.

The following sections will elaborate on the model development and each of the qualifiers in the two part equation.

3.4.1   Facility Maintenance without Backlog Investment

Through literature review, investigation and evaluation, the Bello-Loftness model was developed to estimate annual maintenance investment to maintain the current service conditions of a facility. The model is intended to serve as a facility maintenance budgeting guideline as opposed to serving as a specification. It utilizes both the Plant Replacement Value (PRV) and Current Plant Value (CPV) models as seen in *Equation 6*.

Annual Facility Maintenance Investment = 2% x ((0.35 x PRV) + (0.65 x CPV))

<div align="right">**Equation 6**</div>

3.4.1.1 Combining and Prioritizing the PRV and CPV

In developing the new model, the earlier methodologies were evaluated to determine which metric could be best utilized for determining the adequate investment for facility maintenance. One of the models, the PRV model stood out for a number of reasons.

Firstly, FFC (1996) stated the PRV model was the most widely distributed and frequently quoted model. This fact highlights its high level of familiarity in the facility maintenance community. When the Building Research Board (BRB) was chartered as a committee of the National Research Council (NRC) in 1990 to lead to a determination of the adequate annual investment in building maintenance, they utilized the PRV model. NRC (1990) accounted for a large range of factors in making the recommendation of 2 to 4% of plant replacement value as the adequate annual level to maintain current service conditions in facilities. This study is now one of the most widely cited sources for a budgeting guideline (Tolk, 2007).

The PRV model as indicated in *Table 1* and *Table 2* meets many of the attributes required for a functional and effective model. There is a need to note how each of those attributes are accounted for by the model. The model accounts for the facility type, its function, its size and location by determining the replacement value of the facility based on the criteria. By accounting for the stated criteria, the system costs are factored as well. With regards to other attributes, it is generally applicable to all facility types. The replacement cost of a facility can also be easily obtained using such cost guides as RS Means. With the type, function, size and location of the facility specified, simple multiplication yields the PRV. And since the model yields the annual amount of facility maintenance investment as a percentage of the PRV, it is simple to apply and to understand. There is also the fact that the PRV considers the replacement cost of a facility in the current year or period. Therefore, the value adjusts as time progresses. Using a current cost guide versus an earlier cost guide in determining the PRV easily illustrates this adjusting or increasing of value. In addition to being self-adjusting, the model is reliable in that it enables direct comparison with other facilities in terms of current value. Also, the emphasis on the replacement value of a facility determining how much should be invested in its maintenance is a logical and functional approach.

It is important to express the annual maintenance budget level yielded by the PRV model depends on the percentage assigned by the decision makers or facility managers. NRC (1990) determined 1 percent was too low and 5 percent was not affordable on an annual basis for facility maintenance. The value the study settled on was thus 2 to 4 percent. Other studies placed their levels between 1 and 5 percent. The selected ranges indicate the PRV model can provide an economical budget level.

The PRV model provides a guideline for facility maintenance investment and not specific directions for using the derived amount. This determination is left to the facility managers and decision makers as each facility is different and has distinct components and criticalities of the components. Therefore, the model does not define the function of the resource allocation.

The PRV model is more effective when used on a facility by facility basis. This can however be easily cumulated to derive the annual facility maintenance investment need of a portfolio of facilities. The PRV model however, has some disadvantages. The model does not account for the age of a facility since it only considers the current replacement cost of the facility with regards to function, capacity, size and location.

Additionally, the PRV model does not account for the technologies and complexities of a facility's systems. To further illustrate this, consider 3 buildings of the same function, size, age and location. The facility is a high school with classrooms and laboratories. The facility function is to accommodate 1,000 students. The facility size is 50,000 square feet (4,650 square meters). The 3 school buildings were completed 15 years ago and are all located within the same district.

Building 1: Brick building with typical systems
Building 2: Painted concrete building with typical systems
Building 3: Painted concrete building with energy conserving and harnessing systems

Out of the 3 buildings, Building 3 is likely to cost more with regards to maintenance. This is by nature of its systems' complexity. Building 1 is likely to cost the least to maintain as it has minimal complexity and would not require continuous painting. Meanwhile, the maintenance cost for Building 2 would lie in between due to its painting needs. All these buildings would have the same annual amount of facility maintenance investment determined by the PRV model. This is not adequate.

Another fact is the PRV model does not factor the system lifecycle cost though it does factor the system cost through the facility function. Lastly, the current condition of a facility is not accounted for by the PRV model. The purpose of the model being sought is to determine the annual adequate amount for facility maintenance investment to maintain a facility in its current condition without accumulating maintenance backlog or causing deteriorating conditions. Accounting for current facility conditions may therefore be more critical when it comes to addressing maintenance backlogs or, in determining renovation investment needs.

Construction quality is not accounted for by the PRV model as it only considers facility replacement cost primarily based on function and capacity. For the same reason, it does not consider the current plant value or initial acquisition cost of a facility. The PRV model does not account for facility maintenance planning as it discards all planning that had earlier been in place to make current and future estimates of facility investment needs for maintenance, renewal and repair. This may or may not be beneficial depending on the characteristics of the earlier facility maintenance investment plan. The PRV model also does not specifically account for budget constraints. However, it could be considered by assigning an economically feasible percentage of facility value for determining the maintenance and repair investment needs.

Monterecy (1985) found PRV, size and age had the highest correlation with maintenance and repair funding needs. It is important to note that PRV accounts for size as the cost of replacing a facility considers function and capacity. Facility age is however not accounted for. Tolk (2007) determined the best equation for determining facility maintenance investment levels in her research included age, size, type and use as predictor variables. Tolk (2007) however only used age and size as predictor variables in her equation; this was in the interest of gaining universal appeal for the equation. Since

the PRV model accounts for facility type and use, facility age is further highlighted as a critical feature.

From the assessment of earlier facility maintenance cost prediction models, it becomes apparent a similar model accounts for both facility age and system complexities. This is the Current Plant Value (CPV) model and it accounts for more attributes than the PRV model. The CPV model also has the benefit of being very familiar to the facility maintenance community. It is very simple, popular and among the earliest cited estimating methods (Ottoman et al, 1999). CPV is the initial acquisition cost adjusted to the current year for inflation, improvements and changes in size or capacity (Barco, 1994). The adjustment for inflation and resulting increase in value accounts for a facility's age. This may also account for historical value. The model also accounts for system technologies and complexities because the initial acquisition cost of the systems are inherently factored. This would also apply to other features of the facility such as its type of construction, component materials and level of craftsmanship.

Facility size, type and location are direct determinants of the initial acquisition cost of a facility. As such, they are both accounted for by the CPV. While facility use or function at the time of construction is accounted for, current use is not accounted for. If a school initially intended for 800 students now accommodates 1,000 students, the value of the building should preferably increase to reflect the increased functional demand. The PRV would account for this but the CPV does not. Hence, the CPV does not account for the current replacement value of a facility.

The CPV model factors facility systems' cost through the initial facility acquisition cost. The system lifecycle cost is not accounted for by the definition of CPV. As in the case of the PRV model, the current condition of a facility is also not accounted for. This however remains of minimal concern since the purpose of the model being sought is to determine the annual adequate amount for facility maintenance investment that would maintain a facility in its current condition without accumulating maintenance backlog.

Construction quality is however accounted for by the CPV model. Higher quality construction costs more than poorer quality and this is reflected through the initial acquisition cost of the facility which is the primary value used by the CPV model. Also through the CPV model, historical value may be accounted for by the adjustment for inflation and resulting increase in value used to account for a facility's age.

As in the case of the PRV, the CPV does not account for facility maintenance planning as it discards all planning that had earlier been in place to make current and future estimates of facility investment needs for maintenance and repair. It also does not account for budget constraints though it could be considered in determining the percentage of facility value for determining the maintenance and repair investment needs.

With regards to meeting the attributes of an effective model, the CPV is generally applicable to all facility types. A facility's CPV can also be easily obtained. The initial cost of a facility can be found in historical records. This cost can then be scaled to the

current year using inflation data or time adjusting factors, both of which are available publicly and in cost guides. Additionally, since the model yields the annual amount of facility maintenance investment as a percentage of the CPV, it is simple to apply and to understand. Also, the CPV model is self-adjusting due to the fact that the inflation values applied adjust the facility value as time progresses. The model is also reliable in that it enables direct comparison between facilities. Additionally, the emphasis on the initial acquisition value of a facility determining how much should be invested in its maintenance is a logical and functional approach.

As with the PRV model, the annual maintenance budget determined by the CPV model depends on the percentage assigned by the decision makers or facility managers. The Naval Facilities Engineering Command (NAVFAC) determined 2.3 percent of CPV would be adequate to maintain their facilities in their current conditions. They also found they were expending approximately 1.85 percent of CPV on maintenance and repair (FFC, 1996). The order of the percentage levels indicate the CPV model can provide an economical budget level. The CPV model just as the PRV model is not intended to provide specific directions for using the derived annual facility maintenance investment but to provide a guideline for determining it. Defining the function of the resource allocation is left to the facility managers and decision makers as each facility is different with distinctive components and criticalities of the components.

Based on the evaluation of both plant value methodologies, it is apparent they can complement one another. In structure, both the PRV and CPV models utilize percentages of the determined values as the amount of facility maintenance investment. Additionally, the metric they both use is very appropriate. Many studies determine the amount of facility maintenance investment as a percentage of facility expenditure. This would provide the angle of a slice of pie but not the pie's diameter. Thus, total expenditure would determine whether the annual maintenance budget is adequate or inadequate. This is not effective. The similarity in structure and measure between the PRV and CPV models makes it feasible to integrate the two to yield a more effective model that accounts for more facility features. When taken in combination, all critical facility attributes excluding current facility condition, systems' lifecycle costs, facility maintenance planning, and budget constraints would be accounted for. These unmet attributes have however been adjudged not to interfere with the purpose of the model being developed.

The purpose of the model being developed is to determine the annual adequate amount for facility maintenance investment to maintain a facility in its current condition without accumulating maintenance backlog. By this purpose, it is not necessary to account for the current facility condition. As for systems' lifecycle cost, accounting for it requires data that is not easy to obtain. And since easily obtained data is a key attribute of a good model, it was apparently either one attribute or the other.

As for facility maintenance planning, the PRV and CPV models collectively do not account for it as they discard all planning that had earlier been in place to make current and future estimates of facility investment needs for maintenance, renewal and repair. As earlier stated, this may or may not be beneficial depending on the characteristics of the

earlier facility maintenance investment plan. Both models would also collectively not account for budget constraints but may consider it in assigning a more economically feasible percentage of facility value to define the appropriate maintenance and repair investment needs.

An appropriate combination of the PRV and CPV models would meet all attributes of a good model excluding defining the function of resource allocation. Since both models aim to provide a guideline for facility maintenance investment and not specific directions for using the derived amount, it would remain up to the facility manager to define the function of resource allocation.

As seen in *Table 1* and *Table 2*, two models were assessed to possess as many attributes as a combination of the two plant value methodologies. These were the Dergis-Sherman and Summation methodologies. There are a number of reasons why they are not considered adequate. With regards to the Dergis-Sherman model, it may be logical, easy to understand and to apply but it makes a number of assumptions that no longer apply. Firstly, it assumes a facility life cycle of 50 years. While many facilities were designed for a service life of 50 years, extension of facility service is now the norm as opposed to the exception. This is an explanation of why many aged facilities are used in their poor conditions. In the case of schools, this assumption is simply not appropriate. NCES (2000) found half of the United States existing school buildings were completed before 1959. This means approximately half of the nation's schools are now more than 50 years old. Another assumption is the building renewal constant which makes the supposition that building renewal costs no more than two-thirds the cost of new construction. The building renewal costs depend on the features of the facility under consideration. It could therefore be much lower or even higher. However, it is important to note the Dergis-Sherman model indirectly accounts for current facility condition by adjusting building age for renovations. This is also questionable as determining the degree of adjustment to the building age could prove challenging and if inaccurate, could also create a significant difference in the determined annual maintenance investment need. Hence the amount may be too low causing deteriorating facility conditions or more, better improving facility conditions but not helping the budget constraint.

The Summation methodology does not provide for a fixed guideline because a key component of the model, the estimated annual facility maintenance need (EAFMN), is determined by the predictive model utilized. Thus, the facility features it accounts for in the assessment are actually the facility attributes it could account for depending on which model is used in determining EAFMN. The model in development could even be used to determine the EAFMN values to perhaps yield a very accurate estimate for facility maintenance and repair needs. Additionally, the data required for the Summation methodology is not easily obtained especially for older buildings. Records of maintenance spending would be required for each year of a facility's operation. In the case of school facilities where the average age was determined to be 40 years as of 2000 (NCES, 2000), obtaining this data would be difficult. Furthermore, a predictive model has to be used to determine EAFMN for each year of operation. The ease or difficulty of obtaining this data depends on the model selected. This methodology is not definitive.

A combination of the two plant value methodologies has to appropriately account for the facility attributes factored by both models. Using the structure of the two models, the structure of a new model was developed. This is seen in *Equation 7*.

$$\text{Annual Facility Maintenance Investment} = X\% \times ((Y\% \times PRV) + (Z\% \times CPV))$$

Equation 7

The initial objective was to determine the values of Y and Z. To make the determination, the features met by one model but not the other were categorized. This is since all features factored by both are addressed regardless of the combination proportions. Different facilities were then selected and priorities assigned to each of the categories with regards to importance in determining the amount of maintenance investment. The average priority of each feature was then derived and summed to yield the priorities that are to be given to the PRV and the CPV. It is important to note, the determination is not based on aggregate data from the field.

In the categories for the PRV model, the current replacement value is not considered for the justifiable reason that this is fully accounted for by the model itself. As such, the only feature considered is function or use of the facility. This however, is quite broad. There are two distinct and important functional characteristics that may be individually factored. The first is the criticality of the facility and second is the variations in functional demands of the facility. Meanwhile, the categories for the CPV model include facility age, system complexities and, the quality of construction, materials and craftsmanship. Also, the current plant value is not considered for the justifiable reason that it is accounted for by the CPV model itself.

The facilities used in the determination included a hospital, a warehouse and the U.S. Capitol Building. These were deliberately selected as they varied significantly in all the categories. The hospital is high technology and high intensity. The warehouse is low technology and low intensity. Meanwhile, the U.S. Capitol is historical. The determination process is seen in *Table 4*.

Models	Unique Factors Addressed by the Models	Priorities for Different Facility Types				Total Priorities
		Hospital	Warehouse	U.S. Capitol	Average	
		High Technology and High Intensity Facility	Low Technology and Low Intensity Facility	Historical Facility		
Plant Replacement Value (PRV) Model	Variations in functional demands	20%	5%	10%	**13%**	**35%**
	Criticality of facility	30%	15%	25%	**22%**	
Current Plant Value (CPV) Model	Age of facility	20%	50%	25%	**32%**	**65%**
	Complexities of the facilities' systems	25%	15%	15%	**18%**	
	Quality of materials and craftsmanship	5%	15%	25%	**15%**	
TOTAL	**TOTAL**	100%	100%	100%	100%	**100%**

Table 4

Y and Z were determined to be 35% and 65% respectively. The resulting equation is seen in *Equation 8*.

$$\text{Annual Facility Maintenance Investment} = X\% \times ((0.35 \times PRV) + (0.65 \times CPV))$$

Equation 8

The remaining objective was to determine the value of X. This was necessary because leaving the value of X arbitrary may yield inadequate or uneconomical facility maintenance investment levels which could then result in accumulation of maintenance backlog or non adherence to the determined investment need. There was thus a need for a more definitive guideline.

3.4.1.2 Appropriate Percentage of the PRV and CPV

There have been many annual maintenance budget guidelines that have utilized a percentage of PRV. One of the earliest among this is Kraft (1950) which defined the percentage by a maintenance cost factor (MCF). The MCF depended on the type of construction and included 1.10% for masonry-concrete and masonry-steel construction with concrete floors, 1.30% for masonry-wood construction and, 1.75% for wood frame construction. These MCF specifications are outdated as buildings have gotten more complex with regards to both their construction and their systems. Taking this into consideration, Badgett (1982) modified Kraft's MCF into two categories namely air-conditioned and non-air-conditioned. He regarded Kraft's values as those of non-air-conditioned construction while he added 0.10% to each of the values to account for the increased maintenance need associated with using air-conditioning systems. However, Badgett's maintenance cost factors currently do not encompass the levels of complexity of facility systems and components.

As one of the most widely cited sources for a budgeting guideline, the 2 to 4 percent of PRV as recommended by NRC (1990) seems to be a reasonable starting point. 2 percent was intended for less critical facilities while 4 percent was intended for more critical facilities. In the study, a large number of facility features were considered in making the determination. The study also noted the 2 to 4 percent range was most effective for a long range forecast and applicable only when a facility could remain in a service condition that neither declined nor improved. Therefore, if a maintenance backlog existed, it would not be affected. This guideline was adopted by many organizations towards slowing the degradation of their facilities (Tolk, 2007). The objective of the guideline fits the model in development.

The 2 to 4 percent range was found to create a wide spread of values particularly for facilities of high value. NRC however felt that, since most federal organizations were below 2 percent, investing that much would be a good first step (FFC, 2001). NRC had determined buildings in the federal sector were generally budgeted 1.5 percent of plant replacement value annually. The United States Department of Energy (DOE) and National Air and Space Agency (NASA) now require facility maintenance expenses to be 2 percent of PRV at the minimum in adherence to the recommendation of the NRC.

Meanwhile, the U.S. Navy through its own extensive facilities condition assessment estimated it would require 2.1 percent of PRV to keep the condition of its facilities stable (GAO, 1999).

To determine if the 2 percent specification is generally adequate for the PRV model, data from the detailed condition assessment of Prince George's County public schools in Maryland (2008) was utilized. The assessment classified the school facilities into 3 age categories. The first priority schools were aged 51 to 100 years. The second priority schools were aged 31 to 50 years while the third priority schools were aged 16 to 30 years. For each of the categories, the total replacement cost was provided along with the total gross area. Additionally, the total capital renewal funding need over the next ten years and the total backlog of repair and renovation were provided for the categories. Using the annual capital renewal funding need as a percentage of the total replacement cost, 2.21%, 1.63% and 2.34% of PRV were yielded for the first, second and third priority schools respectively. All the values were near 2 percent of PRV. This is seen in *Figure 6*.
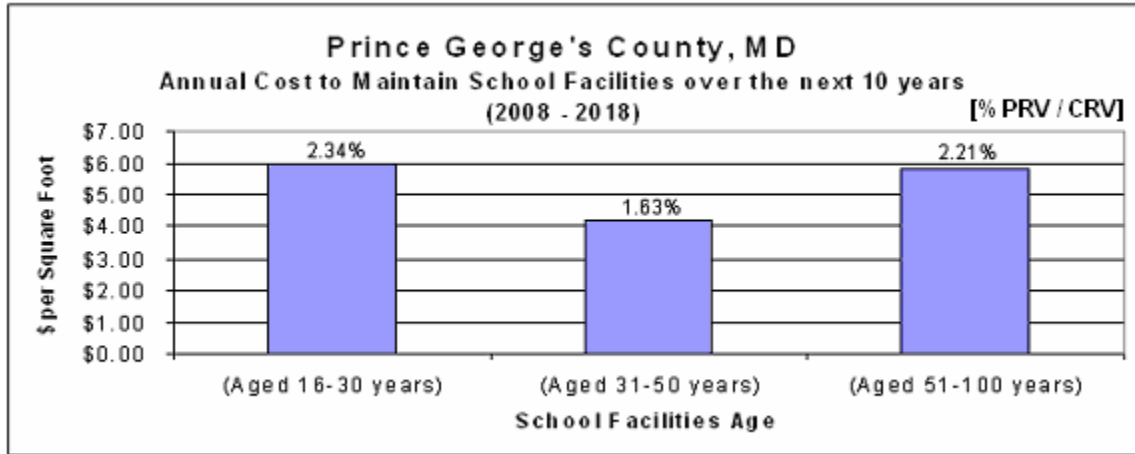
Additionally, DOD (1989) found major colleges and universities budgeted 2 percent of PRV annually for facility maintenance. This serves as a further indication that this particular level is feasible.

As for the percentage of CPV appropriate for the adequate annual facility maintenance investment, the findings of the Naval Facilities Engineering Command (NAVFAC) were utilized. Considering the large and varied portfolio of facilities they manage, this approach is justifiable. NAVFAC determined 2.3 percent of CPV would be adequate to maintain their facilities in their current conditions. They also found they were expending approximately 1.85 percent of CPV on maintenance and repair (FFC, 1996). Based on the proximity of both the adequate and actual levels to 2 percent, it appears it is also a justifiable figure in this case. This completed the development of the Bello-Loftness model as expressed in *Equation 6*. Intended to serve as a facility maintenance budgeting guideline as opposed to serving as a specification, it is better suited to account for more

critical facility attributes that impact maintenance needs than the PRV and CPV models when considered independently.

The Bello-Loftness Model has one main limitation and it has to do with the type of construction. For the same building project, a masonry-concrete construction would cost significantly more than a wood-frame construction. However, the maintenance of the wood-frame construction would cost more than the masonry-concrete construction over the facility's service life. Given the initial acquisition cost and replacement value of a facility are used, the determined maintenance investment will always be highest for the masonry-concrete construction which actually requires less. As such, one may find a concrete and marble school facility built in the 1950s to be less cost-intensive to maintain and repair than one of brick and wood built in the 1970s. This appears to be the basis for the development of the maintenance cost factor (MCF) by Kraft (1950). The MCF specified percentages of PRV that depended on the type of construction and included 1.10% for masonry-concrete and masonry-steel construction with concrete floors, 1.30% for masonry-wood construction and, 1.75% for wood frame construction. As buildings have become more complex with regards to both their construction and systems, the impact of the limitation may be significantly decreased.

The Bello-Loftness Model is applicable to all facility types including schools. As with the PRV and CPV models, it is also more effective on a facility by facility basis though it can be easily cumulated to yield the annual facility maintenance investment for an inventory of facilities.

As discussed earlier, the state of the nation's public schools is poor. Therefore, applying this developed equation would only yield the annual investment to maintain schools in their current poor conditions. This presents the need improve the condition of school facilities and this can be done by also addressing their maintenance backlogs.

3.4.2   Facility Maintenance with Backlog Investment

In developing the model to also address maintenance backlog, the Bello-Loftness equation earlier developed for determining adequate annual investment for facility maintenance was considered. It was determined that when appropriately modified, the model may also be used to address maintenance, renewal and repair backlog. This is based on the fact that it accounts for the facility features factored by its two constituent models while possessing their attributes. These are of course the Plant Replacement Value (PRV) and Current Plant Value (CPV) models. An equal add-on was determined to be appropriate to address backlog. Still intended to serve as a budgeting guideline, the model is seen in *Equation 9*.

Annual Facility Maintenance with Backlog Investment =
  [2% x ((0.35 x PRV) + (0.65 x CPV))] + [2% x ((0.35 x PRV) + (0.65 x CPV))]
                                         Add-on for Backlogged Maintenance
                                         (Till the backlog is eliminated)
Equation 9

3.4.2.1 Combining and Prioritizing the PRV and CPV

The PRV and CPV models have the benefit of high familiarity in the facility maintenance community (Ottoman et al, 1999). They were earlier determined to have the ability to complement one another due to their similarities in structure and measure. When appropriately factored, they can account for more critical facility attributes as depicted by the assessment in *Table 1*. The two models however do not account for current facility condition, system lifecycle cost, facility planning and budget constraint.

In determining appropriate investment levels for addressing both maintenance and backlog, accounting for current facility condition would be useful for more accurate estimation. The two models collectively do not factor it. However, accounting for this value would involve conducting condition assessment and testing. Factoring systems' lifecycle cost would require an even more in-depth condition assessment in addition to requiring manufacturer and other data. A model that factors current facility condition and systems' lifecycle cost thereby utilizes data that is not easy to obtain. This is a very important attribute of a good model because difficulty in obtaining data for a model would make it less likely to be used. The models also do not account for facility maintenance planning. This may or may prove to be beneficial depending on the characteristics of the earlier facility maintenance investment plan.

Budget constraints represent an important cause of deferred maintenance. A model that accounts for budget constraints would better predict how much would actually be spent as opposed to how much should be spent on facility maintenance and backlog. Considering the purpose of the model being sought is to determine the appropriate level of investment to maintain and to improve a facility to adequate service condition, the latter is the objective. While the PRV and CPV models do not specifically account for budget constraints, they consider it by allowing for input of the percentage of facility value which defines the maintenance and repair investment level. Budget constraints are also a consideration in the development of a modified Bello-Loftness model. Conclusively, the unmet facility attributes were determined to neither defeat the purpose of the model in development nor render it ineffective. Monterecy (1985) found replacement value, size and, age had the highest correlation with maintenance and repair funding needs. The two plant value methodologies collectively account for these attributes.

Additionally, an appropriate combination of the PRV and CPV models would still meet all attributes of a good model excluding defining the function of resource allocation. Since both models aim to provide a guideline for facility maintenance and repair investment and not specific directions for using the derived amount, it would remain up to the facility manager and staff to define the function of resource allocation.

In developing the equation to account for maintenance and backlog, the approach used by Brown and Gamber (2002) was considered. Their PRV model for determining annual facility maintenance and backlog investment was 2 percent of PRV in addition to a deferred maintenance reduction plan. The value from the deferred maintenance reduction

plan is an unspecified add-on to be determined by the facility manager. The Bello-Loftness model for maintenance with backlog included an add-on to the original equation. This add-on, like the original equation, was to include both the PRV and CPV. Unlike Brown and Gamber's (2002) model, this add-on was to be defined. Leaving the annual repair investment arbitrary may yield inadequate or uneconomical facility maintenance investment levels which could then result in the continued retention of maintenance, renewal and repair backlog. This highlights the need for a definitive guideline. Furthermore, the combination of the models for the add-on has to appropriately account for the facility attributes factored by both models. The initial modified model is seen in *Equation 10*.

Annual Facility Maintenance with Backlog Investment =
    [2% x ((0.35 x PRV) + (0.65 x CPV))] + [X% x ((Y% x PRV) + (Z% x CPV))]

Equation 10

The initial objective was to determine the values of Y and Z. The development process used for the initial equation was found to be applicable. Since all features factored by both models are addressed regardless of the combination proportions, the features met by one model but not the other were categorized and prioritized for three different facilities. This is as seen in *Table 4*. The facilities used in the determination included a hospital, a warehouse and the U.S. Capitol Building, all deliberately selected because they varied significantly in all the categories. The average priority of each feature was then derived and summed to yield the priorities that are to be given to the PRV and the CPV. Once again, the determination was not based on aggregate data from the field. As in the original equation, Y and Z have values of 35% and 65% respectively. The resulting equation is seen in *Equation 11*.

Annual Facility Maintenance with Backlog Investment =
    [2% x ((0.35 x PRV) + (0.65 x CPV))] + [X% x ((0.35 x PRV) + (0.65 x CPV))]

Equation 11

3.4.2.2 Appropriate Percentage of PRV and CPV

The value of X was also determined in the interest of developing a definitive guideline. As a starting point, NRC (1990), as one of the most widely cited sources for a budgeting guideline recommended a range of 2 to 4 percent of PRV for annual facility maintenance investment. Furthermore, it was expressed 1 percent was too low and 5 percent was not affordable on an annual basis for facility maintenance. A number of organizations adopted this guideline at the lowest value and now require annual facility maintenance expenses to be 2 percent of PRV (Tolk, 2007).

Since 1 percent of PRV is too low for annual maintenance spending, it is deducible that it is also too low to effectively account for addressing backlog investment needs. This is particularly considering facilities in poor conditions such as the nation's aging school buildings. The maintenance part of the equation already accounts for around 2 percent of PRV. An additional 3 percent of PRV for annual backlog spending would result in an unaffordable maintenance and backlog budget of 5 percent of PRV. As such, 2 percent of

PRV for annual backlog spending appears to be economical. This is essentially doubling the facility maintenance investment to also account for backlog. Assigning 2 percent of PRV to X would result in an annual facility maintenance and backlog investment level of around 4 percent of PRV.

To determine if 4 percent of PRV is adequate to maintain and improve facility conditions, data from the detailed condition assessment of Prince George's County public schools in Maryland (2008) was utilized. The assessment classified the school facilities into 3 age categories. The first priority schools were aged 51 to 100 years. The second priority schools were aged 31 to 50 years while the third priority schools were aged 16 to 30 years. For each of the categories, the total replacement cost was provided along with the total gross area. Additionally, the total capital renewal funding need over the next ten years and the total backlog of repair and renovation were provided for the categories. The total backlog was spread over the ten year time horizon and then added to the annual capital renewal funding need. The total annual renewal and backlog funding need was then determined as a percentage of the total replacement cost. 6.99%, 7.17% and 7.52% of PRV were yielded for the first, second and third priority schools respectively. Over a period of ten years, the annual maintenance with backlog investment needs are, on average, more than 3 times annual facility maintenance needs without backlog. This is illustrated in *Figure 7*.
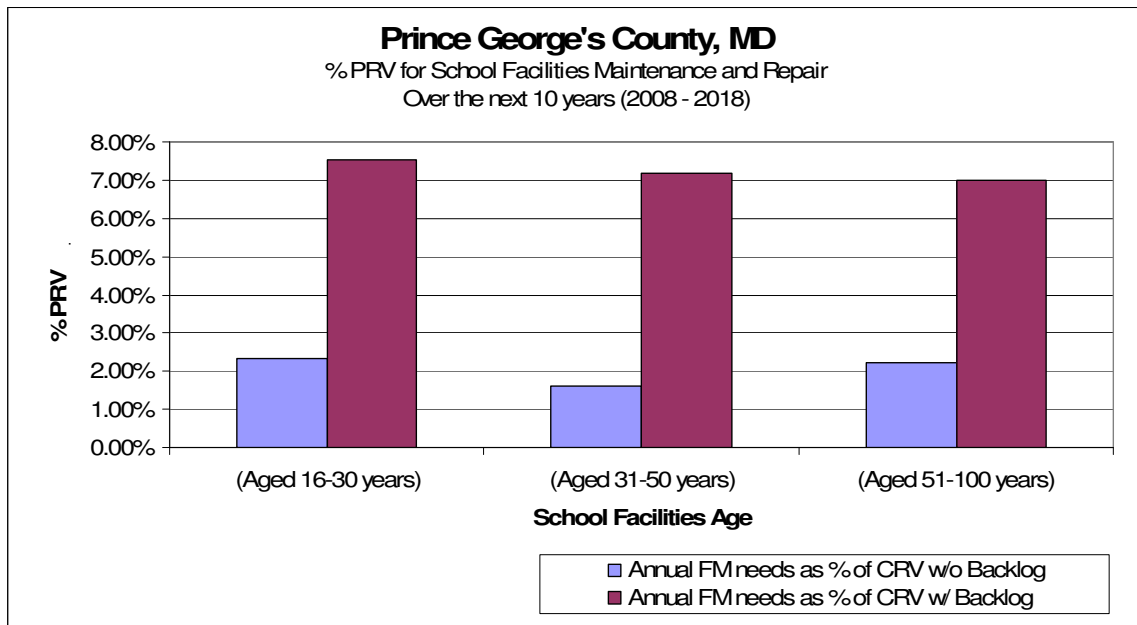

[Source: Prince George's County Public Schools (2008)] **Figure 7**

The disparity between the investment needs of the 3 age categories of the county's school facilities may be due to differences in building materials, complexity of systems, some other feature or simply, lack of maintenance. It may also have been due to the number of major renovation projects executed in the different school categories. Most of the county school facilities were observed to have brick façades and flat roofs with many utilizing window air-conditioning units.

The annual maintenance and repair needs for Prince George's County, MD appears unaffordable. It can however be adjusted to be more economical by spreading the maintenance backlog over a greater number of years. The U.S. Navy meanwhile, estimated that by gradually increasing its annual maintenance and repair spending to 2.59 percent of PRV, all critical-related repairs for its barrack facilities would be "virtually eliminated" over a period of 7 years (GAO, 1999). As for maintaining facilities in their current condition, the Navy estimated an annual funding need of about 2.1 percent of PRV. For an establishment with almost $3 billion in critical backlog, even a 0.49 percent of PRV add-on was estimated to cause a significant improvement in facility conditions.

To adjudge the applicability of using a 2 percent of PRV add-on for the nation's school facilities, maintenance and operations cost data for public school districts in the United States was utilized from the American School and University Magazine (Agron, 2001 – 2008). The values were inclusive of maintenance, repair and operation expenses. Though not optimal, the data provides a reasonable picture of annual maintenance and repair spending. As for the actual construction cost data, a report by the National Clearinghouse for Educational Facilities was used (NCEF, 2009). This data was used as the PRV. The average data values were then used to determine the corresponding percentage of PRV. Seen in *Figure 8*, the data is from 2001 to 2008.
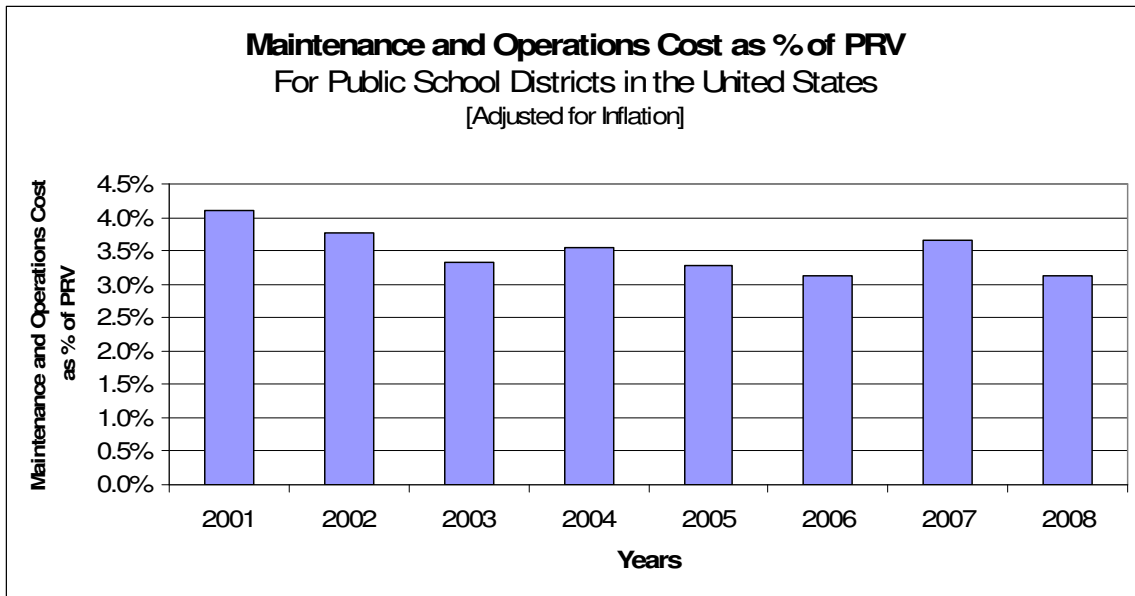
[Source: American School and University Magazine (2000 - 2009)] **Figure 8**

The range of the percent of PRV for maintenance and repair spending stood roughly between 3 and 4 percent. This might have been insignificant were it not for the fact that the American Society of Civil Engineers (ASCE) had improved the grade for school infrastructure over this same period. It thus appears a 2 percent add-on to the initial 2 percent of PRV can be effective in improving school facility conditions as well.

With regards to the percentage of CPV for maintenance and repair, the Naval Facilities Engineering Command (NAVFAC) estimated 2.3 percent of CPV would keep critical

maintenance and repair backlog stable while 2.5 percent of CPV would enable its reduction (FFC, 1996). Here, only a 0.2 percent of CPV add-on was considered. Thus, a 2 percent of CPV add-on could prove effective. With this, the value of X in *Equation 11* was been determined to be 2 percent.

As discussed earlier, some facility inventories including those of many school systems have substantial maintenance, renewal and repair backlogs. Eliminating such backlogs may prove quite lengthy when the repair investment level is specified at 2 percent of PRV or CPV. It is however more practical to do so in light of limited resources and staff. Also, it is generally not economically feasible to renovate all facility inventories to adequate service condition within a year. This is even more so when it comes to school facilities. Therefore a period of model applicability could be defined. The add-on for addressing backlog would therefore be applicable until the deferred maintenance backlog has been eliminated. After which, only the equation part for facility maintenance would be applicable. This is of course, in the case of a facility with maintenance backlog. NRC (1990) also recommended this approach. The period could thus be any numbers of years till adequate facility conditions are achieved. This determination completed the development of the Bello-Loftness model to account for the adequate annual maintenance with backlog investment for a facility as seen in *Equation 9*.

As earlier expressed, the Bello-Loftness model is intended to serve as a budgeting guideline for facility maintenance and repair as opposed to serving as a specification. Where there is available funding to restore all facility conditions to adequate, such an action would be encouraged. Since this is hardly the case, the add-on can be used to provide an investment level that would decrease the maintenance backlog both economically and effectively. The model was developed to be applicable to all facility types including school buildings. Furthermore, as with the PRV and CPV models, it is more effective when used on a facility by facility basis. However, this can be easily cumulated to derive the annual facility maintenance with backlog investment need of a portfolio of facilities. Separately, the Bello-Loftness model still possesses the limitation of not considering the sometimes inverse relationship between the initial facility construction cost and facility maintenance investment needs.

To avoid lost value, school facility replacement has been discouraged. Hence, determining the appropriate funding levels for maintenance, renewal and repair became necessary. To this end, the Bello-Loftness model was developed to factor more critical facility attributes while possessing qualities that encourage its application.

3.4.3 School Facility M

To illustrate the application of the Bello-Loftness model and compare its results to that of its constituent plant value methodologies, a hypothetical school facility was considered. School Facility M is a high school situated in Pittsburgh, Pennsylvania. It is composed of face brick with concrete block back-up and steel framing. It has a floor area of 130,000 square feet (12,100 square meters) and stands at two stories with a story height of 15 feet (4.6 meters). Built at a cost of $14.2 million in 1990, it utilized "high-tech" control technologies for all its mechanical systems. According to RS Means cost guide, replacing

this facility would cost roughly $18 million in 2008. Between 1990 and 2008, the average inflation rate was assumed to be 2.5 percent. The application of the relevant plant value methodologies is seen in *Table 5*.

School Facility M	
Facility Value	
Initial Construction Cost (1990)	$14,200,000
Average Inflation Rate	2.50%
Current Plant Value (CPV): 2008	$22,147,154
Plant Replacement Value (PRV): [RS Means] 2008	$18,074,725
Annual Maintenance Investment (2008)	
CPV Model	
2% of CPV	$442,943
PRV Model	
2% x PRV	$361,495
Bello-Loftness Model (without Maintenance and Repair Backlog)	
[2% x ((0.35 x PRV) + (0.65 x CPV))]	**$414,436**
Bello-Loftness Model (with Maintenance and Repair Backlog)	
[2% x ((0.35 x PRV) + (0.65 x CPV))] + [2% x ((0.35 x PRV) + (0.65 x CPV))]	**$828,872** Until Backlog is Eliminated

Table 5

3.5   Priorities for Addressing Maintenance Backlogs

Having established that school facilities in the United States have accumulated a significant maintenance backlog, there is need to prioritize facility system renovations and repair based on criticality to facility operation and utilization. Based on a number of reasons, the general priorities when it comes to eliminating maintenance backlog were determined to include addressing water damage, HVAC systems, lighting systems, fire protection systems and then acoustics in this specific order. This does not mean the budget for addressing water damage should be highest; it means it should be addressed first even when its budgetary needs are the least.

Water damage constitutes a very critical issue to address in facilities. Besides the unsightliness of the problem, it contributes to a number of implications for facility conditions and health. Water damage in facilities contributes to the growth of mold, mildew and other fungi. According to the United States Environmental Protection Agency (EPA), exposure to mold can cause a variety of health effects and symptoms, including allergic reactions. Fungi produce allergens and spores that can trigger asthma attacks and other allergic reactions. They may also produce potent irritants and toxins. These collectively contribute to poor indoor air quality which has been determined to cause drowsiness, inability to concentrate, lethargy and absenteeism (Lyons, 2001). For two main reasons, these negative consequences are even more pronounced when it comes to elementary, middle and high school facilities. Firstly, schools have four times as many occupants per unit area than offices (Lyons, 2001). Secondly, children breathe more air per pound of body weight and have less fully formed biological defense mechanisms (HSN, 2006). They are thus more susceptible to adverse health consequences. The EPA states that asthma accounts for more than 10 million missed school days per year and, is the leading cause of school absenteeism due to illness. Also important, it may also impact

the performance of teachers. Mold also leads to further facility deterioration as it destroys what it grows on.

Heating, ventilation and air-conditioning (HVAC) systems impact the comfort level in a facility by controlling temperature, ventilation and moisture. Inadequate HVAC systems are therefore very likely to have far reaching ramifications. Earthman (2002) highlights a multitude of research studies that stressed the importance of a controlled thermal environment for satisfactory student performance. Inadequate classroom temperatures were also determined to have adverse effects on teaching performance and effectiveness as well (Schneider, 2003). The EPA indicated indoor pollutant levels may be five to a hundred times higher than outdoor levels (HSN, 2006). The provision of natural ventilation is thus critical particularly where facility maintenance has proven inadequate. Additionally, where indoor moisture and humidity are not appropriately controlled, mold and other fungi may grow and contaminate the air with toxins and allergens.

Good lighting quality has been found to be positively related to increases in student achievement (Earthman, 2004). The same study further expressed persistent poor lighting may cause not only poor student performance but affect the eyesight of students for the rest of their lives. Through an evaluation of seventeen studies, Jago and Tanner (1999) found the consensus that appropriate lighting improves student test scores and reduces off-task behavior. Bosch (2003) also found lighting to be one of the most important design elements for educators. Through a survey of teachers in Washington, DC, Buckley et al (2004) found 21 percent of respondents reported inadequate lighting in their schools. Additionally, where there are natural lighting systems in place, they should also be prioritized for renovation. A study of 21,000 students found schools with day-lighting to score 20 percent higher on achievement tests than those without (Earthman, 2004). Lemasters (1997) also reported natural lighting to foster higher student achievement through a synthesis of 53 studies. Lastly, it is also imperative to decrease or eliminate glare as it also affects visibility in the classroom. These studies collectively highlight the need to prioritize lighting systems when addressing maintenance backlog.

With regards to fire protection systems, it is important for schools to have full functioning smoke detectors, CO_2 sensors and effective means of egress. These should all adequately function to provide a 3 minute exit of any school facility while alerting firefighters in time to address the fire. All school systems should ensure this to prevent occupant and firefighter injury, prevent facility damage and, to avoid being shut down, fines and liability.

Acoustics is considered as an important element impacting student achievement (Earthman, 2004). The ability to clearly hear in the classroom is important to be enable student learning and for teacher effectiveness. Teachers were also found to believe noise impairs the academic achievement of students (Lackney, 1999). Buckley et al (2004) further determined that excessive noise causes stress in students. These collectively highlight the need to prioritize and address acoustics and noise control issues in eliminating maintenance backlog.

This prioritization is a guideline and not a specification. As such, where a detailed condition assessment has revealed components and systems on the brink of catastrophic failure, they can be addressed accordingly. It is important to note, this determination of the prioritized order for addressing maintenance backlog did not involve a very rigorous process.

4.0   Staffing for School Facility Maintenance, Renewal and Repair

Adequate staffing levels are necessary to fulfill facility maintenance, renewal and repair needs. Otherwise, such ramifications as deteriorating facility conditions and unsatisfactory facility utilization may ensue. This is also the case when it comes to school facilities. Both appropriate investment and staffing are required for addressing facility maintenance and backlog.

4.1   The Need for Facility Maintenance, Renewal and Repair Staffing

Staff is required to carry out facility maintenance and repair. The American School and University Magazine classifies facility maintenance staff into two categories, custodians and maintenance workers. Custodians refer to staff responsible for daily facility upkeep and cleaning. Maintenance workers meanwhile, refer to staff that perform skilled jobs such as HVAC, electrical or plumbing repair. They both serve a number of functions.

Custodians ensure the safe utilization of facilities. Towards this, they clean facilities and control their accessibility. This is even more critical in schools as children are both more likely to litter a facility and also to venture to dangerous facility locations. Secondly, custodians operate the mechanical equipment and other systems in a facility. For example, they may adjust the temperature settings of the HVAC system based on seasonal, weekly or daily conditions. Custodians also serve the function of repairing and replacing minor facility components. An example is the replacement of light bulbs. The custodian is charged with alerting the appropriate authority when facility repair involves skilled work. The maintenance worker is then responsible for such specialized work.

Facilities and their components typically possess distinctive features and also tend to differ in their operational conditions. A custodian familiar with a facility can identify facility components and systems with the most immediate maintenance needs particularly when there is need to prioritize in the face of budget constraints. The custodian can thus direct and identify the specific maintenance workers required to ensure the effective functioning of a facility. Besides the management and monitoring of facility and component condition, custodians serve to identify new facility utilization needs in schools based on their observation.

4.2   Staffing Levels for School Facility Maintenance, Renewal and Repair

Public school systems have different methods for determining how many facility maintenance and repair staff to employ. Kowalski (2002) presented a number of

maintenance staffing questions considered to be relevant in determining maintenance staffing requirements. Answering the questions involve identifying the types of components that must be maintained, how they should be maintained, the skills necessary to provide the maintenance, identifying the frequency of skilled or preferred maintenance, factoring the financial resources available for staffing, the jobs that are to be contracted to outside contractors and, whether staff skills can be combined.

Kowalski (2002) also provides a number of facility attributes that could provide inputs in determining appropriate staffing levels. They included facility age, original construction quality, current facility and component condition, the division of labor between custodial and maintenance staff, characteristics of site development and, frequency and types of building used by community groups. Kowalski (2002) further stated that school administrators are very likely to use a combination of qualitative and quantitative data in making staffing decisions. Milshtein (1998) developed a formula for making staffing decisions based on time estimates. The formula is seen in *Equation 12*.

Estimated Cleaning Time =
> (Average time per square foot for cleaning material) X (Total square feet of material to be cleaned) X (Frequency of cleaning the material)

Equation 12

Some school districts determine their staffing levels based on a space ratio where a number of custodians are determined for a given number of school square footage. Other school districts determine theirs based on a number of custodians for a given number of school rooms (room ratio) or even for a number of students (enrollment ratios). Studies such as Shaw (1998) expressed that school districts should have staffing plans for their facility maintenance and repair services. Despite this, many school systems neither have a plan nor a formula for determining appropriate staffing levels. A general guideline appears necessary for cases where there is no plan for making staffing decisions. Though only few studies have attempted to make this determination, one of the most cited is that by Greenhalgh (1978). Greenhalgh (1978) recommended one custodian to be employed for every 15,000 square feet (1,400 square meters) of space, for every 11 classrooms, for every eight teachers, and for every 250 pupils.

As earlier discussed, the condition of school facilities in the United States is currently poor. Current facility maintenance and repair staffing levels must thus be assessed for adequacy considering its possible role in the deterioration of school building conditions. The American School and University Magazine reported the area maintained per custodian and per maintenance worker in American public schools from 2000 to 2009. The data is illustrated in *Figure 9*.

The substantial disparity between the area maintained by per custodian and that maintained per maintenance worker is justifiable. While a custodian maintains and monitors facility conditions on a very frequent basis, a maintenance worker is only required where there are specialized maintenance and repair needs. As such, a HVAC maintenance worker may be adequate to serve two schools' HVAC maintenance and repair needs where eight custodians are required for those same schools' general facility needs.

Area maintained per Custodian and per Maintenance Worker
American Public School Districts
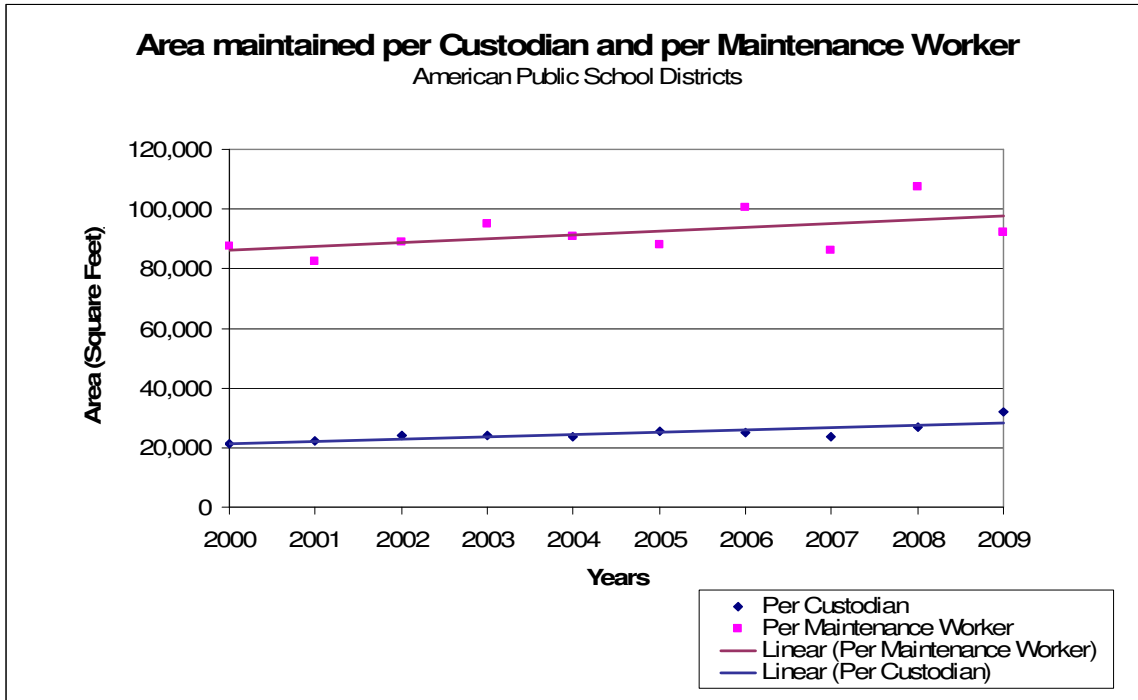
[Source: American School and University Magazine (2000 - 2009)] **Figure 9**

In terms of adequacy, current custodian staffing levels are inadequate judging by the recommended level by Greenhalgh (1978). Furthermore, the actual staffing level has been diverging and now, custodians are maintaining twice the recommended area. This is seen in *Figure 10*.

Area maintained per Custodian
American Public School Districts
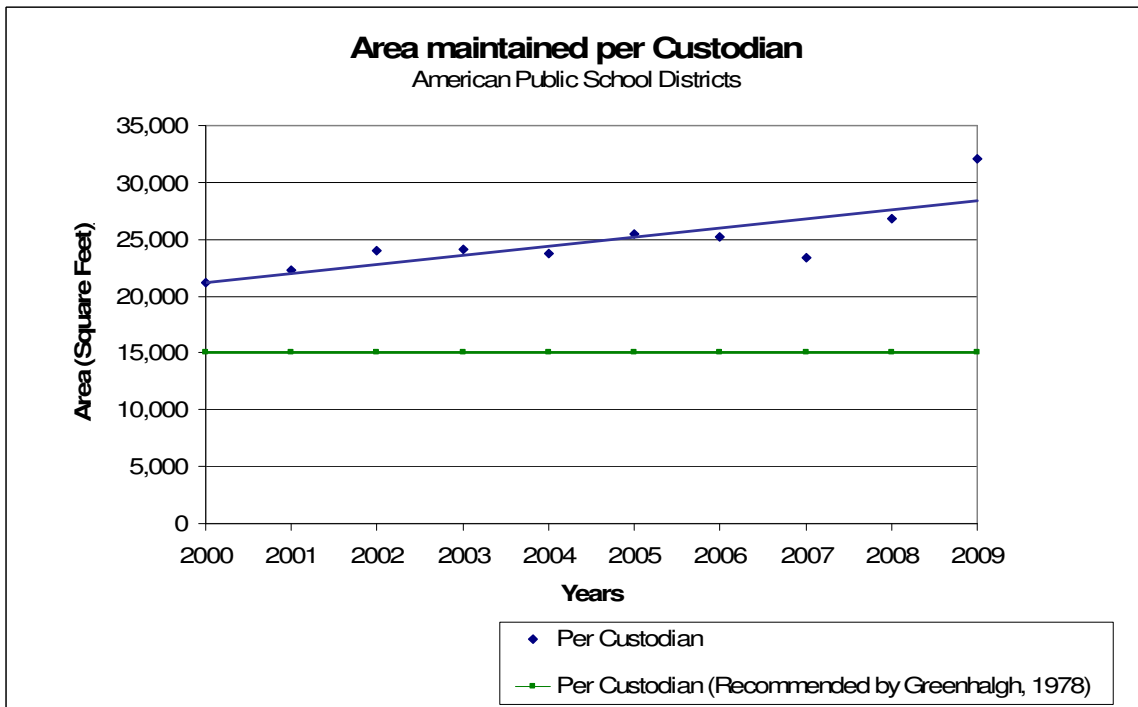
[Source: American School and University Magazine (2000 - 2009) and; Greenhalgh, 1978] **Figure 10**

With regards to the area maintained per maintenance worker, there are similar concerns as those for the custodian. The area maintained by both categories of maintenance staff is increasing when school facilities are not only increasing in their age but also in their complexity. One would have expected the square footage maintained per staff to be declining instead of increasing. This is very likely due to the same budget constraints that drive the accumulation of maintenance backlog. This situation clearly needs to be addressed since the effectiveness of maintenance and repair staff is likely to decrease with increased responsibilities and thereby cause further deterioration of school facility conditions. The space maintained per custodian needs to be brought down to the recommended level of 15,000 square feet (1,400 square meters) in order to prevent and decrease the ramifications of inadequate maintenance staffing. With regards to maintenance workers, the space maintained per worker should be brought closer to 80,000 square feet (7,400 square meters) to enable prompt and efficient repair of all specialized facility systems in schools and school districts. These levels both appear to be effective and feasible.

5.0   Outsourcing School Facility Maintenance, Renewal and Repair

Outsourcing of school facility maintenance, renewal and repair has been gaining popularity over the past few decades. Agron (2009) determined 11 percent of school districts were contracting out maintenance and operation services. Some school districts outsource for capability while others outsource for cost saving. Where a school district lacks staff with the expertise to carry out certain types of maintenance work, outsourcing becomes necessary for reasons of capability. Other schools and school districts find they may save costs when they outsource their maintenance and operation. Some smaller districts find it infeasible to employ maintenance workers for all relevant trades and as such, find they must rely on outside contractors to execute some of the specialized maintenance and repair work (Kowalski, 2002). This is a type of outsourcing known as out-tasking (Hui and Tsang, 2004). In the case of outsourcing, a whole package of support function is performed by an outside contractor. To determine whether or not outsourcing should or should not be encouraged, the arguments must be considered.

There are a number of arguments in favor of outsourcing school facility maintenance. The first of which is cost saving. Generally, the bid prices offered by the contractors tend to be initially lower than recent maintenance expenses of the school or school district. Separately, outsourcing facility maintenance may allow schools to focus on their core competencies. Improved accountability is another argument in favor of outsourcing. Also, considering maintenance, renewal and repair is the core competency of the contractor, they may have access to more highly skilled individuals that may better improve facility operations (Hui and Tsang, 2004). Lastly, outsourcing may offer operational flexibility to schools allowing school administrators ease in making budgetary decisions not at the expense of facilities needs (Kowalski, 2002).

Outsourcing school facility maintenance also has a number of opposing arguments. The first argument is it leads to loss of control (Hui and Tsang, 2004). This is in two dimensions namely, loss of control over operations and over personnel. In the first, school administrators are at the mercy of the contractor so if the contractor encounters financial or some other difficulty, the schools will bear the effects. In the latter, administrators may lack the power to employ, discipline or dismiss the contractor's employees (Kowalski, 2002). Another argument is the likelihood of increased contract cost. Initially, outsourcing offers such advantages as a sum reduction in maintenance costs. Eventually, this initial cost advantages may be usurped due to increased costing under contract. Contractors may also compensate for their low bid by using completely untrained workers. Lastly, whenever school facility maintenance is outsourced, there is a breakdown in the knowledge of a facility, its systems and changes.

Having considered the arguments supporting and opposing the outsourcing of school facility maintenance, it is discouraged though not entirely. Custodial services should not be outsourced since custodians manage and monitor the facility on a frequent basis. The knowledge of the facility mostly lies with them. The services of the specialized maintenance workers can be outsourced considering the infrequent nature of their work and, the fact that they are less likely to acquire working knowledge of a school facility as in the case of the custodian.

There is need to determine whether outsourcing offers more expertise or decreases effectiveness due to the absence of the knowledge of building system oddities. This may not even constitute an issue considering the drive towards standard and easy to maintain buildings. In such a case, the advantages, disadvantages and recommendations with regards to the subject matter may be revaluated. This however, is a topic for another research study.

6.0   **Conclusion**

The poor condition of school facilities in the United States can no longer be ignored. School infrastructure was given a D grade by ASCE in their 2009 edition of the "Report Card for America's Infrastructure". Furthermore, the total deferred maintenance of schools in the United States was determined to be $254.6 billion (Crampton and Thompson, 2008). Given the ramifications of poor school facility condition on student achievement, student attendance, teacher performance, occupant health and safety, teacher retention and recruitment, there is a clear need to adequately invest in facility maintenance renewal and repair.

In this research investigation, earlier models and methodologies for determining the appropriate investment for facility maintenance were discussed and evaluated. They were then assessed to determine the facility attributes they factored along with their feasibility of use. None was found to account for all desired features. Thus, a new plant value methodology, the Bello-Loftness model, was developed to account for more critical facility attributes and to possess the characteristics of an effective model. The model

utilizes an equal add-on to account for maintenance backlog. Priorities were also set with regards to the order of addressing maintenance backlog.

Adequate staffing levels were also highlighted as necessary to fulfill school facility maintenance and repair needs while deterring such ramifications as deteriorating facility conditions and unsatisfactory facility utilization. Current staffing levels were found to be inadequate as they were below recommended levels. Furthermore, staffing levels for both custodians and maintenance workers were found to be decreasing as both the complexity and average age of school facilities was increasing. Outsourcing was also investigated as an emerging development for addressing school facility maintenance, renewal and repair.

Conclusively, this research highlights the need to address the poor condition of elementary, middle and high schools in the United States. Towards addressing the conditions, guidelines were developed for meeting appropriate facility maintenance investment and staffing needs. As these are not specifications, the facility portfolio manager with a good knowledge of his facilities' condition, a mature condition assessment program and a detailed customized maintenance plan may not only accurately determine the required funding level but define the specific function of the resource allocation and possibly, staffing needs. The elimination of accumulated maintenance backlog in addition to more appropriate maintenance budgeting can in some time, renovate school facilities to adequate conditions.

7.0   <u>Bibliography</u>

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