Interstitial Building Space and its Relationship to Evidence Based Design

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ABSTRACT

Healthcare facilities are dynamic, long-term investments that must be able to respond to change in order to avoid obsolescence. Flexibility is a response used in healthcare facility design and construction to counter uncertainties, such as changing medical technologies, medical science and regulations. Flexible infrastructure design offers healthcare facilities the opportunity to combat obsolescence stemming from uncertainties.

Interstitial Building Space (IBS) is one of many flexible infrastructure design options that assist with both mid-range and long-term flexibility. IBS is an unfinished and unoccupied horizontal space between a building's floors, fully accessible to people for the purpose of service and maintenance.

The advent of Evidence Based Design (EBD) introduced a new dimension to the already dynamic healthcare facility. "EBD represents a body of science that links elements of the built environment with patient, staff and resource outcomes" (Malone et al. 2007 p.5). The incorporation of EBD increases the complexity for the design and construction of healthcare facilities.

A framework was developed that articulates the dependent relationships between flexibility, IBS and EBD. The framework is comprised of three key elements: 1) a comprehensive "IBS Spectrum of Benefits" matrix resulting from a systematic literature review 2) a "Flexibility-EBD Conceptual Model" illustrating the relationship between flexibility and EBD, while identifying a continuum of flexibility enabled by this relationship; and 3) a "IBS-EBD Component Mapping Framework" articulating direct matches between the "IBS Spectrum of Benefits" and EBD components.

The framework and the key elements within provide a foundational resource for stakeholders and researchers alike, navigating the interrelated intricacies associated with flexibility, EBD and IBS.

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GENERAL AUDIENCE ABSTRACT

Healthcare facilities are dynamic, long-term investments that must be able to respond to change in order to avoid obsolescence. Flexibility is one response which enables facilities to combat changes and/ or uncertainties. This thesis explores the relationships between flexibility, Interstitial Building Space and Evidence Based Design, documents each relationship, and depicts their interrelated nature with the establishment of an overarching framework.

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Chapter 1 – Introduction

Today there is more information readily available than ever before. Science and technology continue to progress and evolve at rapid rates. The sheer amount of information, as well as the continual progress and evolution of that information can become overwhelming and difficult to navigate. To cope with this reality, specialty careers have emerged which focus on very select niches. Building design and construction is representative of this.

The complexities of the construction industry have caused an evolution from the master builder into specialized trades and professions, such as builders, engineers and architects. The continual growth of complexities has impacted the ways in which these trades and professions conduct business. The architecture profession is not immune to this. Designers traditionally have had to navigate site constraints, owner demands, regulations and codes while simultaneously infusing design and artistic influence.

Designers face new sets of challenges brought with the advancements of science and technology. These advancements have crept into the very foundation of the building industry, the contract, which affects project delivery methods and stakeholder relationships. Beyond contractual changes, complexities introduced by evolving sciences, disciplines and/ or best practices such as ergonomics, biophilic design, evidence based design, green building, lean construction, etc. have had a compounding effect within the construction industry. These sciences, disciplines and/ or best practices typically do not operate within a vacuum. Often, they are reliant on, affected by or influenced by one another.

These sciences, disciplines and best practices continue to evolve, being amended or replaced to reflect state-of-the-art advancements. These increased complexities have caused many designers to specialize and cater to specific niches. In complex projects designers, builders, owners, interdisciplinary team members, users and other stakeholders must coordinate their efforts to effectively navigate project specific intricacies to ensure the best possible outcomes. Healthcare facilities are one example of a complex and multifaceted project involving numerous stakeholders, necessitating coordination between those stakeholders to produce an effective outcome.

Healthcare facilities are dynamic and highly complex, that must respond to a multitude of demands throughout their lifespan (Tusler Jr. 2014). Healthcare infrastructure is typically designed for a lifespan that ranges from 30-100 years or more (Bradley et al. 2015; de Neufville et al. 2008). A medical facility is a dynamic, growing system, which can achieve permanence only by adapting to change (Alvarez 1989).

In the context of healthcare facility design and construction, flexibility can play a critical role in responding to uncertainties. Uncertainties such as changing medical technologies, regulations and medical science are drivers that create the need for healthcare facilities to be flexible and avoid obsolescence. Flexible infrastructure design offers facilities the opportunity to adapt and expand.

Interstitial Building Space (IBS) is one of many flexible infrastructure design options able to assist with different characteristics of flexibility. IBS is an unfinished and unoccupied horizontal space between a building's floors, fully accessible to people for the purpose of service and maintenance. IBS offers many benefits, aside from flexibility: construction schedule compression, reductions in life cycle costs and unique benefits specific to healthcare such as infection control and disruption reduction.

Evidence Based Design (EBD) embodies unique design benefits specific to healthcare. "EBD represents a body of science that links elements of the built environment with patient, staff and resource outcomes" (Malone et al. 2007 p.5). EBD is a relatively new science and its use continues to be adopted by both the public and private healthcare sectors. Specifically, the Military Health System (MHS), which in 2007 mandated EBD be incorporated into all Medical Military Construction projects (Winkenwerder 2007). One EBD principle adopted by the MHS states that healthcare facilities should "be designed for maximum standardization, future flexibility and growth" (Malone et al. 2007).

1.1 Problem Statement: The Impetus for the Research

Flexibility plays an integral part in how healthcare facilities respond to change. Furthermore, existing literature advertises IBS as offering numerous benefits, one of which is flexibility. The implementation of Evidence Based Design by the Military Health System engages flexibility directly and indirectly. Directly, with the endorsement of a guiding principle specifically stressing flexibility. Indirectly, by subscribing to the implementation of EBD. Wherein, existing EBD literature advocates the beneficial impacts of flexibility.

The existing literature on IBS, however, is fragmented, failing to accurately capture a majority of the benefits it offers. Presently there is not a comprehensive source detailing the benefits offered by IBS. Moreover, existing EBD literature acknowledges the importance of flexibility conceptually, but does not explore how flexibility serves as a foundational driver which supports numerous EBD components. Finally, limited evidence exists that demonstrates the feasibility of IBS to support overarching EBD principles endorsed by the MHS, while concurrently enabling specific EBD components. It is important to understand the intricacies for each of the gaps identified so that a framework can be established that is able to articulate their interrelated nature.

1.2 Objectives

The intent of this research is to create a framework, which through synthesis, will provide a detailed understanding of the relation between Flexibility, IBS and EBD. The Venn Diagram in Figure 1.1 illustrates the conceptual relationship between Flexibility, IBS and EBD that the framework intends to expand upon. The primary objectives are to:

1. establish and validate a current spectrum of benefits offered by Interstitial Building Space

2. parallel the principles of Evidence Based Design embraced by the Military Health System to the concept of flexibility established in existing literature; thus, demonstrating how flexibility may serve as a foundational mechanism which supports certain Evidence Based Design features or responses

3. identify specific components of Evidence Based Design embraced by the Military Health System which are satisfied by the use of Interstitial Building Space

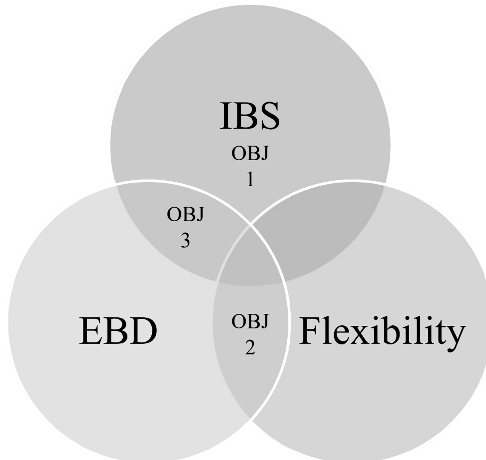

Figure 1.1 Venn Diagram Overlay of Flexibility, IBS and EBD

1.3 Scope

The establishment of benefits offered by IBS will be conducted using a systematic literature review. The intent is to establish a current and comprehensive framework for the spectrum of benefits offered by IBS. However, the resultant publications discovered during the systematic literature review are not necessarily comprehensive. A continuous attempt was made to follow the methodology associated with the systematic literature review. The methodology varied slightly between databases as a result of their proprietary software. However, the methodology, once established, remain constant. The selected databases were EBSCO Discovery, EBSCO Host, ProQuest, Google Scholar, Scopus, Engineering Village and WorldCat. The databases were not filtered for a time frame, enabling a wide-ranging collection of data.

EBD is a dynamic and ever evolving science using research informed design. The intent of EBD is not to create a "cookbook" design that results in facilities stamped from a mold. Instead, organizations are able to implement EBD in a way that is specific to their unique goals or objectives. Therefore, the EBD principles and goals identified are representative of the endorsement made by the Military Health System.

This research will present the relationship between flexibility and EBD features or responses. Examples will be used from both literature domains, EBD and flexibility, to illustrate the foundational and dependent nature flexibility has in acting as a driving mechanism for the successful implementation of specific EBD features or responses. It is not the intent of this research to provide an exhaustive or comprehensive matrix which documents the intricacies of this relationship. Instead, it is intended to serve as an observation, which documents select examples of this relationship.

The results containing the benefits of IBS discovered during the systematic literature review portion of this research will be overlaid with EBD components. The overlay will only focus on those benefits of IBS which are able to directly satisfy components of EBD. The selected EBD components are derived within the context Military Health System. Finally, every effort was made to keep the process unbiased and scientifically rigorous.

Chapter 2. Preliminary Investigation

2.1 Introduction

Currently there is a wealth of literature that focuses on flexibility as it relates to healthcare facility design. There is sufficient literature which maps out the organizational hierarchy and responsibilities as it relates to the Military Health System (MHS) and the Army's Health Facility Planning Agency (HFPA). Additionally, there is an abundance of literature focused on the qualities and requirements of Evidence Based Design (EBD) as a science and the implementation of that science into the built environment, specifically the MHS. The bulk of EBD research focuses on how the implementation of EBD into the built environment affects the outcomes of patients, staff and resources (Malone et al. 2007). Finally, there is substantial literature which focuses on flexible infrastructure design options, specifically Interstitial Building Space (IBS). The literature on IBS varies from commercial facilities, to healthcare facilities to laboratories. However, the bulk of the IBS literature used in this research was focused on healthcare facilities and laboratories.

The following literature review will be broken into three sections: Section 1, 2 and 3. Section 1 will focus on flexibility and the role of uncertainty. Section 2 will cover Evidence Based Design within the Military Health System and the U.S. Army. Section 3 will be used to explore Interstitial Building Space as a flexible infrastructure design option.

2.2 Flexibility

Flexibility will be defined in this context as: designs that can be easily modified, adapted or expanded enabling systems' owners and managers to respond easily and cost-effectively to changing circumstances (De Neufville and Scholtes 2011). Often in the literature, the terms expandability, adaptability and flexibility are used interchangeably and synonymously (Figure 2.1). For the purpose of this research the concepts of expandability and adaptability have separate and distinct meaning, but still are encompassed under the umbrella of flexibility.

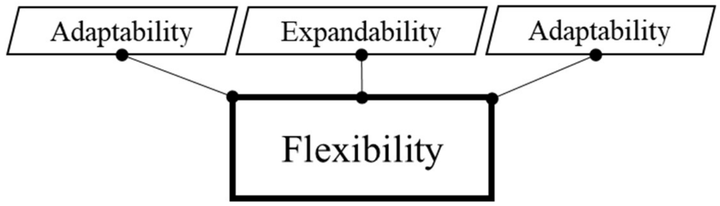

Figure 2.1 Establishing Flexibility

The quality of expandability shortens the duration of the addition of a new service or expanding an existing service. “The quality of adaptability could be viewed as a more frequent need to respond to fluctuations in workload, acquisition of new equipment or special events” (Malone et al. 2007 p. 52). Simply put, “expandability involves taking a long-range view and adaptability refers to adjusting quickly to immediate needs” (Malone et al. 2007 p.52). “Flexible designs fall into three major categories: those that enable the system to change its size, those that enable changes in function or capability, and those that protect against particular failures or accidents”(De Neufville and Scholtes 2011 p.9).

De Nuefville et al. (2008) goes on to state that flexibility can be categorized as strategic, tactical and operational. “Operational flexibility could be used on a daily or weekly basis and can quickly adapt the infrastructure usage to deal with short term volatility. A flexible furniture system that can be configured in various ways is an example of operational flexibility.” “Tactical flexibility is somewhat slower. Examples of tactical flexibility include ‘shell space’, and flexible design of footprints and operating theatres.” “Strategic flexibilities, options that we may in fact only exercise years from today. The effect of such strategic flexibility is often a substantial increase of the life-time of the infrastructure.” Tactical and strategic flexible timelines should be considered important considering “healthcare infrastructure typically has a lifespan of 50-100 years” (Bradley et al. 2015 p.2).

“Most military healthcare facilities remain in the Department of Defense (DoD) inventory for fifty years” (Malone et al. 2007 p.52). “Most health care facilities experience seven or more remodels or changes during the life of the facility” (Malone et al. 2007 p.52). “If the Military Health System (MHS) mission and medical practices were static, flexible buildings would not be needed. But the reality is different. Missions (therefore functional requirements) change. Change happens at varying time cycles (short, middle and long term) and at various levels" (Kendall et al. 2012 p.6). Consequently, "each Medical Military Construction (Med MILCON) investment requires a dual approach to first satisfy the anticipated healthcare demand when the facility opens and then to anticipate those aspects of healthcare delivery most likely to change, for which future alterations and additions may be needed" (Malone et al. 2007 p.52). One of the most pressing issues in healthcare facilities is the rate of change, which is typically so great that the facility becomes obsolete before they naturally decay (Alvarez 1989).

This is especially important because regardless of how hard we try to predict long term requirements, the forecast is "always wrong" due to changing trends and surprises. "There is a mismatch between what actually happens to a project over the span of its existence and for what the facility was designed. The reality is that future benefits and costs are uncertain, future adaptation to evolving circumstances is commonplace, and designers face a broad range of possible circumstances" (De Neufville and Scholtes 2011 p. 8).

"Forecasts are fundamental to design. We plan and implement systems around anticipated future demands and opportunities. These projections focus our thinking and determine major design characteristics. The value of any design derives from how well it matches the realizations of future demands and opportunities" (De Neufville and Scholtes 2011 p. 18). With that said, the design should remain on the fixed facility, a long-term return on investment and not equipment which is variable and subject to frequent change. Decisions about equipment cannot drive the design of the building; Instead the building must be designed to offer the "spatial and technical capacity to accommodate a spectrum of equipment and outfitting decisions" (Kendall et al. 2012 p. 14). "Forecasts are "always wrong" because there are two inescapable obstacles to good forecasting. The first consists of "trend-breakers." These are the ever-changing sets of surprises that disrupt our expectations. The second lies in the inevitable ambiguities that forever confuse our interpretation of historical records" (De Neufville and Scholtes 2011 p. 30).

These obstacles illuminate the need for the adoption of a new forecasting paradigm, which focuses on understanding the range of circumstances that might occur. (De Neufville and Scholtes 2011). "Requirements provide an alternative way to specify what a design or project should look like. The military goes to great lengths to specify the requirements for future systems, working with experts and consultants to define future threats, or the new capabilities their future strategies might require" (De Neufville and Scholtes 2011 p. 29). Requirements frequently change. The things developers once proclaimed to be "required" often turn out to be no longer necessary. This happens when events or technology change the system managers' perceptions of what is needed (De Neufville and Scholtes 2011). The bottom line is that relying on accurate forecasting to predict future needs is highly unlikely. Flexibility in design provides a framework which nests the current requirements with future uncertainties.

To achieve the best results in an uncertain environment, we need to adapt to circumstances as they arise. We need to have designs that we can modify easily to take advantage of new opportunities—or to mitigate adversities. The future is uncertain. "Design that does not account for a range of possibilities that may occur over a long lifetime runs the risk of leaving significant value untapped—or incurring major losses. An uncertain future provides a range of opportunities and risks. We can deal best with these eventualities and maximize our expected value if we build flexibility into design" (De Neufville and Scholtes 2011 p.xiii).

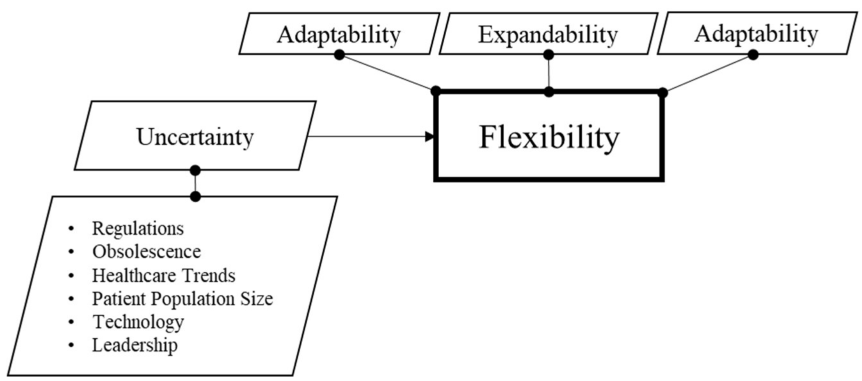

Figure 2.2 Uncertainty Driving Flexibility

2.2.1 Uncertainties

"It is a well-known fact that healthcare facilities are never finished – they continue to be adapted, part-by-part, and are often incrementally expanded before eventually being demolished" (Kendall et al. 2012 p. 9). "The forces that influence the need for flexibility are numerous and ever-evolving" (Bradley et al. 2015 p. 5). Uncertainties are a driver which establishes the need for flexibility within healthcare facilities (Figure 2.2). These uncertainties can be represented by technical change, such as equipment, communication technologies, care or treatment practices and locations. The changes can be social or organizational, affecting demographics, markets and customer satisfaction. Or these changes can be political or administrative in nature, with changes in professional standards, administrative policy, regulations, and reimbursement patterns (Alvarez 1989; Bradley et al. 2015; de Neufville et al. 2008). A healthcare facility finds itself in a unique position where so many variables that effect its ability to succeed are unknown.

When variables like science and technology advance, we can assume a perpetual rhythm of unknowns will occur. These advancements may be a blend of disciplines which marry the best of science and technologies. An architect plays a vital role in the translation and application of advancements in research by integrating it into a useful design. These advancements, nested with the vast numbers of confounding variables, make single-minded solutions questionable (Hamilton 2003). An example of this is illustrated by the way "technology and family involvement in patient care have changed the way healthcare spaces are designed. In the 1990's it was hard to convince administrators and planners of the benefits of a healing environment" (McCullough 2009 p. 93) Today, healing environments are an expectation.

Science that blends both healthcare outcomes with facility design is known as Evidence Based Design (EBD). EBD is one example of advancements in science and technology, predicating its current recommendations on state-of-the-art research-informed design. This research-informed design is not static and fails to conform to fixed regulations, which will become obsolete by new findings (Hamilton 2003). Forecasting what this body of science will recommend in the future creates an additional dimension of unknowns that are unlikely predictable and thus, require flexibility as a solution. This demonstrates how flexibility can serve as driver for EBD as depicted in Figure 2.3.

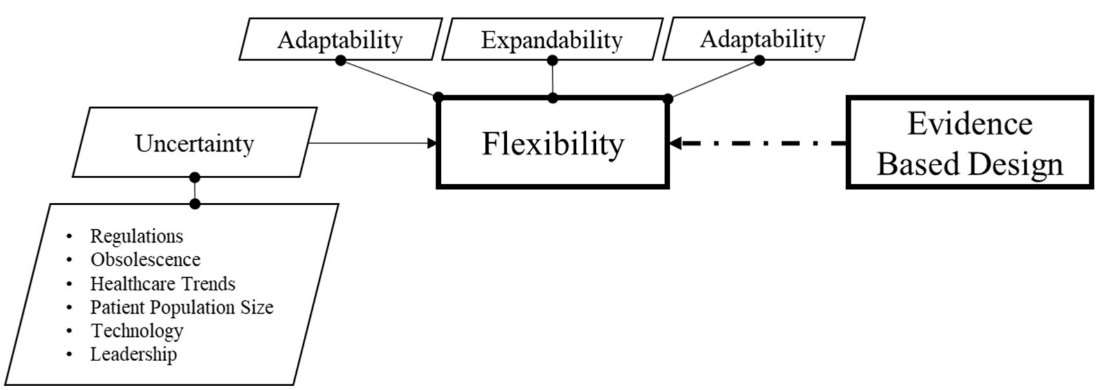

Figure 2.3 Introduction of EBD

2.3 Evidence Based Design (EBD)

Evidence Based Design (EBD) can be defined as "the process of basing decisions about the built environment on credible research to achieve the best possible outcomes" (The Center for Health Design, 2009). "EBD represents an emerging body of science that links elements of the built environment with patient, staff and resource outcomes. Science has shown that certain aspects of hospital design can improve or worsen a patient's condition. The goal is to create a healing environment that is safe, comfortable, and that supports the patient, the patient's family, and the staff" (Malone et al. 2007 p. 5,11). "EBD specifies causal relationships between features of designed environments and both desired and undesired outcomes, and the increasing importance of designing for sustainability" (Ballard 2008 p. 1). EBD is a never-ending process of knowledge accretion. The implementation of that knowledge increases the consequential understanding of decisions made about the planning, design and management of the built environment (Becker and Parsons 2007).

"EBD has the potential to create a community of practice to solve healthcare challenges by employing scientifically derived facility, technology and clinical and business process solutions. This "community" is a multidisciplinary group consisting of clinicians, administrators, patients and family members, facility and technology experts along with policy makers" (Malone et al. 2007 p. 11). The successful implementation of EBD precepts into the design process involves the combination of streamlining processes, examining new technologies, and then creating an adaptable design which can accommodate both improved processes and technologies (McCullough 2009). Designers and clients must collaboratively sift through available research and project evaluations which have been completed, and use critical thinking to develop appropriate solutions for each unique project (Hamilton 2003).

"EBD uses the scientific method—presents a hypothesis, tests it in various ways, and reports the results. This ensures the ways in which individual elements of the built environment affect patients, their families, the facility staff, and resource utilization in healthcare delivery" were accomplished in a rigorous manner (Malone et al. 2007 p.11). The EBD label should only be applied to projects where current research has validated the hypothesized outcomes in a manner that can be adequately evaluated (Hamilton 2003). The progression of EBD research over the last two decades has impacted professional design standards, such as The American

Institute of Architects (AIA) Guidelines and the Department of Defense (DoD) Space Planning Criteria, which have begun to reflect advances in EBD research. In 2007 the Military Health System (MHS) embraced five EBD principles, with attendant goals and desired outcomes.(Malone et al. 2007)

2.3.1 Evidence Based Design and the Military Health System

The five principles and associated goals embraced by the Military Health System were consequently adopted by the U.S. Army's Health Facility Planning Agency. These principles and goals were coded and aligned with each other in Table 2.1. The first four principles (P1-P4) are fluid, evolving and dependent on state-of-the-art implementation of accepted industry best practices, supported by both compelling science and business case analysis (Malone et al. 2007). The fundamental focus of the fifth principle (P5) relates to the careful stewardship of limited MHS infrastructure resources.

Evidence Based Design					
MHS EBD Principles (P)	P1: Create a Patient and Family Centered Environment	P2: Improve Quality and Safety of Care	P3: Enhance Care of Whole Person w/ Contact w/ Nature and Positive Distractions	P4: Create Positive Work Environment	P5: Design for Max Standardization, Future Flexibility and Growth
MHS Goals (G)	G1.A: Increase Social Support	G2.A: Reduce Airborne Transmitted Infections	G3.A: Decrease Patient and Family Stress	G4.A: Decrease Back pain and Work Related Injuries	G5.A: Reduce Room Transfers
	G1.B: Reduce Spatial Disorientation	G2.B: Reduce Infections Spread Through Contact		G4.B: Reduce Staff Fatigue	G5.B: Facilitate Care Coordination & Patient Service
	G1.C: Improve Patient Privacy and Confidentiality	G2.C: Prevent Waterborne Infections		G4.C: Increase Team Effectiveness	
	G1.D: Provide Adequate and Appropriate Light Exposure	G2.D: Reduce Medication Errors		G4.D: Eliminate Noisy and Chaotic Environments	
	G1.E: Improve Patient Sleep and Rest	G2.E: Preventing Patient Falls			
		G2.F: Reduce Noise Stress and Improve Speech Intelligibility			

Table 2.1 MHS EBD Principles and Goals

Each of the goals represented in Table 2.1 were conscious decisions made by the MHS to support the principles with which they are aligned. For example, G1.A is the first goal and G1.B is the second goal that align under the first principle (P1). For the purpose of this thesis, the dependence on state-of-the-art implementation of accepted industry best practices are referred to as EBD features or responses.

New developments continually arise to displace established technologies. What was state-of- the-art yesterday may be out of date tomorrow. New technology affects the value of investments directly and indirectly because of the way it changes patterns of demand. Advances may have complicated, unanticipated ripple effects (De Neufville and Scholtes 2011). Therefore, it is important to recognize the interdependence future flexibility and growth has on EBD implementation within the MHS. Figure 2.4 expands on EBD to include the components associated with the MHS' EBD, demonstrating how flexibility impacts not only EBD as an overarching science, but also its components.

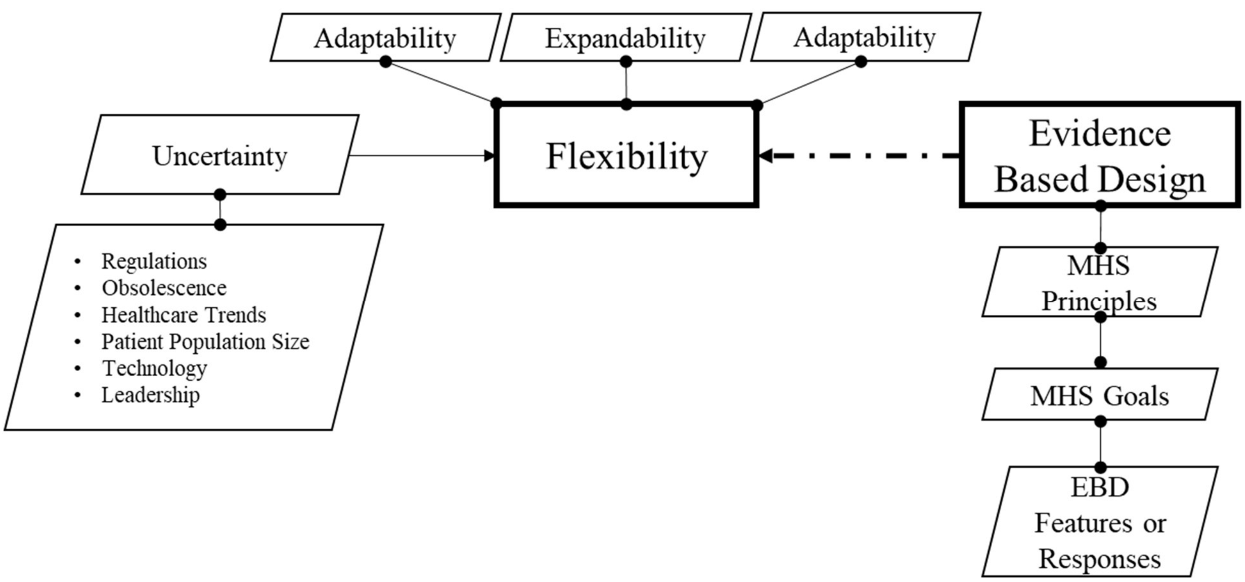

Figure 2.4 Context for MHS EBD within Framework

2.3.2 Evidence Based Design (EBD) and the Military Health System (MHS)

The MHS is one of the largest and complex healthcare institutions. Its mission is threefold: Ensuring the 1.7 million active and reserve component personnel are healthy, allowing them to complete their national security missions, ensure that all active and reserve medical personnel in uniform are trained and ready to provide military care in support of operational forces around the world, and to provide medical benefits for the more than 9.4 million active duty personnel, military retirees and their families ("About the Military Health System" n.d.). Leading the MHS, is the Office of the Assistant Secretary of Defense for Health Affairs (OASD(HA)).

The ASD(HA) is a civilian, Senate-confirmed official who serves as the chief medical adviser to the Secretary of Defense and oversees health policy and budgeting across the system, as well as directing the activities of the Defense Health Agency (DHA) ("About the Military Health System" n.d.). In 2007, the Assistant Secretary of Defense for Health Affairs (Dr. William Winkenwerder), drafted a Memorandum for Record mandating the implementation of Evidence-Based Design in all Military Medical Treatment Facilities (MTF) within the Military Health System (Winkenwerder 2007). In response to this request, the Army's Surgeon General directed the U.S. Army's Health Facility Planning Agency to act.

2.3.3 Health Facility Planning Agency (HFPA)

The HFPA's primary role is to serve as the U.S. Army Surgeon General's contracting agent and user representative for health facility development. The organization consists of a consortium of architects, engineers, project managers, and construction management professionals whose primary job is the planning, programming, design, and construction of military medical treatment facilities (MTFs) and medical research facilities (Salazar 2017). The organization is charged with the oversight of the capital improvement portfolio for all of MEDCOM's medical infrastructure. This includes managing plans and programs not only for the facilities' design and construction, but also for the maintenance, repair, energy management and sustainability of both the existing medical footprint, and new replacement facility construction (Salazar 2017).

The HFPA has many guidelines, policies and regulations which assist the organization in the accomplishment of its mission, one of which is the Unified Facilities Criteria (UFC). The UFC is a living document that provides mandatory policies and procedures for programming, planning, design, and construction throughout the lifecycle of military medical facilities

(Department of Defense (DoD) 2017). The UFC states EBD standards shall be included where applicable based on the project scope and building type. Furthermore, the UFC highlights the importance of flexibility; it states that planners and designers of MHS facilities must consider impacts of decisions throughout a project's life-cycle including future adaptation, conversion and operation of the facility.

Design considerations are used by the UFC with the objective of achieving a building with optimum functionality, appearance, maintainability, flexibility and adaptability. One design consideration suggested by the UFC is the use of the Interstitial Building System. The concept of the Interstitial Building System goes by various names within the healthcare industry: The Veterans Health Administration calls it the VA Hospital Building System (Office of Construction, Veterans Administration 1977) and those in the private sector often refer to it as the Integrated Building System (Tusler Jr. 2014). Regardless the naming convention, a key component of to these systems is the use or allocation of an Interstitial Building Space.

2.4 Interstitial Building Space (IBS)

For the purpose of this research Interstitial Building Space (IBS) will be defined as unfinished and unoccupied horizontal space between a building's floors, fully accessible to people. Its purpose is to house the majority of the facilities utility distribution and terminal equipment thus, reducing the need for access from, and the consequent disruption to, the uninvolved occupied areas (Vondrak and Riley 2005). The literature uses a variety of terms such as: horizontal service runs, service zones, service floors, interstitial service space, interstitial floor and interstitial space which comply with the definition used above.

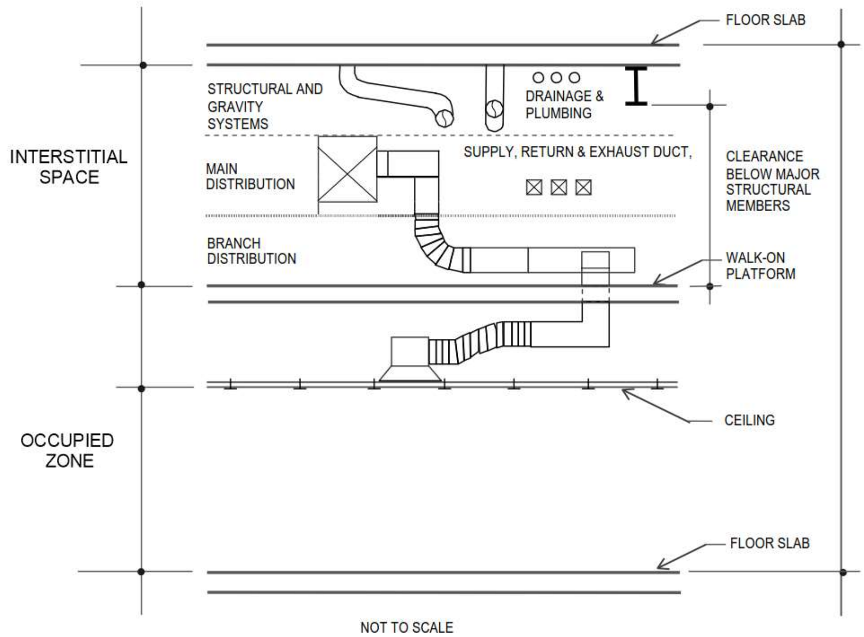

Figure 2.5 IBS Diagram
Source: DoD "Unified Facilities Criteria" (2017)

Figure 2.6 IBS Example
Source: DoD "Unified Facilities Criteria" (2017)

IBS can be applied either universally i.e. full spans between each floor, or partially i.e. only on select floors or in the vicinity of certain departments. Additionally, they may provide full access i.e. a walk on deck, or provide only partial access i.e. a catwalk system in predetermined locations (Alvarez 1989). However, it is important to note that for the Department of Defense, the "walk-on platform" of the service or distribution zone is not considered a separate floor of the building (Leveridge 2013).

IBS is one of many flexible infrastructure design options which address flexibility or adaptability in buildings (Tusler Jr. 2014). Buildings needing flexibility, frequent access and minimal disruptions are the best candidates to fully realize the benefits of IBS. These facilities include information technology, microelectronics, laboratories, radiation suites, hospitals and healthcare facilities (Haxton 2003). IBS is well suited for the dynamic nature of healthcare facilities. Therefore, the benefits of IBS will be explored within the context and applicability to healthcare facilities (Figure 2.7).

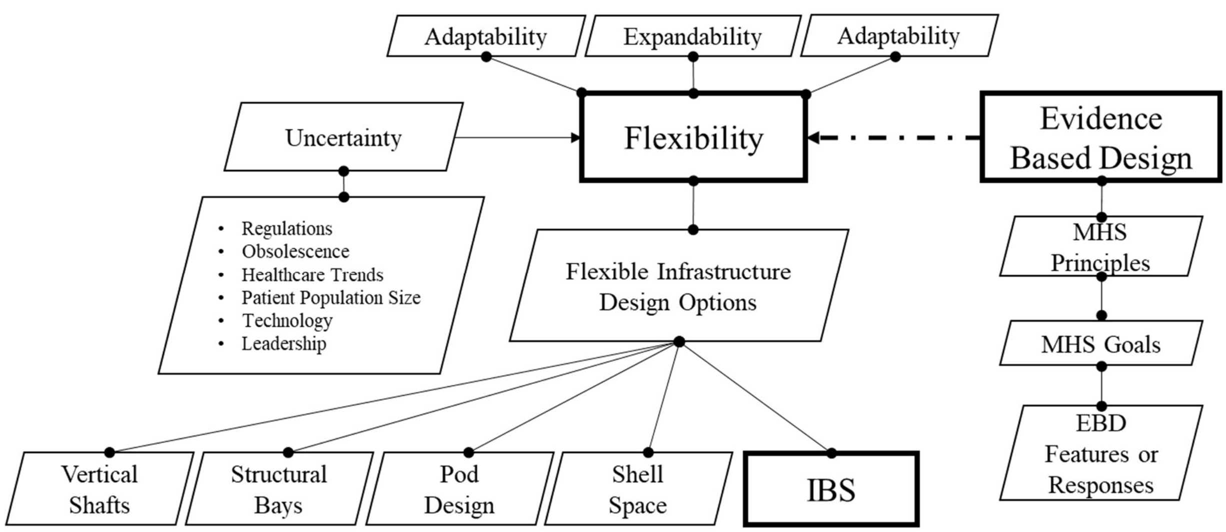

Figure 2.7 IBS Inclusion to Framework

There are numerous benefits IBS offer applicable to healthcare related facilities, including laboratories, and hospitals. In hospitals IBS design is thought to offer advantages in infection control, reducing the potential for acquiring healthcare associated infections(HAI); in flexibility, maximizing the potential to adapt to technological changes; in disruption control, reducing the potential to impact daily clinical operations; in construction, maximizing the potential to most effectively employ various crews; and in maintenance, minimizing the costs and time associated with facility maintenance (Leveridge 2013). Interstitial space provides good long-term adaptability and has proven successful for modernizing older buildings (Bell et al. 1996).

Laboratories can be a standalone facility or incorporated as a department in a hospital. "Interstitial spaces have excellent advantages to provide energy-efficient layouts of the services required for laboratory-type facilities. They provide excellent access for maintenance personnel and provide good long-term adaptability and a more efficient maintenance program" (Design Guide 2003) The use of interstitial spaces that create additional floors for mechanical systems is a design strategy that can facilitate both the construction and operation of laboratories. By providing additional space and easier access to mechanical systems, interstitial designs facilitate maintenance and reconfiguration of laboratories, thus reducing life cycle costs. Despite these and other advantages, the use of interstitial space is often eliminated as a laboratory design option due to perceptions of high first costs. However, studies have been conducted which indicate IBS does not require first cost premiums (Vondrak and Riley 2005).

Reductions in life cycle costs are the most compelling economic argument in favor of interstitial design configurations. The facilities manager of the Salk Institute identifies life-cycle savings to be the most enabling property of IBS, and that many of their most complex projects would not have been feasible without interstitial configurations. In reference to the operational cost savings of interstitial spaces, premiums paid for interstitial floors were found to pay for themselves within a two-year period depending on the projects complexity (Vondrak and Riley 2005).

In addition to the advantages of design and maintenance, there are less obvious advantages realized during construction phase. For example, IBS enables concurrent construction/ trade stacking of MEP trades and finishing trades. This results in a tremendous savings in time which can reduce general conditions costs, financing, and owner opportunity costs. Additionally, the extra space can also minimize the cost of last-minute design changes. One study found the cost of minor rerouting due to field conflicts to be between $500 and $3,500 whereas the cost of major conflicts was anywhere from $2,000 to $25,000 (Vondrak and Riley 2005).

2.5 Summary and Conclusion

In summation, literature exists that discusses flexibility and its associated dependent and independent variables. Furthermore, literature also confirms the dynamic and ever-changing composition of healthcare facilities. Illustrating how the appropriate use of flexibility is able to simultaneously assist facilities meeting current requirements while combating future uncertainties, through the implementation of designed adaptability and expansion measures.

The awareness for the need and utilization of flexibility has been propagated within the literature to reflect various flexible infrastructure design options, one of which is Interstitial Building Space. Existing literature has successfully established a strong correlation between flexibility and IBS. IBS since its conception in the late 1960s, it has received varying degrees of research. Some of the results are conflicting and many fail to accurately capture the majority of the benefits contributed by IBS.

The literature highlights how the emergence of Evidence Based Design has gained substantial traction as a legitimate body of science in recent years. It has been endorsed and incorporated by major organizations such as the AIA and the MHS. The literature surrounding EBD primarily focuses on linking elements of the built environment with patient, staff and resource outcomes (Malone et al. 2007). Additionally, EBD literature acknowledges, at a high level, the importance for the use and incorporation of flexibility into its framework.

Therefore, the intent of this research is to establish a current and comprehensive IBS spectrum of benefits framework, identify the relationship between flexibility and specific EBD features or responses substantiated by existing literature and finally, and establish those benefits offered specifically by IBS as it relates to solving or addressing EBD components.

Chapter 3. Research Methodology

3.1 Introduction

The design of this research was structured in a way that directly nests with the research objectives. The first objective was to establish the spectrum of benefits offered by IBS through the development of a framework. For this objective, a systematic literature review was conducted for this purpose.

The purpose of the second objective was to demonstrate a parallel between the concept of flexibility and EBD features and responses; thus, demonstrating how flexibility may serve as a foundational mechanism which supports certain EBD features or responses. The establishment of flexibility at a foundational level of EBD gives rise to a framework suggesting a continuum of flexibility within EBD.

The third and final objective was to establish specific EBD components embraced by the MHS which are satisfied by the use of IBS. This phase of the research built upon the outcomes/ variables used in the previous two steps. A framework model was created that nested the IBS spectrum of benefits with EBD components.

Figure 3.1 was originally used to illustrate a conceptual overlay between Flexibility, IBS and EBD. Figure 3.2 is an expansion of Figure 3.1, establishing a framework that articulates the alignment and relationships of the objectives as discussed in the Chapter 2.

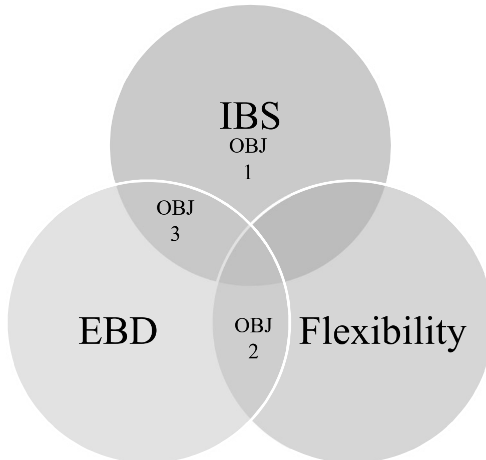

Figure 3.1 Venn Diagram Overlay of Flexibility, IBS and EBD

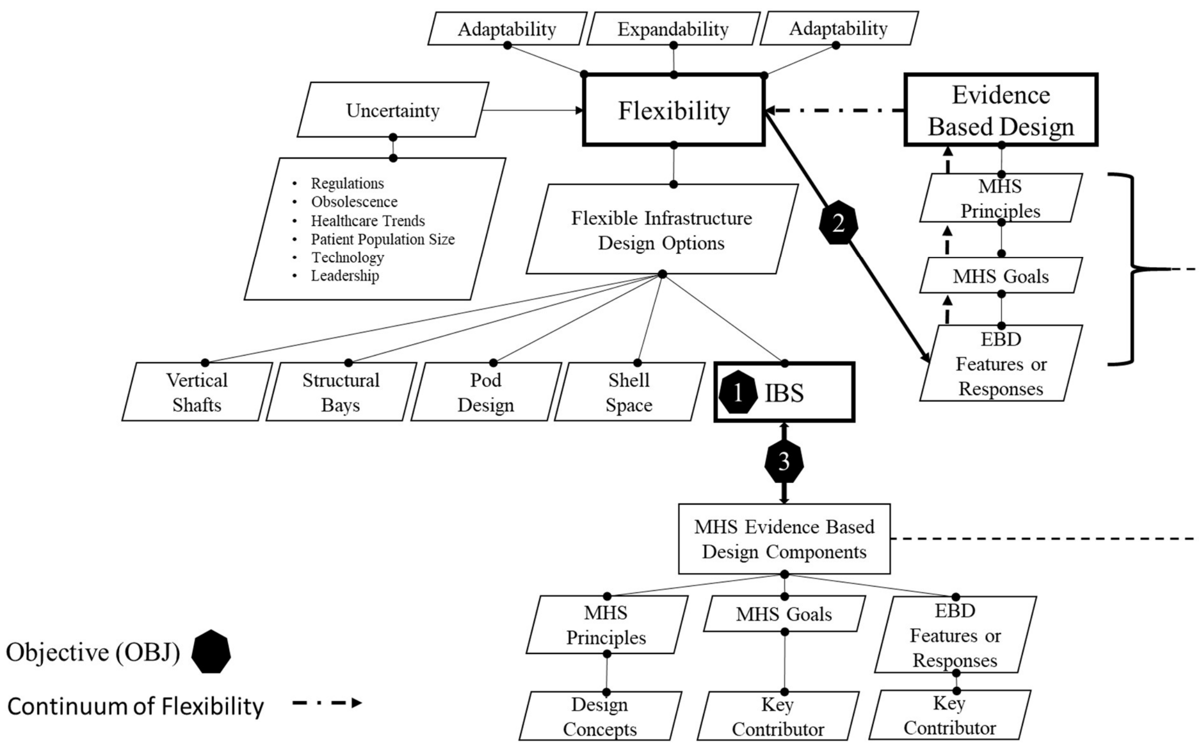

Figure 3.2 Framework Objectives

3.2 Interstitial Building Space Spectrum of Benefits

3.2.1 Introduction

During the preliminary investigative phase for this research it became apparent that there was little literature that focused on IBS. A significant portion of the literature that did exist was fragmented i.e. not covering all of the benefits offered by IBS which had been previously published. Furthermore, a significant portion of the literature was not current and was published in the 1970's. Due primarily to these two factors it was determined that a current and comprehensive investigation was needed. The intent of the first objective (Figure 3.3) was twofold: first, to establish a process that was replicable and second, to create a current and comprehensive spectrum of benefits offered by IBS to produce a baseline. The methodological design selected for the first objective was the use of a systematic literature review.

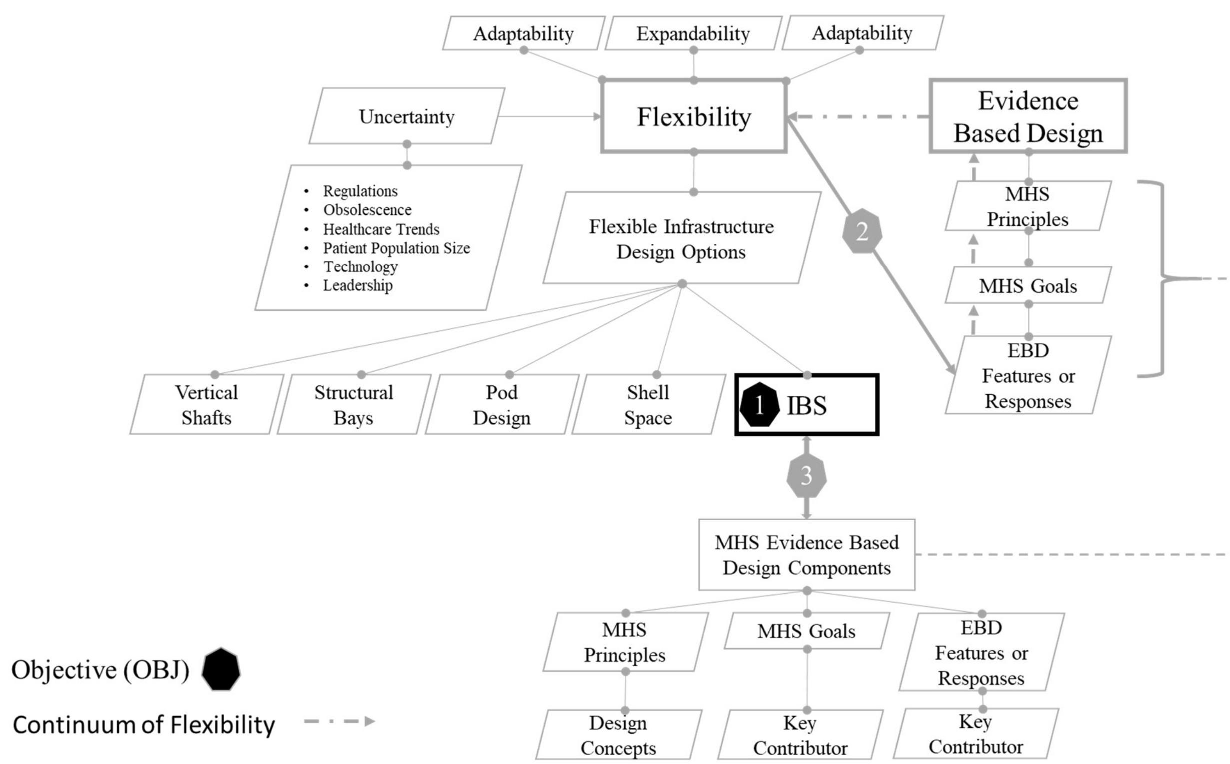

Figure 3.3 Objective 1

The systematic literature review was used in order to search for and draw together all known knowledge on the benefits of IBS. The review aimed for an exhaustive and comprehensive search, however the search conditions revealed a fragmented indexing structure within the available databases. This resulted in a unique methodology during the search string establishment but, resulted in a set of core publications offering a comprehensive scope for the benefits offered by IBS. Figure 3.4 represents the progression used for the systematic literature review process.

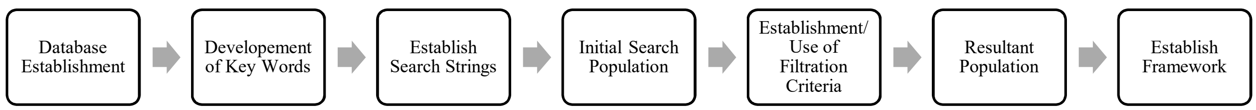

Figure 3.4 Systematic Literature Review Process

3.2.2 Database Establishment

The systematic literature review process was initiated with the selection of databases. The first criteria for selection of the databases was predicated on their open market availability or subscription by the Virginia Tech University Library system. The only open market database selected was Google Scholar. This decision was made primarily based on its prominence as a free open market tool that is widely available and well known. The Virginia Tech Library system had 648 available databases. These databases where then filtered by subject: Architecture, Art and Design with 44 databases, and Engineering and Physical Science with 132 databases, both of which are categorized by the Virginia Tech Library system (Figure 3.5).

Initially the Architecture, Art and Design subject database was reviewed. The title and associated description for each database was then reviewed. During the review process two particular database platforms were referenced repeatedly: EBSCO and ProQuest. Subsequently, an in-depth review was completed on these two platforms. It was determined that both EBSCO and ProQuest would meet the needs of the research because both are platforms which are able to pull from multiple databases. Thus, they provide a far-reaching selection of databases that indexed citations, abstracts, journal articles, books, dissertations and theses.

The Engineering and Physical Science subject database was then reviewed. The same process was used for the Architecture, Art and Design subject database. Within the Engineering and Physical Science subject both EBSCO and ProQuest were referenced repeatedly as different database platforms. This validated the decision to use these database platforms as a framework for the research. Additionally, the Engineering Village database platform was used. This decision was based on the need for additional database augmentation. This platform is able to reference four additional databases with a specific focus on engineering.

Finally, in an effort to ensure a comprehensive database or database platform search, four additional databases were used (Figure 3.5). As mentioned, Engineering Village, an Engineering and Physical Science database platform that was selected to augment EBSCO and ProQuest. Next, Google Scholar was selected due to its open market availability. The other two databases did not populate within the Architecture, Art and Design subject or the Engineering and Physical Science subject; instead they came as recommendations for consideration from a library sciences expert. The first selection was Scopus which is an archival literature database. Scopus advertises it as the “largest curated abstract and citation database of peer-peer reviewed literature, in the fields of science, technology, medicine, social sciences, and arts and humanities” The second selected database used was WorldCat. This database searches libraries worldwide for literature or material over a variety of formats. WorldCat was selected primarily because its database indexing structure is successfully able to populate printed material, which is not available in digital format.

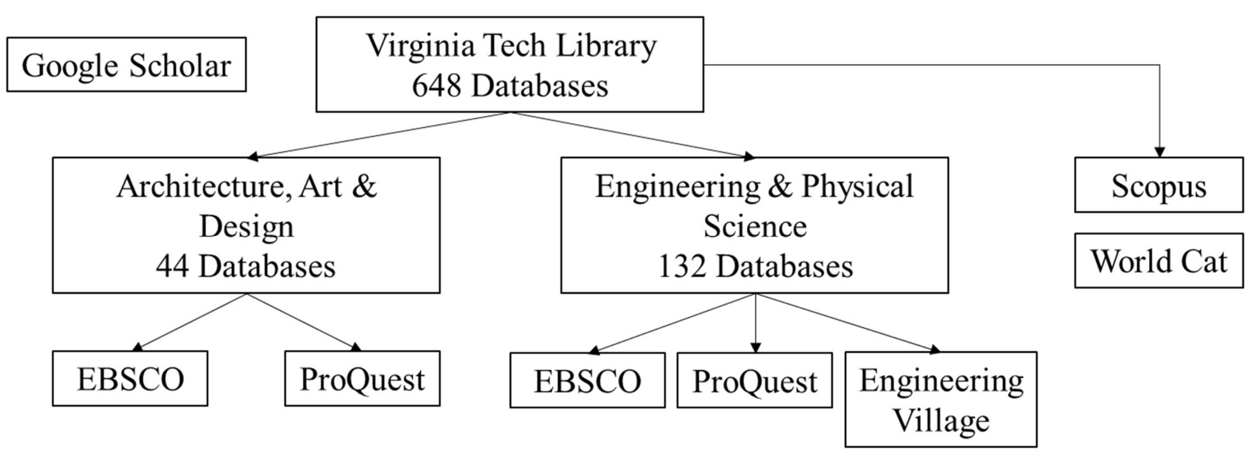

Figure 3.5 Database Establishment

3.2.3 Search String Establishment

The search string establishment was broken into four phases. The first phase involved testing identified key words through preliminary searches. The second phase commenced once a discretionary level of confidence was established in a set of search strings that were likely to produce valuable results. The third phase consisted of a complex final search string that used the knowledge from previous search strings to build a compounded search that best captured the spirit/ intent of the search. The fourth and final phase consisted of replicating the search string used in the third phase within other mentioned databases.

In the first phase multiple search strings were experimented with to see both the quantity and type of search results. Here, the intent was to explore how the databases indexing structure responded to different types of search strings. The initial databases used for preliminary searches were EBSCO Discovery and ProQuest. This phase resulted in, through a trial and error, a set of refined search strings demonstrating the ability to succinctly capture relevant results. Below is Table 3.1 representing the search strings used during the first phase and the unfiltered results.

interstital building space	interstitial space AND building	service floor AND interstitial
service floor AND building AND interstitial	interstitial space AND building	service zone interstitial floor
service floor AND building AND interstitial space	service floor AND interstitial	interstitial design space
"interstitial space"	interstitial mechanical space	"evidence based design" AND flexibility
flexible infrastructure design AND interstitial building space AND facility AND healthcare	flexible infrastructure design AND interstitial building space AND building AND healthcare	flexible infrastructure design AND interstitial AND facility AND healthcare
"evidence based design" AND principles		

Table 3.1 Search String Keyword Experimentation

The decision was made to begin the second phase once search strings demonstrated the ability to capture relevant results. The search strings (Table 3.2) used in this phase were entered into EBSCO Discovery, ProQuest and Google Scholar. During this phase the methodology was recorded in order to comply with the goal of future replication.

interstitial mechanical space	interstitial building space
interstitial building space healthcare	"interstitial space"
service zone interstitial floor	interstitial space

Table 3.2 First Set of Recorded Search Strings

To this point in the process the EBSCO Discovery search platform was used. However, after several attempts to filter, it was recognized that the software was not accurately recognizing subject indexing. For example, if there were “5” documents that were recorded as having a subject of “architecture” in each document’s detailed record, the filter for “subject” drop down in the database platform would not have an option for architecture. Furthermore, when filtering by subject EBSCO Discovery would incorrectly represent the actual number of available sources. For example, EBSCO Discovery would state there were “1000” results available under a specific subject (e.g. engineering), if only engineering was selected in the search it may only populate “8” results. Therefore, an attempt was made to see if EBSCO Host, a sister platform, was plagued with the same issue. It was determined that EBSCO Host functioned properly and was selected as the database platform moving forward. ProQuest functioned properly and did not demonstrate any inaccurate or erroneous results.

The third phase used one search (Table 3.3) string that utilized passive filtering due to its increased complexity. The development, utilization and evaluation of results from the search strings used during the second phase provided some valuable insights: First, it suggested how “interstitial” was used within literature. Interstitial is heavily used within the medical profession/ community. In order to combat this the terms “architecture” OR “design” were added. Second, a significant portion of the literature focusing on IBS was discussed in the context of healthcare facilities (e.g. Laboratories and Hospitals). Therefore, additional terms related to healthcare were added in order to assist with the indexing within the databases. During this phase EBSCO Host and ProQuest were used. Additionally, the methodology was recorded for replication purposes.

interstitial space OR "interstitial NEAR space" OR "interstitial floor" OR "interstitial NEAR floor" OR "mechanical floor" OR "horizontal mechanical floor" OR "horizontal service run"
AND
architecture OR design
AND
hospital OR healthcare OR "health care" OR "health NEAR facility" OR "health facility" OR lab OR laboratory

Table 3.3 Second Recorded Search String

The fourth and final phase used the search string from the third phase and ran it through the remaining selected databases. The intent was to determine how the indexing from other databases may respond to the increased complexity of the search string. These databases included Engineering Village, Google Scholar, Scopus, and WorldCat. While each of these databases produced results generated from the search string, their associated yields were low. The exception was Google Scholar, which produced 12,100 results. However, due to Google Scholar's inability to filter search results beyond author, publisher, or date range it was not used as a database in this phase. Again, the methodology was recorded throughout this phase for all other databases.

3.2.4 Database Filtering

3.2.4.1 Introduction

Once the databases were identified and the search strings were selected, a replicable process for the filtration of results was established. This process was necessary to ensure replication. However, due to the unique and proprietary nature of each of the databases used, mirrored replication was not possible. With that said, each database was filtered using an identical foundational process (Figure 3.6) which catered to the unique qualities of the individual databases, producing a resultant population meeting the same specifications.

Figure 3.6 Database Filtering Process

For simplicity of discussion, each database-filtering methodology will be discussed by search string phase and by database.

3.2.4.2 Phase 1 Database Filtering

It is important to note that during this phase the results of the search strings were not filtered beyond the initial database configuration. The intent was to only capture how each database responded to each search string within its indexing structure. Thus, producing a set of search strings which demonstrated the ability to capture relevant results. "Relevance" in this context is defined as: search string terms which appear in key fields (e.g. Title, Subject, or Abstract) and that the resultant publication maintained applicability to how this research defines IBS (i.e. Publication Subject)

EBSCO Discovery

Once the database home page was populated within the web browser the advanced search option was then selected. First the search string was entered into the database platform's search field. In the "search options" the following selections were made: 1) "find all my search terms" 2) "also search within the full text of the articles" 3) "apply equivalent subjects" and 4) "available in library collection". The results are listed in Table 3.4.

Search String	Results
interstitial space AND building	243,867
interstitial building space	231,764
service floor AND building AND interstitial s	157,412
service floor AND building AND interstitial	150,918
interstitial mechanical Space	205

Table 3.4 EBSCO Discovery Search String Results

ProQuest

The ProQuest database selected during this phase was ProQuest Dissertations and Thesis. The database "advanced" search option was then selected and the search string was entered into the search field. Next to the "in" option, the drop-down selection of "anywhere" was chosen. The results are listed in Table 3.5.

Search String	Results
interstitial design space	65,078
interstitial space	64,998
interstitial building space	27,837
"interstititai space"	12,257
service zone interstitial floor	8,766
service floor AND interstitial	8,753
"evidence based design" AND principles	892
flexible infrastructure design AND interstitial building space AND building AND healthcare	563
flexible infrastructure design AND interstitial AND facility AND healthcare	510
"evidence based design" AND flexibility	508
flexible infrastructure design AND interstitial building space AND facility AND healthcare	459

Table 3.5 ProQuest Search String Results

3.2.4.3 Phase 2 Database Filtering

During the second phase three databases were used: EBSCO Discover, ProQuest, and Google Scholar. This process was initiated with database configuration and ends with the final results as outlined in Figure 3.4 above. Each of the databases and search strings used in this phase varied slightly in the database configuration and the 1st filter however, the 2nd and 3rd filters remained constant. It is important to note, that this phase was documented allowing for future replication and each of the final results were accounted for within the findings. Additionally, there are variances in the search strings used for each database. This was done to mitigate indexing variances between databases in order to provide a broader population of relevant results.

3.2.4.3.1 Database and 1st Filter Configuration

EBSCO Discovery

In this segment of phase 2 there were two search strings used in EBSCO Discovery. Each search string had a slightly different database configuration associated with it. The first configuration was only used for the for the first search string (interstitial mechanical space) This configuration began with selecting advanced search. Then the search string was entered into the search field and the following "search options" were selected 1) "Boolean/phrase" 2) "also search within the full text of the articles" 3) "apply equivalent subjects" and 4) "available in library collection". The next configuration was only used for the second search string (interstitial building space healthcare). The same selections were made from the first configuration except the "1)" selection was changed from "Boolean/phrase" to "find all my search terms."

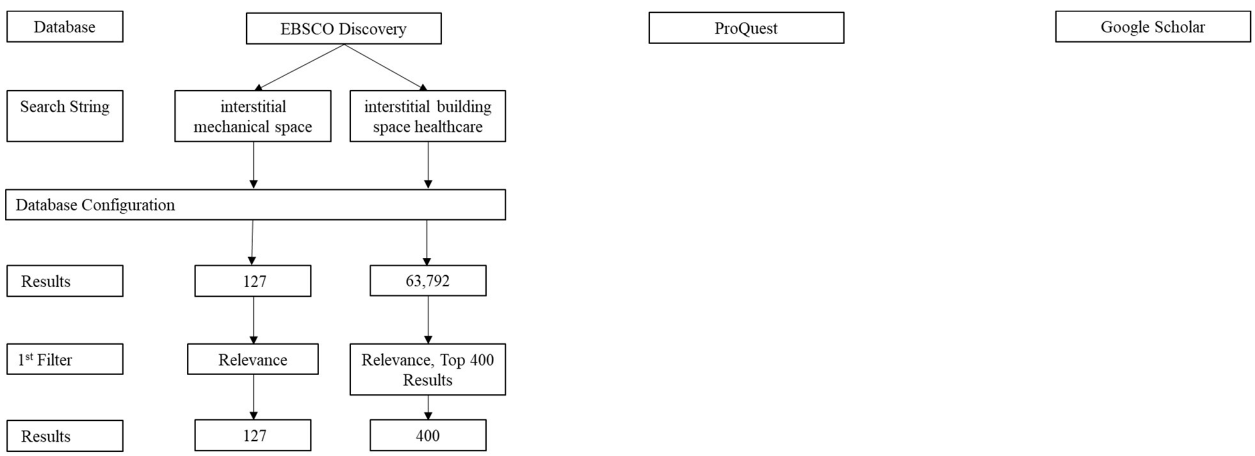

Figure 3.7 Phase 2 EBSCO Discovery 1st Filter Results

This resulted in the initial results for each search string (Figure 3.7). No selection was made in the column containing options to refine the search results. However, along the top right of the page there are options to sort the results and options for page formatting. Here the results were sorted by "relevance" and the page formatting options selected were "standard" result format, "50" results per page, and "3 columns" for page layout.

The "standard" result format used in the page formatting would typically present the following results: The title, author, type of publication (e.g. academic journal, book, etc.), "one line of text from the publication" and a list of the associated subjects. The information which populated for each publication was dependent on the proprietary indexing of EBSCO Discovery. For example, the subjects or the "one line of text from the publication" may not have been displayed for every resultant publication.

It was determined in this phase that EBSCO Discovery was not able to properly refine the search results. Therefore, the 63,792 initial results populated by the second search string could not be reliably filtered, thus, only the first 400 results were used. This decision was predicated on the decreasing number of "relevant" documents beyond 350. Between publication "301" and "400" there were no "relevant" documents which met the inclusion criteria (Figure 3.8).

Range of Populated Database Results	Number of Results Meeting Inclusion Criteria
1-50	22
51-100	11
101-150	4
151-200	2
201-250	3
251-300	1
301-350	0
351-400	0

Table 3.6 EBSCO Discovery Phase 2 Inclusion Results

ProQuest

In this segment of phase 2, two search strings were used in ProQuest: (service zone interstitial floor) and ("interstitial space"). Both search strings had an identical database configuration associated with it. In the advanced search option each search string was respectively entered into the search field. Next, the database tab was selected. ProQuest offers 35 database options within their platform, seven were selected (Figure 3.9).

Database Selection
ABI/INFORM Global
Design & Applied Arts Index (DAAI)
Dissertations & Theses @ Virginia Polytechnic Institute and State University
eBook Central
ProQuest Dissertations & Theses Global
Publicly Available Content Database
Technology Collection

Table 3.7 ProQuest Database Selection

Once the seven databases were chosen “All dates” was selected. No selection was made under the “source type”, “document type” or “language”. The page expander labeled “result page options” was chosen and the following selection were made: “relevance”, “50” items per page, and “exclude duplicate documents”. This resulted in the initial results for each search string (Figure 3.8), for this segment the following refinements/ filters were selected: Under “source type”: “Dissertations/ Thesis” and “Scholarly Journals”, Under “Subject”: “architecture” and “civil engineering”.

ProQuest only offers a standard format for displaying the populated results. The result format used in the page formatting would typically present the following results: The title, author, type of publication (i.e. dissertation/ thesis or academic journal), and “up to three lines of text from the publication”. The information displayed in the “up to three lines of text from the publication” were generated by the software and would highlight terms found in the search string. The information which populated for each publication was dependent on the proprietary indexing of ProQuest. For example, the “up to three lines of text from the publication” may not have been displayed for every resultant publication.

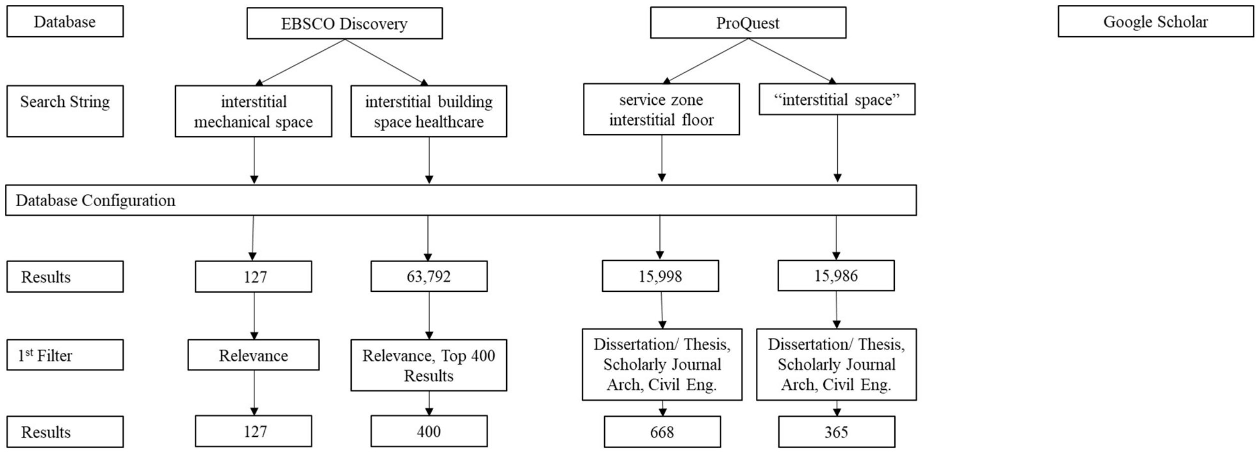

Figure 3.8 Phase 2 ProQuest 1st Filter Results

Google Scholar

In this segment of phase 2, there were two search strings used in Google Scholar: (interstitial building space) and (interstitial space). Both search strings had an identical database configuration associated with it. First, the advanced search was selected and then each respective search string was entered into the search field "find articles with all of the words" text box. Finally, the "in the title of the article" was selected and the author, published in, and date range text boxes were left blank. This resulted in the initial results for each search string (Figure 3.9). The following four options to refine/ filter the search results were selected: "any time", "relevance", "include patents" and "include citations".

Google Scholar only offers a standard format for displaying the populated results. The resultant format would present the following results: the title, author, publication title, year published, source of the publication and "up to three lines of text from the publication". The information displayed in the "up to three lines of text from the publication" were generated by the software and would highlight terms found in the search string. The information which populated for each publication was dependent on the proprietary indexing of Google Scholar.

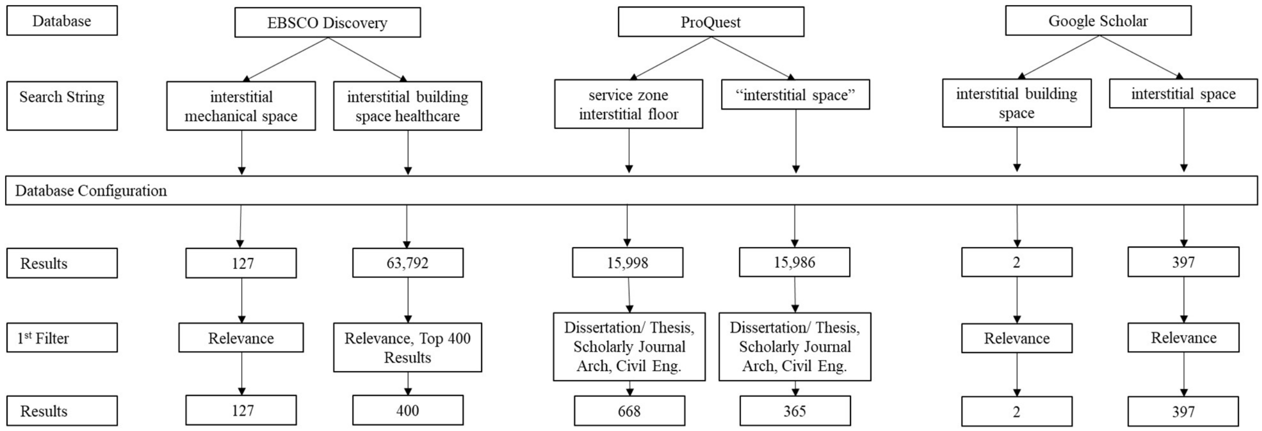

Figure 3.9 Phase 2 Google Scholar 1st Filter Results

3.2.4.3.2 Second and Third Filter Configuration

While all three databases had unique database configurations and different criteria for the 1st filter, they all had the same criteria applied in the 2nd and 3rd filter. The 2nd filter applied the exclusion and inclusion criteria to each resultant publication. To ensure consistency within this process a repetitious flow was used to screen each resultant publication.

First the title would be read, next the one to three lines of text from the publication would be read, then the subjects and finally the type of publication would be screened. Newspaper articles automatically met the exclusion criteria for their inconsistent merit. The exclusion and inclusion criteria are listed below in Table 3.8. Additionally, at this time all duplicates were removed. A publication would be selected for inclusion if its applicability could not be determined from the "standard" database information. The results from the 2nd filter are found in Figure 3.10.

Exclusion Criteria			
Agriculture	Alternative Food	Chemistry	City/ Community Planning
Civil Rights	Creative Writing	Culture	Energy Conservation
Film	Flight	Geography	Health Policy
History	Homelessness	Humanism	Immigration
Information Technology	Legislative Branch	Lighting	Living Walls
Machining	Medical or Medicine	Misc. Sciences	Mold
Newspaper Articles	Poetry	Poisoning	Politics
Psychology	Radio	Religion	Roof Systems
Social Interactions	Transgender Spaces	Urban Studies	
Inclusion Criteria			
Architecture	Buildings	Construction	Design
Engineer	Environment	Facility	Facility Layout
Flexibility	Healthcare Facility	Hospital	HVAC, Electrical, Plumbing
Interstitial	Laboratory	Lack of Contextual Applicability	Lifecycle
Maintenance	Mechanical	Planning	Project Management
Space	Sustainable	Zoning	

Table 3.8 Database Inclusion and Exclusion Criteria

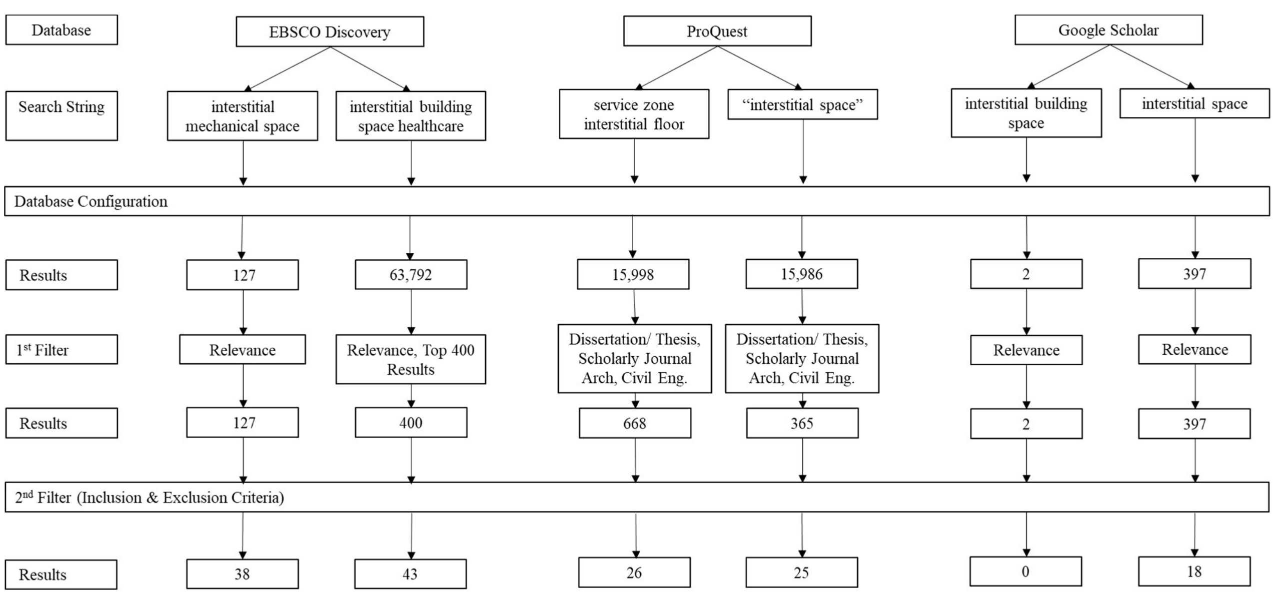

Figure 3.10 Phase 2 Second Filter Results

In the 3rd and final filter, each resultant publication was opened as a full document. The type of document (i.e. PDF, HTML, eBook) accessibility was determined by the database platform. If the full document was not available through the database platform, then a Virginia Tech interlibrary loan request was submitted. If the publication was not available through an interlibrary loan, the publication was documented as “not available” and not included in the final results.

Once each publication was opened as a full document, the term “interstitial” was searched for. The primary means to accomplish this search was using the “find” feature used by the document type. If the document or document type did not support a “find” feature, then the document was manually read. At a minimum, each time the term “interstitial” appeared in the document, the sentence prior to, the sentence containing and the sentence after, were read in their entirety. This methodology resulted in the publication meeting the second stage of inclusion or exclusion criteria.

The publications which met the inclusion criteria contained some level of discussion as to the benefits associated with IBS. Each publication was read/ scanned in its entirety in order to ensure a complete extraction of all discussed benefits of IBS. Each IBS benefit was documented and associated to the authors last name and publication date. Additionally, the type of publication was determined by EBSCO Discovery.

The resultant publication was determined to meet the exclusion criteria if: the publication only mentioned the term “interstitial” and had no associated discussion, the publication defined or used the term “interstitial” outside the context as defined by this research, there was no mention of the term “interstitial” within the publication, or the full document was not available. The publications which met the inclusion criteria for this filter were captured in the final results (Figure 3.11). The final results each contain three sets of numbers. The first number is representative of the total publications found that met the inclusion criteria. The second or middle number represents the number of publications unique to the specific database. While the third number represents the number of duplicates shared with other databases.

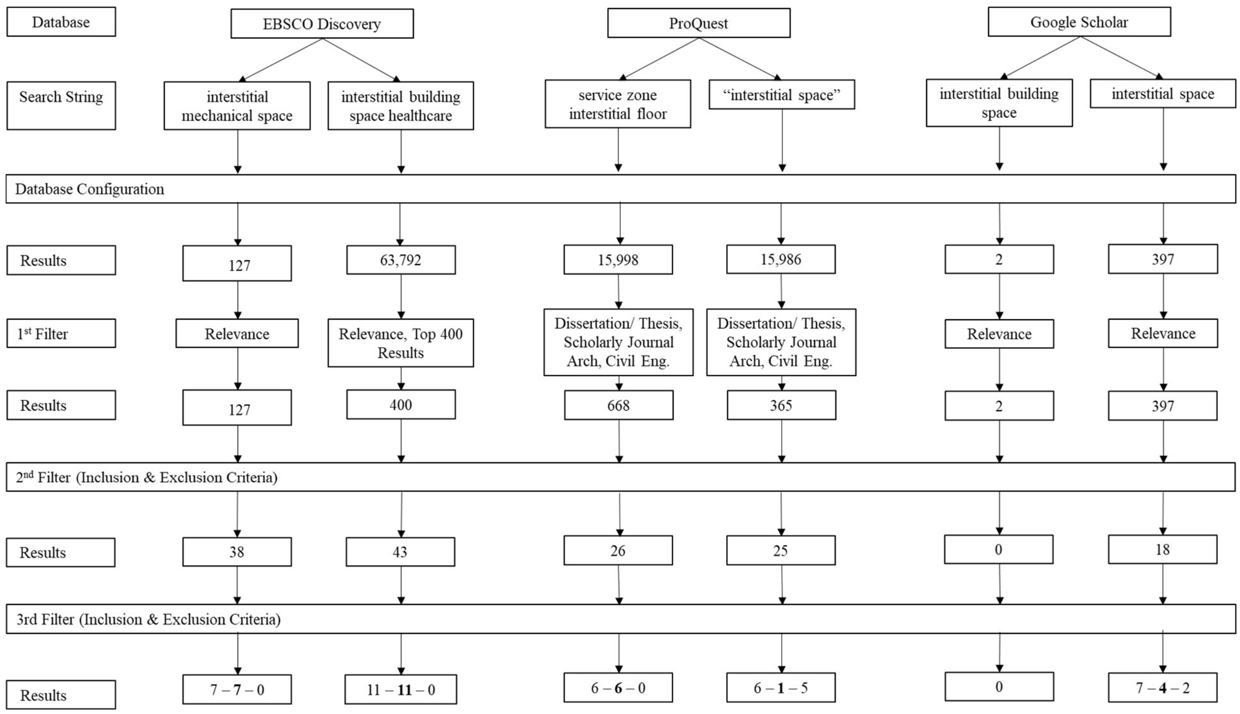

Figure 3.11 Phase 2 Third Filter Results

3.2.4.4 Phase 3 Database Filtering

During the third phase two databases were used: EBSCO Host and ProQuest. This process was initiated with database configuration and ends with the final results as outlined in Figure 3.6. Each of the database platforms used in this phase varied slightly in the platform configuration and the 1st filter. However, the 2nd and 3rd filters remained uniform between the two platforms. A key difference in this phase is that the same search string (Figure 3.12) was used in both database platforms. As in phase two, phase three also documented the methodology allowing for future replication, and the final results were also accounted for within the findings.

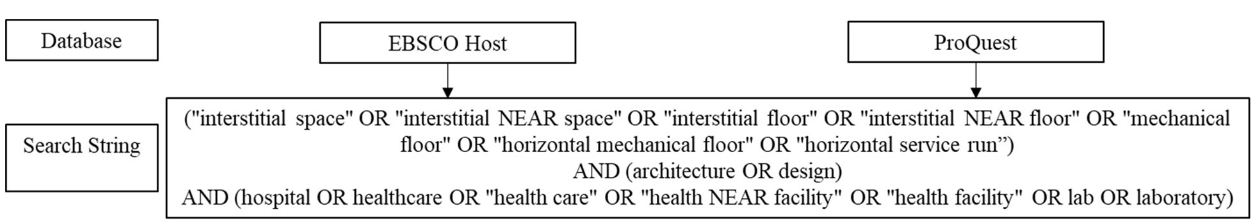

Figure 3.12 Phase 3 Search String Establishment

3.2.4.4.1 Database and 1st Filter Configuration

EBSCO Host

First the EBSCO Host database platform's advanced search option was selected. The search string (Figure 3.12) was then entered into the search field. The "( )" in the search string identify the limit of text to be placed within each text search field. The "AND" is the Boolean operator selected from the drop-down menu to the left of the text search field. It is important to note that the "AND" & "OR" Boolean operators must be all capitalized for the software to properly recognize them. Beside the text search field, "select a field (optional)" was selected in the drop-down for all three text search fields.

Next, the "choose databases by subject" above the search field was selected. Once prompted, all database subjects (13) were selected. In the "search options" the following selections were made: 1) "Find all my search terms" 2) "also search within the full text of the articles" and 3) "apply equivalent subjects". No further selection were made and resulting in the initial resultant population (Figure 3.13).

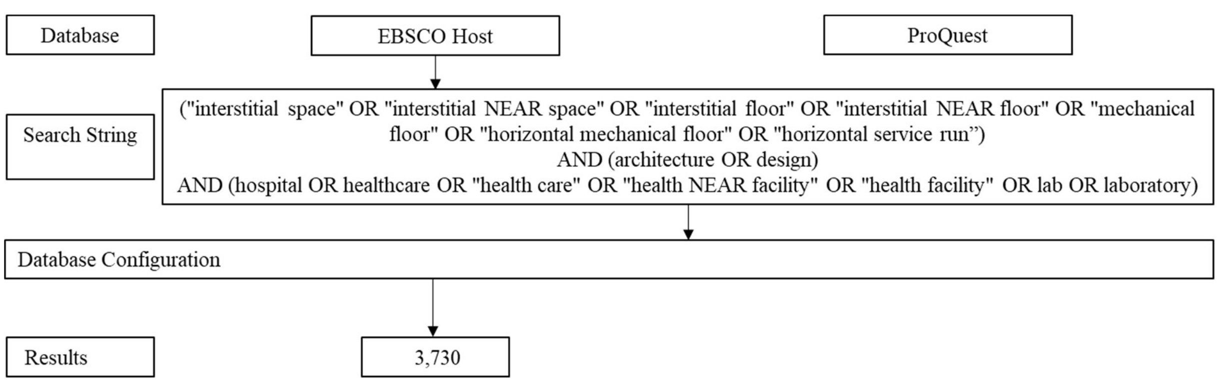

Figure 3.13 Phase 3 EBSCO Host Database Configuration Results

Under the "refine the search results" column the "subject" drop-down was selected. Table 3.9 reflects the subjects that were selected for the 2nd filter. Additionally, once the subjects are selected EBSCO Host automatically removes exact duplicates from the results (Figure 3.14).

Subject Selections		
Architects	Architectural Design	Architecture
Building Additions	Building Information Modeling	Buildings
College Building Design and Construction	Construction Projects	Factories
Health Facilities	Health Facility Design and Construction	Hospital Design and Construction
Hospitals	Laboratories	Laboratory Design and Construction
Strategic Planning	United States	

Table 3.9 Phase 3 EBSCO Host Subject Selection

At the top right of the page there are options to sort the results and options for page formatting. Here the results were sorted by "relevance" and the page formatting options selected were "standard" result format, "50" results per page, and "3 columns" for page layout. The "standard" result format used in the page formatting would typically present the following results: The title, author, type of publication (e.g. academic journal, book, etc.), "one line of text from the publication" and a list of the associated subjects. The information which populated for each publication was dependent on the proprietary indexing of EBSCO Host. For example, the subjects or the "one line of text from the publication" may not have been displayed for every resultant publication.

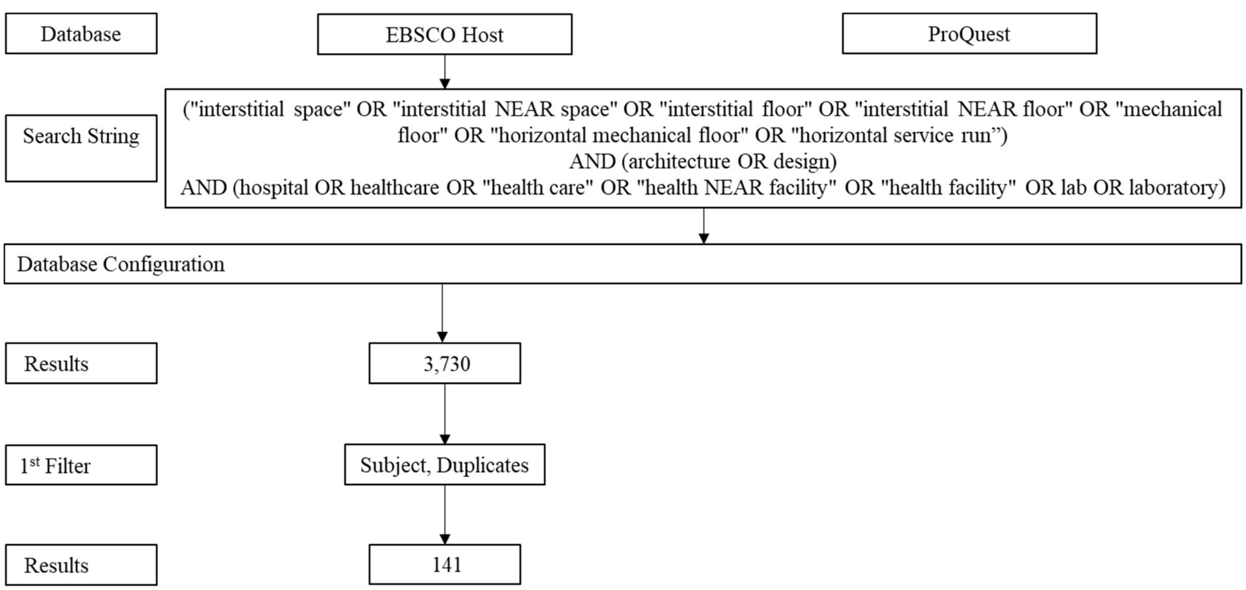

Figure 3.14 Phase 3 EBSCO Host 1st Filter Results

ProQuest

As previously stated the same search string (Figure 3.14) was also used in ProQuest. First the “advanced search” option was selected. Then the search string was entered into the search field. The “( )” and Boolean operators maintain the same functions as used in EBSCO Host. Beside the text search field, “anywhere” was selected in the drop-down for all three text search fields. Next, the database tab was selected. ProQuest offers 35 database options within their platform, the five databases found in Table 3.10 were selected.

Database Selection
Design & Applied Arts Index (DAAI)
Dissertations & Theses @ Virginia Polytechnic Institute and State University
eBook Central
ProQuest Dissertations & Theses Global
Technology Collection

Table 3.10 Phase 3 ProQuest Database Selection

Next, “All dates” was selected from the drop down for publication date. Under “source type” the following selections were checked: trade journals, standards and practice guidelines, scholarly journals, reports, government and official publications, dissertations and thesis, conference papers and proceedings, and books. The page expander labeled “result page options” was opened and the following options were selected: “relevance”, “50” items per page and “exclude duplicate documents”. This resulted in the initial results for each search string found in Figure 3.15. The refine/ filter the search results represented in Table 3.11 reflects the “subject” refinements/ filters that were selected.

Subject Selection	
Architecture	Civil Engineering
Design	Health Care
Hospitals	

Table 3.11 Phase 3 ProQuest Subject Selection

3.2.4.4.2 Second and Third Filter Configuration

The second and third filters used in phase 3 used the same methodology for the application of the inclusion and exclusion criteria as in phase 2 (see Chapter 3.1.4.3.2). Below in Figure 3.15 are the results from the application of the second and third filters. The three sets of final number use the same formatting as previously discussed in Chapter 3.2.4.3.2.

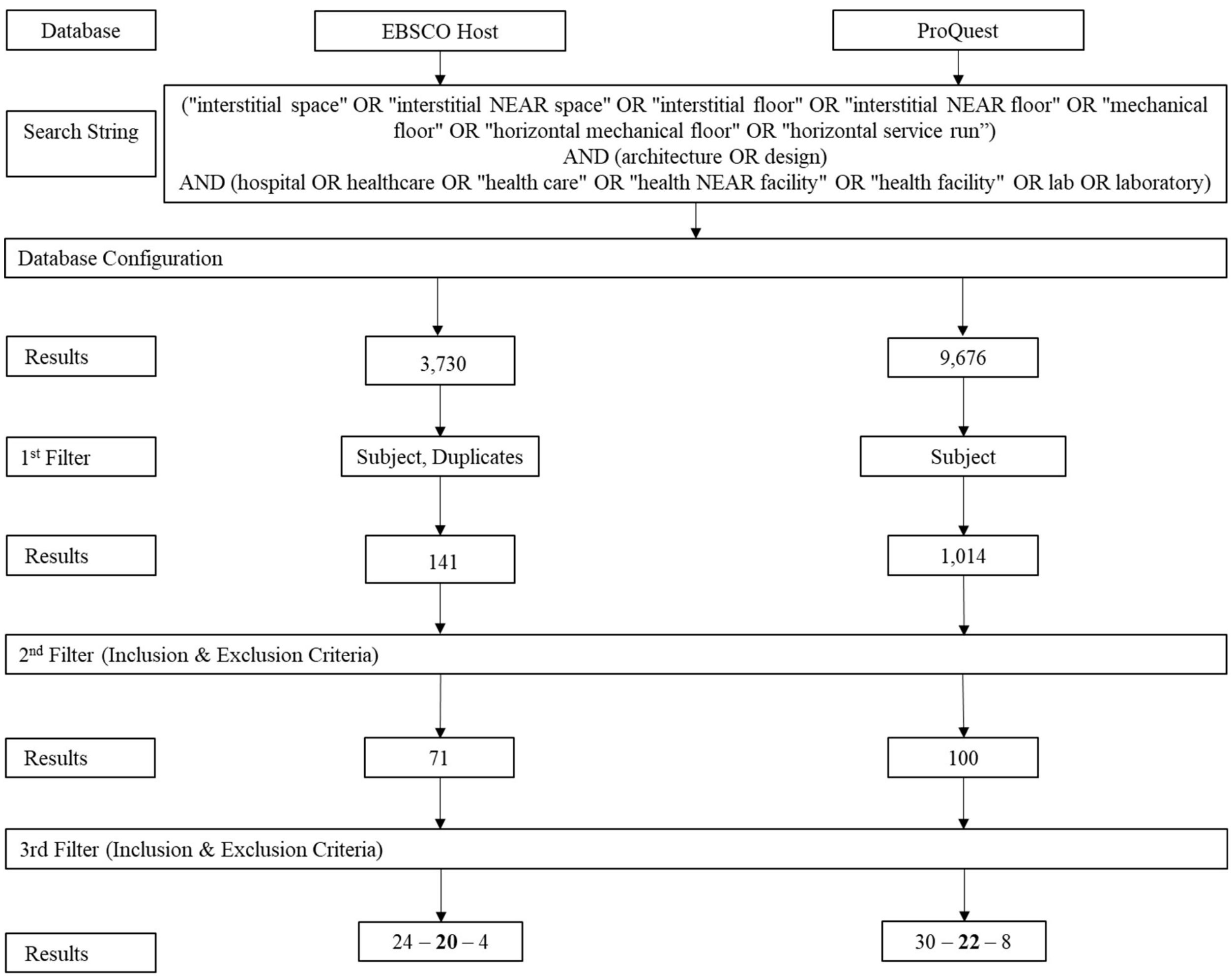

Figure 3.15 Phase 3 Database Results

3.2.4.5 Phase 4 Database Filtering

The fourth and final phase used the search string from the third phase and ran it through the remaining databases. These databases included Engineering Village, Google Scholar, Scopus, and WorldCat. The intent was to determine how the indexing from other databases may respond to the increased complexity of the search string. The process used in the fourth phase is the same as the third phase. That is, each of the database platforms used in this phase varied slightly in the platform configuration and the 1^{st} filter. However, the 2^{nd} and 3^{rd} filters remained uniform between the two platforms. Again, The “( )” and the Boolean operators maintain the same functions as used throughout phase three. Additionally, phase four also documented the methodology allowing for future replication, and the final results were accounted for within the findings.

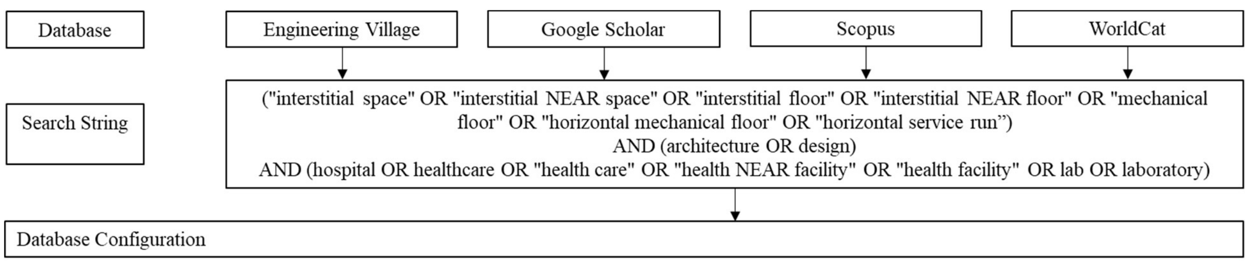

Figure 3.16 Phase 4 Database Configuration

3.2.4.5.1 Database and 1^{st} Filter Configuration

Engineering Village

The search string (Figure 3.16) was entered into the search field. Again, this is the same search string used in phase three. To the left of the text search field, “All Fields” was selected in the drop-down for all three text search fields. Next, “all” databases were selected. The four databases offered within the Engineering Village platform are: Compendex, Inspec, NTIS and Knovel. A date range of “1884-2019” was selected and “relevance” was selected in the “sort by” drop-down.

This resulted in the first set of results (Figure 3.17). For the first filter segment, under the “controlled vocabulary” filter the following options were selected: metals, health care, patient treatment and structural design. Of note, at this point Engineering Village automatically removes duplicates from the first 1000 results. Thus, resulting in the second set of results.

Google Scholar

First "advanced search" was selected from the drop-down settings at the top left of the page. Next, the search string (Figure 3.16) was entered into the database's search field of "Find articles with all the words". Then, "anywhere in the article" was selected for "where my words will occur".

The results published by Google Scholar were in excess of 12,000 results. Scholar does not offer the functionality to filter search results beyond author, publisher, or date range. Because of this Google Scholar was removed from the database population at this point in phase four.

Scopus

First the "advanced" tab was selected. Then same search string previously used (Figure 3.16) was placed into the "enter query string" text box. This produced the initial search results (Figure 3.17).

Under the "refine results" section the drop-down for "subject area" was selected. Here, "engineering" was selected, Table 3.12 reflects the subjects which are classified under "engineering". At the bottom of the column the option "limit to" was selected. This populated the next page containing the set of 2nd results.

Subjects Classified under "Engineering"		
Engineering(all)	Engineering(miscellaneous)	Aerospace Engineering
Automotive Engineering	Biomedical Engineering	Civil and Structural Engineering
Computational Mechanics	Control and Systems Engineering	Electrical and Electronic Engineering
Industrial and Manufacturing Engineering	Mechanical Engineering	Mechanics of Materials
Ocean Engineering	Safety, Risk, Reliability, and Quality	Media Technology
Building and Construction	Architecture	

Table 3.12 Scopus Engineering Classifications

WorldCat

Within the "advanced search" the search string was entered into the text field. To the left of the search field "keyword" was selected for each of the text box fields. No changes were made within the “search tools”. Finally, all of the available databases were selected, 390 in total. This resulted in the initial results (Figure 3.17).

Next, within “search tools” under the “topic” expander “architecture” and “healthcare” were selected. This was done independently for each “topic” selected, because the database would automatically direct the page to filter just the topic selection. In other words, multiple topics could not be simultaneously searched for. Therefore, each topic was selected and the aggregate results were included in the 2nd resultant population.

3.2.4.5.1 Second and Third Filter Configuration

The second and third filters used in the phase four had the same methodology, inclusion and exclusion criteria as used in phase 2 and 3 (see Chapter 3.1.4.3.2). Below in Figure 3.17 are the results from the application of the second and third filters.

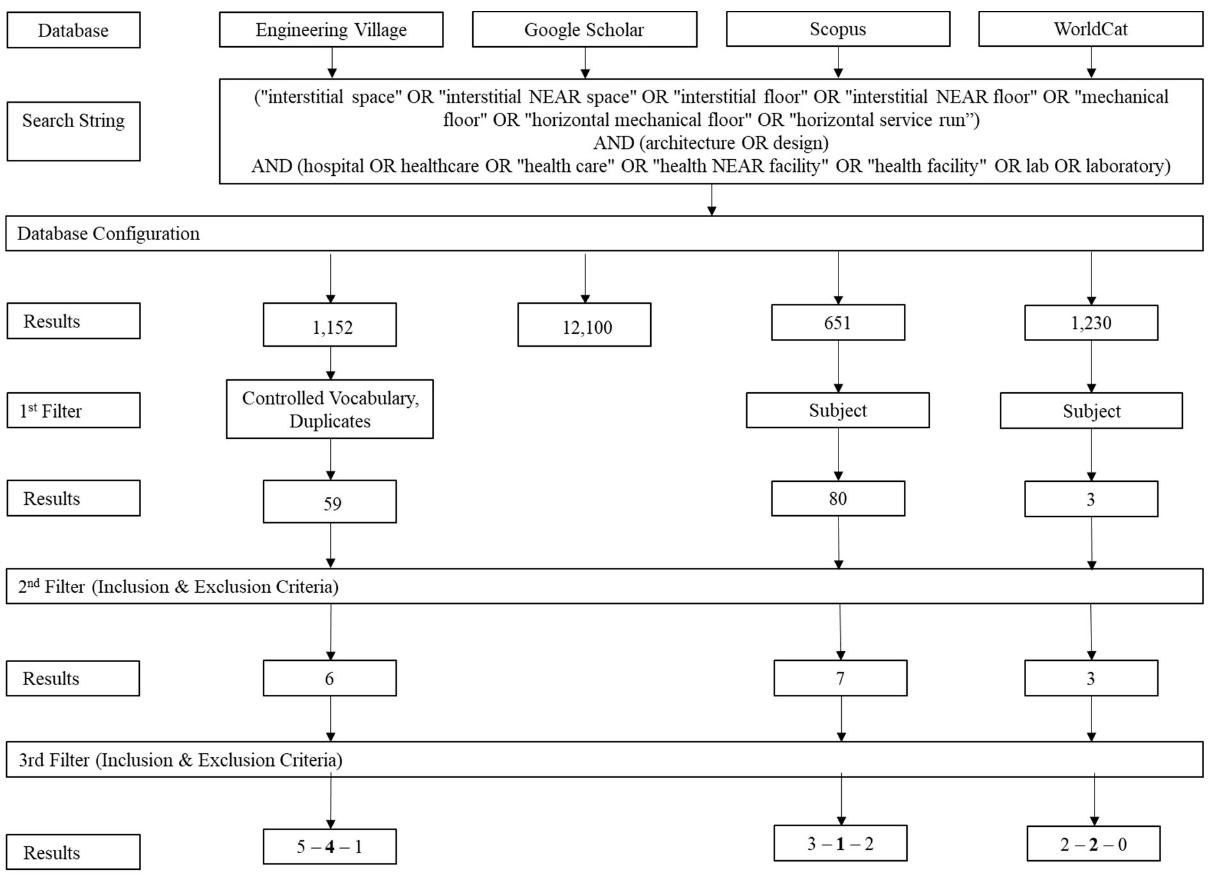

Figure 3.17 Phase 4 Database Results

3.2.5 Conclusion

Due to the fragmented and dated literature surrounding IBS, a systematic literature review was conducted. The intent was twofold: first, to establish a process that was replicable. and second, to identify a current and comprehensive spectrum of benefits provided by IBS through the establishment of a systems map. Initially, the review aimed for exhaustive and comprehensive searching; however, the search conditions revealed a fragmented indexing structure within the available databases. Consequently, the review did not produce comprehensive search results for all available knowledge on the benefits of IBS. It did however, establish a very robust network of literature highlighting the benefits of IBS.

The robust network of literature discovered was found in part to the large aperture used in the database selection process. Due to the interdisciplinary nature of IBS both engineering and architecture disciplines were used in the database establishment process. Additionally, the aperture drew on other databases such as Engineering Village, Google Scholar, Scopus and WorldCat which did not have distinct associations with either discipline.

The search string selection process produced a wide and varied population of terms. This was intended to maximize the results selected by the proprietary indexing structure for each database. This search string process used four phases; each building in succession from the previous. This resulted in a complex search string used to passively navigate the indexing of databases in both the third and fourth phase.

Throughout the literature review each database offered a unique and proprietary way to configure the search and subsequently filter/ refine those results. This created some variance within the process, however detailed records were kept to ensure that replication was possible. Furthermore, the discretionary decisions made during configuration and filter/ refining were done with the intent of capturing the widest range of relevant results.

The methodology used for the second and third filter remained constant through all four phases. These filters used inclusion and exclusion criteria which was able to create uniformity and standardization where it could be controlled. The methodology during this process was recorded in detail in order to assist in the replication process.

The data was collected and recorded into a database. Any publications that were duplicates between phases and/or databases were removed. Once the aggregate population was finalized the data was synthesized and recorded, see “Findings”. Here the data is analyzed determining: what is known, what remains unknown; a discussion of any uncertainties around the findings, and recommendations for future research.

3.3 Parallels Between Evidence Based Design and Flexibility

3.3.1 Introduction

Flexibility plays an integral part in how healthcare facilities respond to change. The implementation of Evidence Based Design by the Military Health System (MHS) engages flexibility directly and indirectly. Directly, with the establishment of their fifth guiding principle specifically stressing flexibility. Indirectly, through their subscription for the implementation of EBD. The indirect nature of this relationship will be explored by the second objective of this research.

The second objective of this research aims to parallel the principles of Evidence Based Design embraced by the Military Health System to the concept of flexibility established in existing literature; thus, demonstrating how flexibility may serve as a foundational mechanism which supports certain Evidence Based Design features or responses.

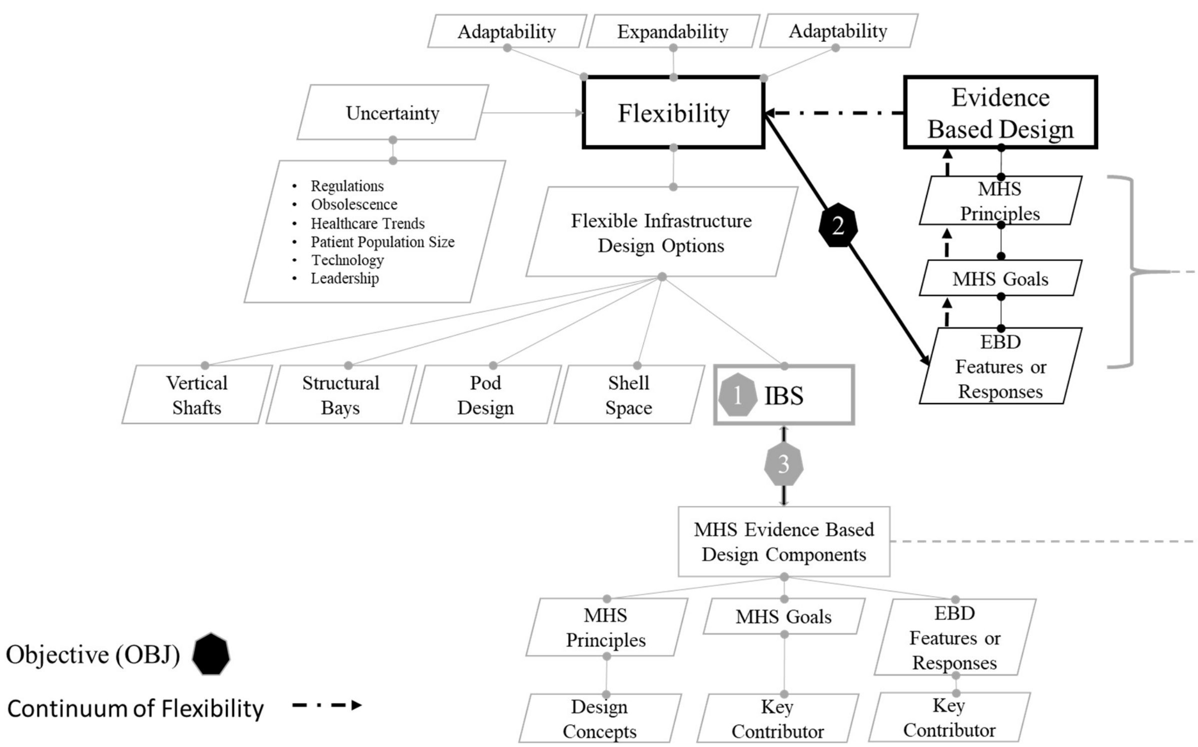

Figure 3.18 Objective 2

This relationship will be documented with the presentation of relational comparisons from both literature domains: EBD and flexibility; this illustrates the foundational and dependent nature flexibility has in acting as a driving mechanism for the successful implementation of specific EBD features or responses. The establishment of this relationship gives rise to a continuum of flexibility which flows from the foundational elements of EBD to the MHS organizational EBD principles. It is not the intent of this research to provide an exhaustive or comprehensive matrix which documents the intricacies of this relationship. Instead, it is intended to document select and representative examples of this relationship.

3.3.2 Evidence Based Design Framework Establishment

As highlighted in the literature review “EBD represents an emerging body of science that links elements of the built environment with patient, staff and resource outcomes” (Malone et al. 2007 p.5). EBD does not require organizations, public or private, to follow a pre-determined set of standards, instead organizations are free to implement EBD practices as they see fit. The MHS established five principles and associated goals to serve as the framework, outlining how they planned on implementing EBD into their organization. It is important to note, that these principles and objectives are organizationally unique and are not requirements established by the EBD community. Instead, they are nested in a way which concurrently complement one another. “Evidence-based design is a process for the conscientious, explicit, and judicious use of current best evidence from research and practice in making critical decisions, together with an informed client, about the design of each individual and unique project.” (Stichler and Hamilton 2008 p.3)

The establishment of the framework began with EBD. Then the five principles and goals established by the MHS were aligned under EBD. This is because the principles and goals are the MHS’s response to align their organizational nuances to the construct of the science associated with EBD. Therefore, the goals were aligned with their associated principles, as established by the MHS. The framework was structured in a way that uses a bottom-up refinement, beginning with EBD features and responses and moves upward into the goals and principles. This framework (Figure 3.20) is an expansion of Figure 3.19 below.

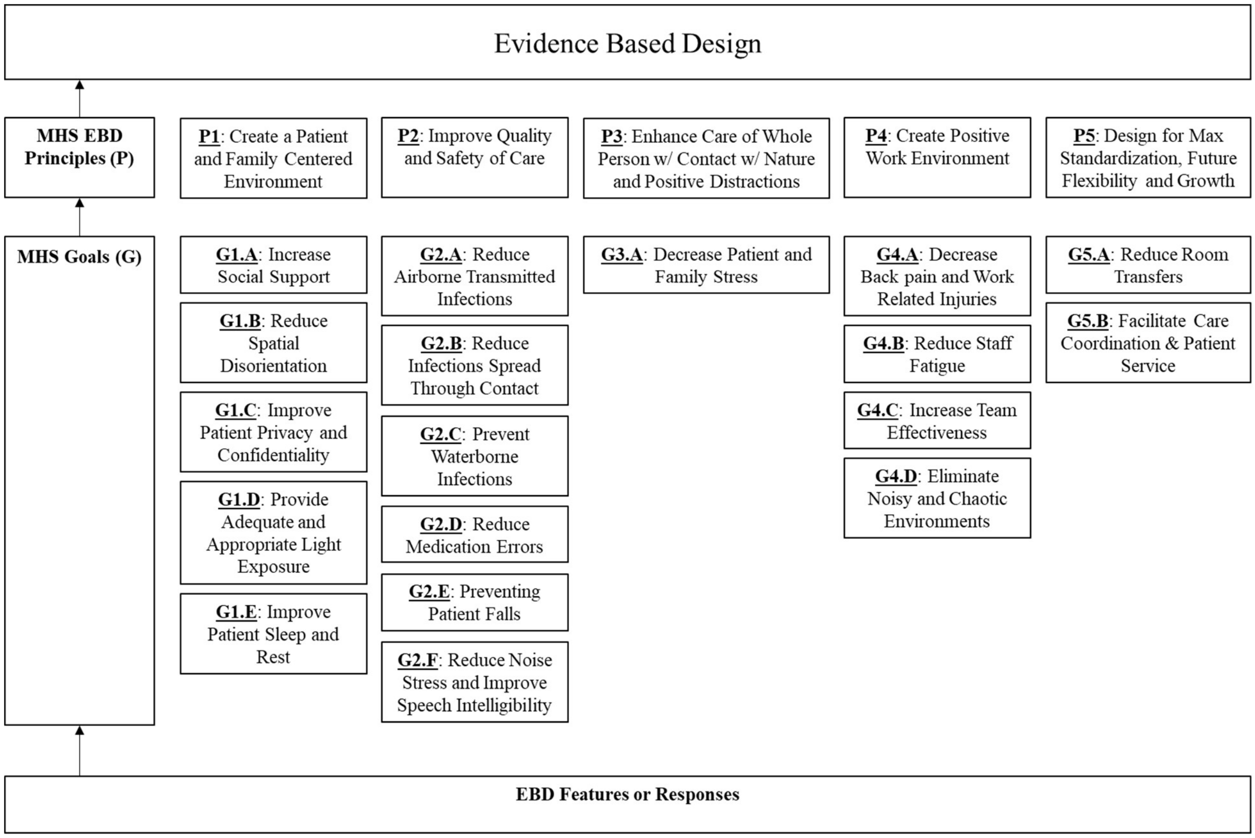

Figure 3.19 Objective 2 Framework Expansion

Once aligned, a coding mechanism was established to clearly delineate the relationships (Figure 3.19). Each EBD principle "P" was assigned a respective number "1-5". Below each principle are the associated goals "G". For example, "G1" identifies the goals that are aligned with "P1". Furthermore, each principle may have a varying number of aligned goals (e.g. "G1.A, G1.B, G1.C, G1.D or G1.E").

3.3.3 Evidence Based Design Features and Responses Establishment and Validation

In 2007 Noblis was funded by the TRICARE Management Activity Portfolio Planning and Management Directorate to produce a research study which could be used to educate military healthcare planners within HFPA (Malone et al. 2007). Malone et al. (2007) utilized an extensive literature review to recommend EBD features and responses that were applicable to the MHS EBD principles and goals, and this study became the foundation for the selection of applicable EBD features and responses.

To substantiate the recommendations made by Noblis, their recommendations were compiled and filtered for relational applicability to flexibility. It is important to note that the filtering mechanism for applicability was discretionary. Again, the purpose of this objective was to demonstrate how the concept of flexibility can be applied to EBD as a foundational element, able to support certain EBD features and responses. The aim of this filter was to select features and responses that could readily demonstrate this relationship.

Therefore, the features and responses used do not account for all the recommendations made by Noblis. Instead, only the recommendations that represented characteristics that could be potentially impacted by flexibility were included. Once the list of recommendations made by Noblis was compiled, a validation exercise was used verify the applicability for each recommended EBD feature and response to its associated MHS EBD goal. The validation exercise was conducted through a literature search. The initial database used was provided by the Center for Health Design at healthdesign.org.

This search was initiated using the search feature provided within healthdesign.org. The list with populated publications would typically only provide the title and a brief extract of text which had a reference to the associated text searched. Clicking on the title of the publication would bring up a detailed page referencing the selected document. At this point several scenarios were possible: publication was available for download, a link was made available to another repository, or a varying level of publication information was documented. At a minimum, the title, author, date, publication source/ title was made available. If the full document was not accessible then the publication was searched in either ProQuest, EBSCO Host or Google Scholar.

The publication was then searched for supporting documentation which validated the associated recommendation made by Noblis. The validation results were recorded, documented and aligned with each applicable recommendation. Table 3.13 provides an example of how the validation was conducted, please reference Appendix A for the complete table.

The first column in Table 3.13 “EBD Feature/ Response Reference Link to Figure 3.20” demonstrates how the reference between a specific EBD Feature or Response found in Figure 3.20 is linked to sources Appendix A. The starting point for this reference is a feature or response found in Figure 3.20. At the end of each feature or response an bolded and underlined alphabetical identifier is listed i.e. "**A**".

EBD Feature/ Response Reference Link to Figure 3.20	**MHS EBD Goal**	**EBD Feature or Response**	**Baseline Source (Noblis Study)**	**Validation Source**
A	Increase Social Support **G1.A**	Single Bed Rooms **F1.A.1**	"Both the American Institute of Architects Guidelines (2006) and DoD Space Planning Criteria (2006) recommend that most, if not all rooms on a unit be single-bed. DoD Space Planning Criteria for a single-patient room includes space for a sleeper chair and a side chair, which can be used by family members and visitors." (Malone et al. 2007 p.27)	"Single-occupancy rooms increase patients' privacy, which provides patients with control over personal information, an opportunity to rest, and an opportunity to discuss their needs with family members and friends. (Bobrow & Thomas, 1994; Burden, 1998; Morgan & Stewart, 1999)." (Chaundhury et al. 2004 p.7)
				The majority of patients prefer single rooms because of greater privacy, reduced noise,

				reduced embarrassment, improved quality of sleep, opportunity for family members to stay, and avoidance of upsetting other patients (Douglas, Steele, Todd, & Douglas, 2002; Kirk, 2002; Pease & Finlay, 2002; Reed & Feeley, 1973). (Chaundhury et al. 2004 p.8)
B	Improve Patient Privacy and Confidentiality **G1.C**	Avoid Open Admitting, Exam, or Treatment Spaces **F1.C.2**	"Avoid Open-Plan Cubicle Curtained Admitting, Examination and Treatment Spaces. Ensure that admitting, exams and treatments occur inside walled rooms. Current DoD Space Criteria includes open-plan rooms with cubicles separated by curtains: e.g., in the post-anesthesia care unit, primary care clinic treatment rooms. A ROI analysis is	"According to Mlinek & Pierce [37] , overhearing conversations at the reception desk was the main problem in the waiting room. Mlinek & Pierce suggested achieving a more audibly secure area by changing the structural design. Thus, the addition of background music or the use of physical barriers could be used to limit noise transmission and overhearing of conversations." (Huisman et al. 2012 p. 5)

			needed." (Malone et al. 2007 p. 30)	
D		Avoid Proximity Between Staff and Visitors **F1.C.4**	"Avoid Physical Proximity between Staff and Visitors Ensure that admission and reception areas are designed to avoid physical proximity between staff and visitors to minimize overhearing confidential telephone conversations and discussions." (Malone et al. 2007 p. 30)	"According to Mlinek & Pierce [37] , overhearing conversations at the reception desk was the main problem in the waiting room. Mlinek & Pierce suggested achieving a more audibly secure area by changing the structural design. Thus, the addition of background music or the use of physical barriers could be used to limit noise transmission and overhearing of conversations." (Huisman et al. 2012 p. 5)

Table 3.13 EBD Recommendation Validation

This alphabetical identifier is used to reference where in Appendix A the validation is depicted for that specific EBD feature or response. Additionally, the bolded and underlined alpha-numerical identifier found under each EBD goal or feature/ response in Table 3.13 and Appendix A reference the coding structure used within Figure 3.20. The alpha-numeric identifier allows for quick reference from Appendix A back to Figure 3.20.

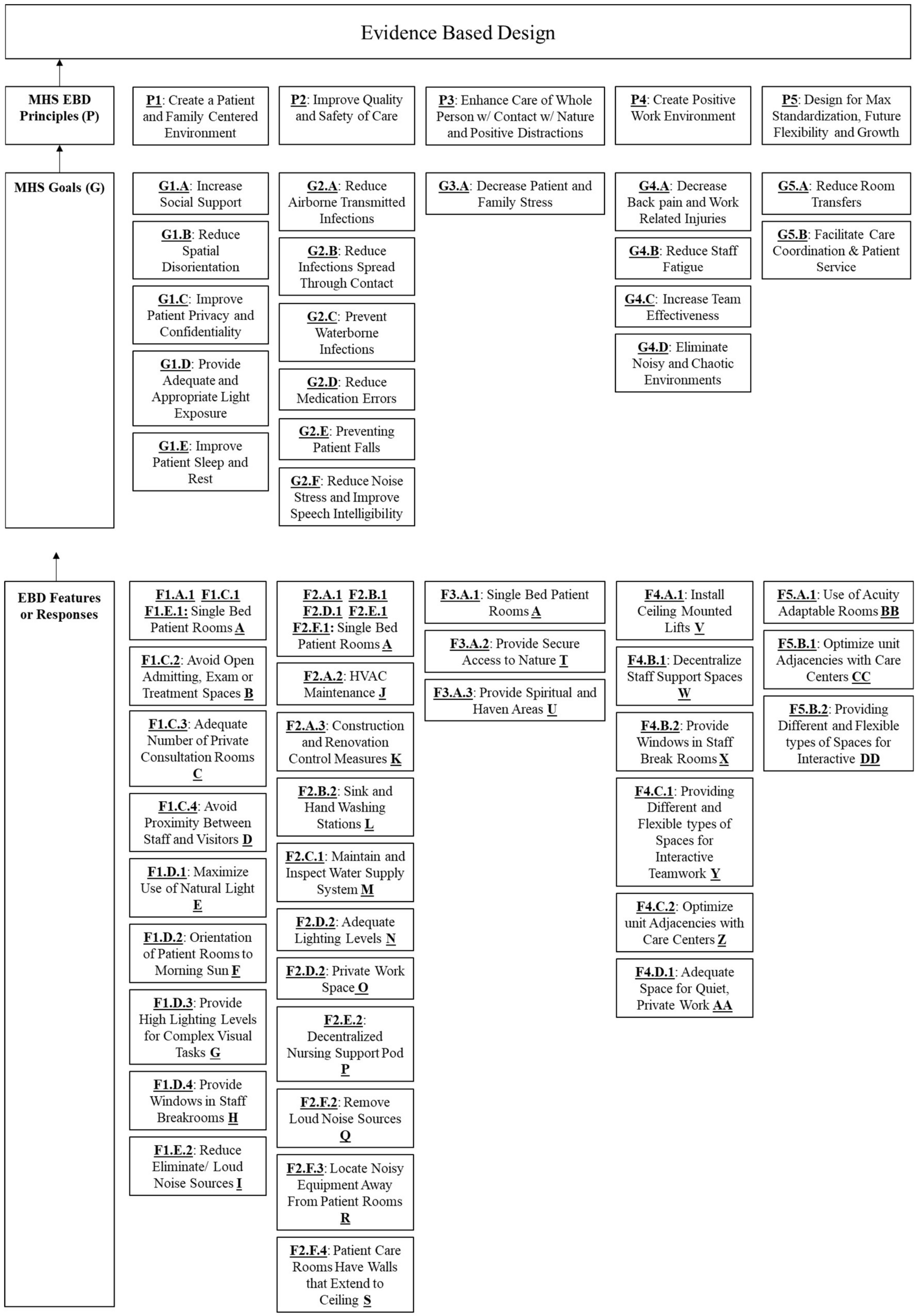

Figure 3.20 MHS EBD Alignment of Features/ Responses, Goals and Principles

The EBD features and responses as diagrammed in Figure 3.20 needed to be established in the context of this research in order to be aligned with specific goals. It is important to remember that EBD features and responses are results of credible research being conducted. The features and responses used here are derived from current literature found within the EBD community.

Once each of the recommendations were validated, they were compiled, aligned and coded with their associated MHS EBD goal. The coding used in Figure 3.20 followed the same methodology used previously. An “F” was used to identify an EBD feature or response. Unique to this portion of the coding however, is the ability for an EBD feature or response to have more than one associated code. This is because each feature or response may be applicable to more than one goal. For example, the EBD feature single bed patient rooms has applicability to principle 1, 2 and 3. Under the first principle, single bed patient rooms applies to multiple goals, as annotated with three codes: F1.A.1, F1.C.1, and F1.E.1. Furthermore, multiple EBD features and responses can apply to the same goal, as depicted in Figure 3.21.

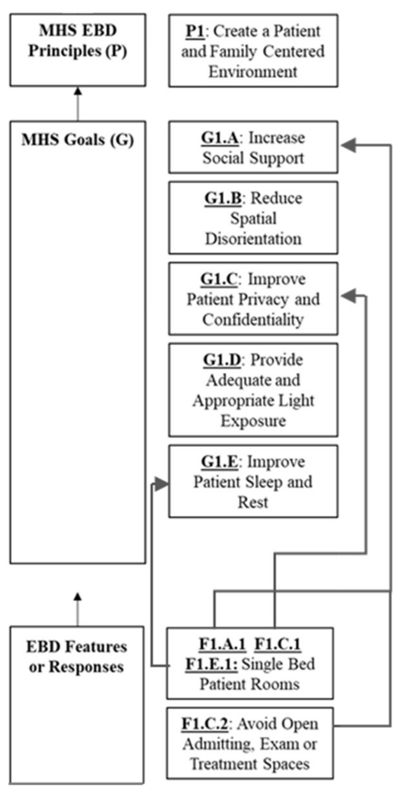

Figure 3.21 EBD Features and Responses Coding

3.3.4 Integrating Flexibility

New developments continually arise to displace established technologies, what was state-of- the-art yesterday may be out of date tomorrow. New technology affects the value of investments directly and indirectly because of the way it changes patterns of demand. Advances may have complicated, unanticipated ripple effects (De Neufville and Scholtes 2011). Therefore, it is important to recognize the interdependence future flexibility and growth has on EBD implementation within the MHS.

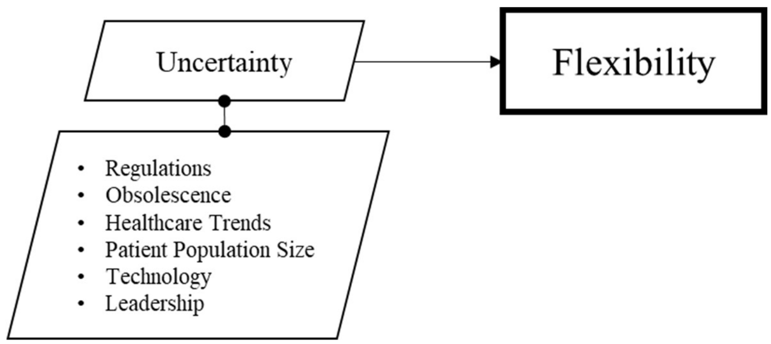

Figure 3.22 Uncertainty Integration

Pending change creates uncertainties. When the response to uncertainties is flexibility, the resultant is the creation of a flexible result. The fundamental focus of the fifth principle relates to the careful stewardship of limited MHS infrastructure resources. While the first four principles are fluid, evolving and dependent on state-of-the-art implementation of accepted industry best practices, supported by both compelling science and business case analysis (Malone et al. 2007). The dynamic and evolving nature of science within the medical profession creates uncertainty. "Change is driven by developments in medicine, medical technology and change in health care philosophy and practice and to a lesser extent by improvements in building and related technologies, it is also driven, above all, by the human desire to employ the latest available techniques when life is at stake" (Shahid 1993 p.6).

Within the construct of EBD, uncertainty corresponds to a pending change. That change may then drive the need for a medical related variance. In this example the response is EBD. Figure 3.23 demonstrates how EBD can be depicted schematically as a flowchart. As previously stated EBD relies on the scientific method to make informed decisions on the best intervention to be used. This process produces evidence-based results that are implemented as EBD responses or features. In Figure 3.23 the solid line from intervention 2 represents the best option as determined from credible research.

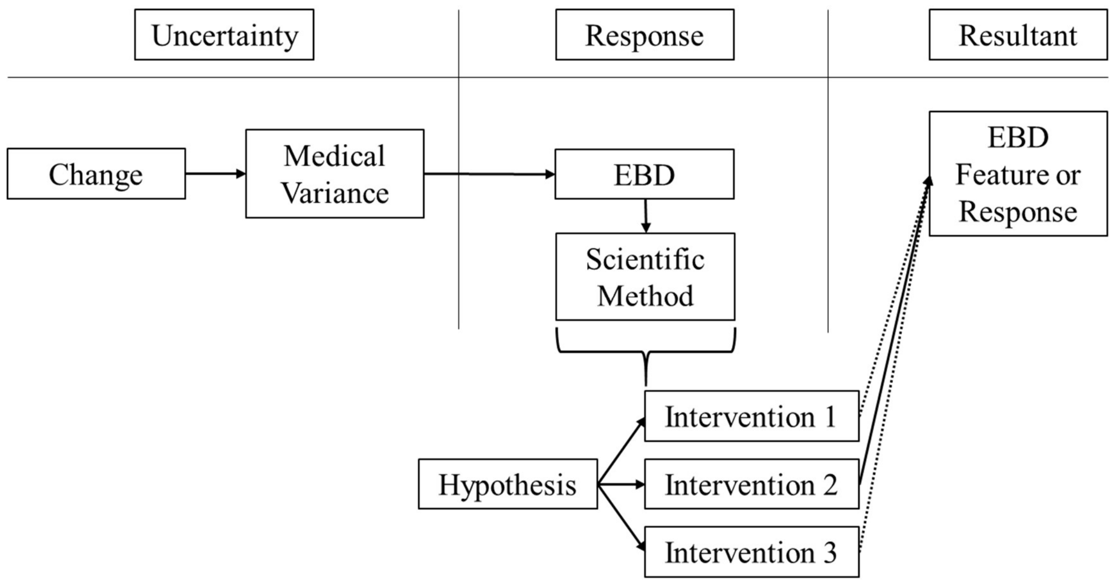

Figure 3.23 EBD Flowchart Overlay with Flexibility Framework

An issue for consideration under this model is that when another change occurs, driving a medical variance or if the scientific method was flawed, the resultant EBD feature or response is no longer able to function as intended or is not applicable; hence, a new EBD process will need to be initiated. However, if flexibility is incorporated, its addition would provide an opportunity for a flexible response to the change. The flexible response may be able to impact the dynamics of the relationship established in Figure 3.23.

The EBD features and responses identified in Figure 3.20 represent a set of best practices, their change predicated on the variance of science. Therefore, those variances in essence, are uncertainties. A plausible response to these uncertainties is flexibility. The incorporation of flexibility into this flowchart is broad and rather difficult to specify because there is no standard way of defining flexibility (Kendall et al. 2012). Flexibility should, however, have the ability to respond to changing requirements (i.e. uncertainties) in an era of continual medical change. Accordingly, the importance of flexibility is demonstrated if, for example, it enables a quick response for any improvement affecting patient safety or reduction of infection (Mathers and Haldenby 1979).

Typically, flexibility is added with an upfront capital expense. In this context flexibility could be recognized as having the ability to "turn on" when needed. "Flexibility is often described as an option - the right but not obligation to a specific future action. One way of thinking about any particular type of flexibility is to regard it as a system switch which is either "on" or "off", and "off" acts as a default setting. Switching to "on" will change the way the system operates" (de Neufville et al. 2008 p.2).

Using the "on/ off" concept as described by de Neufville et al. (2008), flexibility would remain in the "off" position and would not be affected by a medical variance if the facility was designed and constructed in order to handle the variance. Additionally, flexibility when in the "off" position is not impacting EBD responses. However, as previously discussed the probability of change in a healthcare facility is likely, necessitating future access to flexibility.

So, when a change occurs flexibility can be turned "on". In this scenario, flexibility is given the opportunity to respond to the change or medical variance. The way in which flexibility responds to that medical variance now affects how EBD needs to respond. The fact that the EBD response is predicated on the flexible response creates additional opportunities for flexible responses.

This is because flexibility is not constrained by preset conditions; rather, it is able to respond in a non-linear manner. Therefore, the flexible response has provided an opportunity to address the medical variance without affecting the EBD response. This scenario mitigates the change spurred by uncertainty by avoiding the need for a change in the EBD feature or response. If the flexible response can only partially address the medical variance, then the impact of change required by the EBD response is minimized. The third scenario would be that the flexible response was ineffective at addressing the medical variance. This would require an EBD response able to completely address the change, the same conditions which would present themselves in the absence of flexibility. This demonstrates how flexibility is able to serve as an enabling response, maximizing the potential of EBD features or responses. The intent for the incorporation of de Neufville et al's (2008) concept for flexibility being viewed as an "on/ off" switch was to demonstrate how flexibility may serve as a foundational mechanism which supports certain Evidence Based Design features or responses as depicted below in Figure 3.24.

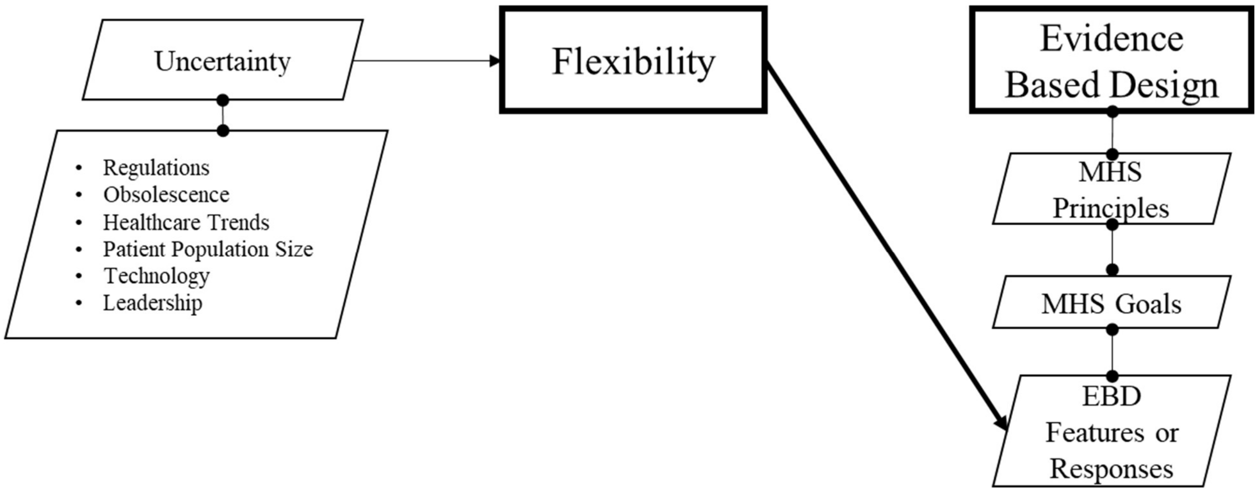

Figure 3.24 Application of Flexibility into EBD

3.3.5 Conclusion

The intent for the second objective was to compare the EBD principles embraced by the MHS to the concept of flexibility; illustrating how the incorporation of flexibility into certain EBD features or responses may serve as a mechanism which support their associated principles. It was not the intent of this research to provide an exhaustive or comprehensive matrix which documents the intricacies of this relationship. Instead, it is intended to document selected and representative examples of this relationship.

The methodology for establishing this relationship was rooted in existing literature from both the flexibility and EBD domains. The relational similarities from the two literature domains were then nested to draw possible conclusions as to how EBD is dependent to flexibility. The establishment of this relationship gives rise to a continuum of flexibility which flows from the foundational elements of EBD to the organizational EBD principles established by the Military Health System (MHS).

3.4 Interstitial Building Space's Ability to Satisfy Components of Evidence Based Design

3.4.1 Introduction

The third objective within this research was to identify specific components of EBD embraced by the Military Health System which are satisfied by the use of interstitial building space. This was accomplished by comparing the benefits of IBS discovered during the systematic literature review conducted to meet Objective 1 with the components of EBD. The purpose for the comparison is to highlight the benefits associated with IBS that are able to directly satisfy MHS EBD principles and goals, EBD features and responses, key contributors to an EBD response or feature, or design concepts that support EBD.

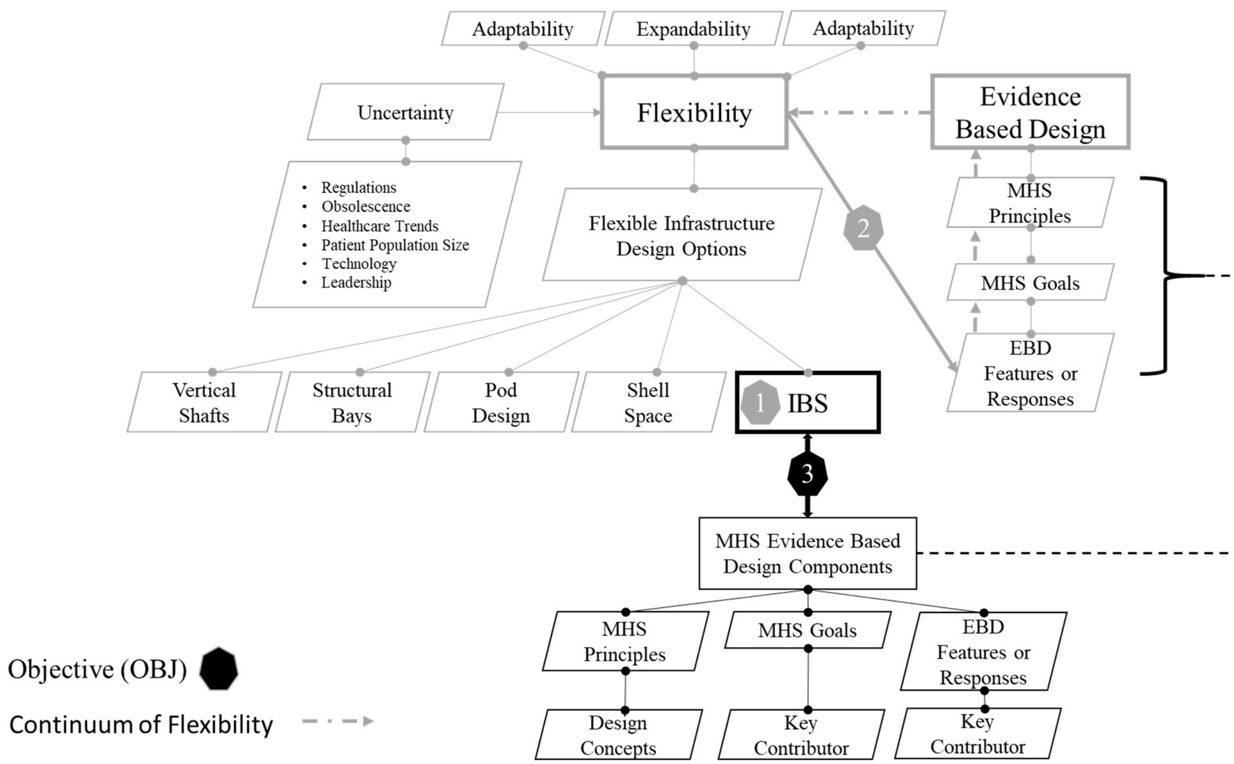

Figure 3.25 Objective 3

3.4.2 Interstitial Building Space Satisfying Evidence Based Design Components

The methodology used for this objective was structured and built upon the first two objectives of this research. The process was initiated by taking the spectrum of benefits offered by IBS determined from the systematic literature review competed for the first objective and using it as a foundational underlying document. Next the EBD framework presented in the second objective was nested within the IBS spectrum of benefits. The EBD components depicted in Figure 3.26 are comprised of: MHS EBD principles and goals, EBD features and responses, key contributors to an EBD response or a MHS EBD goal, or design concepts that support EBD. The principles, goals, features and responses are the same which were previously discussed in the 2nd objective. However, the relationship between: 1) key contributors and their associated EBD response or MHS EBD goal and 2) design concepts and MHS EBD principles, need to be established.

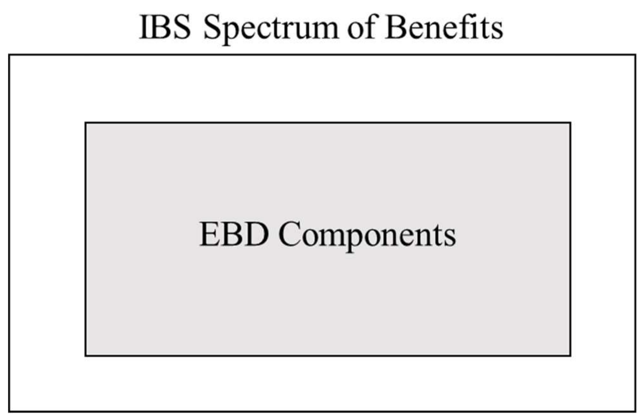

Figure 3.26 IBS-EBD Overlay

A key contributor will be defined as an integral component to a higher echelon group. The change of a key contributor would result in direct change to the higher echelon group. Thus, the trait or quality of a key contributor is essential to the trait or quality of the higher echelon group. Key contributors are not covered in the literature as an element of EBD. Therefore, an additional step was needed to establish the dependent relationship between the spectrum of benefits offered by IBS and the key contributor to an EBD feature or response. This was accomplished by first comparing how the trait or quality of a key contributor was essential to the trait or quality of the higher echelon group, i.e. an EBD feature or response, or an MHS EBD goal.

Validation exercises were used to establish the dependent relationship between a key contributor and higher echelon group. There are only two applicable examples of this validation which needed to be conducted during this research. The first is illustrated in Table 3.14 with the comparison of key contributor, “Disruption Control” and its relationship to EBD response, “Reduce or Eliminate Loud Noise Sources.” This validation used existing EBD literature to demonstrate the relationship between “Disruption Control” and “Reducing or Eliminating Loud Noise Sources”

EBD Key Contributor	**EBD Higher Echelon**	**Validation within EBD Literature**
Disruption Control	EBD Response (Reduce or Eliminate Loud Noise Sources)	"Sources of disturbance were mainly therapeutic procedures, staff talking, and environmental noises." (Huisman p.7)
		"In a survey of neurosurgery ICU patients, among those who reported sleep disturbance, 58% considered environmental noise a frequent disturbing factor (Ugras & Oztekin, 2007)." (Ulrich, 2008 p.27)

Table 3.14 EBD Key Contributor Validation

The second comparison was between the key contributor, “Disruption Control” and the MHS EBD goal, “Reduce Room Transfers.” Disruption control in this context refers to facility maintenance or renovations. The validation for this relationship is demonstrated with the following rational; If maintenance or renovations require a patient to be transferred to a different room, then by definition “a break or interruption in the normal course or continuation of some activity, process, etc.” (Merriam-Webster), they experienced disruption.

Finally, design concepts that support EBD are derivatives of the recommendations made by Noblis in their research report. “MHS facilities should be designed for flexibility best supported by the concepts of expandability and adaptability.”(Malone et al. 2007 p.52) The quality of expandability abbreviates the addition of a new service or increasing an existing service. The quality of adaptability could be viewed as a more frequent need to respond to changes in capacity, acquisition of new equipment or special events. Simply put, expandability involves taking a long-range view and adaptability refers to adjusting quickly to immediate needs (Malone et al. 2007). The recommendations made by Noblis reference the implementation of flexibility into EBD with the design concepts of adaptability and expandability.

Once the components of EBD were nested with the spectrum of benefits all direct matches were extracted and recorded. A direct match produced from the overlay meant that either identical terms or near identical terms with supporting contextual identifiers were discovered. For example, using the following EBD features and responses: "Maximize Use of Natural Light, Orientation of Patient Rooms to Morning Sun, Provide Windows in Staff Breakrooms" were considered matched with the following IBS spectrum of benefits: "Access to Nature, Increased Views/ Daylight". This methodology was used for establishing the relationship between the spectrum of benefits offered by IBS and the following EBD components: MHS EBD principles, MHS EBD goals, and EBD features or responses. A complete table demonstrating these matches can be found in Appendix B.

3.4.3 Conclusion

The intent for the third objective within this research was to identify specific components of Evidence Based Design embraced by the Military Health System which are satisfied by the use of interstitial building space. This was accomplished by comparing the benefits of IBS discovered during the systematic literature review with the components of EBD. The results of this comparison are not intended to include all possible matches pertaining to EBD. Instead, the comparison only represents direct matches in the context of the MHS EBD population explored. The methodology for establishing this relationship was rooted in existing literature from both the IBS and EBD domains. The similarities from the two literature domains were then nested, enabling conclusions to be drawn as to the dependent relationship IBS has to EBD. Resulting in the development of the "IBS-EBD Component Mapping Framework."

Chapter 4. Findings

4.1 Introduction

This chapter will present the findings in the same sequence as the methodology section was presented; beginning with the systematic literature review, followed by the relationship between EBD and flexibility, and concluded with specific EBD components that are satisfied with IBS.

4.2 Systematic Literature Review of Interstitial Building Space

The systematic literature review process yielded 124,841 results from phases two, three and four. After the respective database configurations, and three filters were applied the resultant publication population was reduced to 101. The 101 publications were screened against each other for duplicates. This screening resulted in 22 duplicates. Therefore, 79 total publications resulted from the literature review.

During the preliminary portion of this research and prior to the initiation of the systematic literature review, seven publications were discovered that contained rich content relating to IBS. The seven publications are products of different U.S. government agencies, and did not populate as results during the systematic literature review. However, they were included in the overall population for the synthesis of the spectrum of benefits offered by IBS. These seven publications are listed at the bottom of Tables 4.2, 4.5, 4.6 and annotated by a "*". Consequently, 86 total publications were synthesized in the spectrum of benefits.

Tables 4.1 and 4.2 below are organized by source. The second column labeled "total references" represents the total number of benefits found within each publication. The next column identifies whether the majority of those references were qualitative or quantitative in nature. Following this, each of the eight databases used in phases 2-4 are listed. Here an "x" was used to identify which database discovered each source. Overlap occurs because duplicates were not removed. The intent of Tables 4.1 – 4.2 is to illustrate the relationships between database results and the associated search phases employed. This demonstrates the relative strength of each database to index results based on the associated search strings. In general, ProQuest (phase

3) and EBSCO Host (phase 3) were the most productive; though, interestingly these searches did not yield any duplicates.

Source	Total References	Dominance (Qualitative vs. Quantitative)	Publication Type	EBSCO Discovery (phase 2)	ProQuest (phase 2)	Google Scholar (phase 2)	ProQuest (phase 3)	EBSCO Host (phase 3)	Engineering Village (phase 4)	Scopus (phase 4)	WorldCat (phase 4)
(Allen and Rand 2016)	1	Qualitative	Ebook				x				
(Alvarez 1989)	20	Quantitative	Thesis	x		x					
(Anastopoulos 1982)	15	Qualitative	Book								x
(Anonymous 1994)	2	Qualitative	Trade				x				
(Anonymous 1995)	2	Qualitative	Trade					x			
(Anonymous 2000)	7	Qualitative	Trade				x				
(Anonymous 2008)	3	Qualitative	Trade					x			
(Anonymous 2014) Consulting Engineer	2	Qualitative	Trade				x				
(Anonymous 2014) R&D Magazine	1	Qualitative	Trade					x			
(Bachman 2003)	2	Qualitative	Ebook	x							
(Bardwell and Saba 2005)	2	Qualitative	Trade					x			
(Barista 2003)	1	Qualitative	Trade				x				
(Bonge 2002)	2	Qualitative	Trade					x			
(Briller 2014)	2	Qualitative	Academic				x				
(Brown 1995)	2	Qualitative	Trade	x				x			
(Cahnman and Kulka 1995)	1	Qualitative	Trade					x			
(Carthey et al. 2015)	2	Qualitative	Academic	x							
(Cohen 2000)	4	Qualitative	Academic		x		x				
(Committee on Design, Construction 2000)	5	Quantitative	Ebook					x			
(DeLauter and Roadarmel 1995)	1	Qualitative	Academic			x					
(DiBerardinis et al. 2013)	2	Qualitative	Ebook				x				
(Domby 2012)	1	Qualitative	Trade	x							
(Drickhammer 2003)	1	Qualitative	Trade					x			
(Dussault and Nelson 2014)	2	Qualitative	Trade	x							
(Eagle 2005)	3	Qualitative	Trade					x			
(Eagle 2015)	1	Quantitative	Trade	x							
(Faloon 2013)	2	Qualitative	Trade					x			
(Gibson 1990)	4	Qualitative	Thesis		x		x				
(Griffin 2004)	1	Qualitative	Ebook				x				
(Higginbotham and Studt 2001)	1	Qualitative	Trade					x			
(Higgins 2007)	1	Qualitative	Trade					x			
(Holness 1987)	3	Qualitative	Trade							x	
(Howatson 2001)	3	Qualitative	Trade				x				
(Hrickiewicz 2012)	1	Qualitative	Trade	x				x			
(Iselin and Lemer 1993)	1	Qualitative	Ebook	x							
(Keller 2002)	2	Qualitative	Trade				x				
(Kelly and Borthwick 1985)	9	Qualitative	Academic				x				
(Kim 2001)	3	Qualitative	Thesis				x				
(Landon 2006)	2	Qualitative	Trade	x							
(Leary and Meyer 2009)	12	Qualitative	Ebook			x					
(Leveridge 2013)	11	Quantitative	Thesis	x							

Table 4.1 "IBS Database Reference" 1 of 2

Source	Total References	Dominance (Qualitative vs. Quantitative)	Publication Type	EBSCO Discovery (phase 2)	ProQuest (phase 2)	Google Scholar (phase 2)	ProQuest (phase 3)	EBSCO Host (phase 3)	Engineering Village (phase 4)	Scopus (phase 4)	WorldCat (phase 4)
(Lombardi et al. 1997)	1	Qualitative	Patent			x					
(MacKenzie 1992)	6	Qualitative	Trade			x					
(Macmillan 2003)	6	Qualitative	Ebook				x				
(Mathers and Haldenby 1979)	13	Qualitative	Book						x		x
(McCarthy 1995)	3	Qualitative	Trade						x	x	
(MCW Consultants 2006)	2	Qualitative	Trade				x				
(Merkel 2006)	1	Qualitative	Trade					x			
(Moe 2008)	2	Qualitative	Academic	x							
(Mudry 2001)	4	Qualitative	Thesis		x		x				
(Nadel 1997)	1	Qualitative	Trade					x			
(Neuman 2013)	2	Qualitative	Ebook				x				
(Nitch 2006)	2	Qualitative	Thesis		x		x				
(Odegard 1996)	3	Qualitative	Trade	x							
(Odegard and Justison 1996)	2	Qualitative	Trade					x			
(Pancham 2004)	1	Qualitative	Thesis		x		x				
(Phillips 2005)	3	Qualitative	Trade				x				
(Phillips 2012)	2	Qualitative	Trade				x				
(Poirier 2012)	4	Qualitative	Trade					x			
(Rechel et al. 2009)	1	Qualitative	Ebook				x				
(Roulo 2010)	1	Qualitative	Trade					x			
(Shahid 1993)	21	Qualitative	Thesis		x		x				
(Schatveta et al. 2017)	7	Qualitative	Academic			x					
(Schmidt 2002)	1	Qualitative	Trade					x			
(Scholer Corporation 2000)	2	Qualitative	Trade					x			
(Smallbridge 2004)	3	Qualitative	Trade				x				
(Starr 1997)	1	Qualitative	Trade				x				
(Stillman and Graves 1998)	2	Qualitative	Trade					x			
(Streets 1995)	5	Qualitative	Trade						x		
(Teramura and Yomaru 1992)	2	Qualitative	Academic				x				
(Thompson 2009)	4	Qualitative	Thesis		x		x				
(Thrun 2004)	7	Qualitative	Trade				x	x			
(Tusler Jr. 2014)	4	Qualitative	Trade	x							
(Verderber 2015)	1	Qualitative	Ebook	x							
(Vondrak and Riley 2005)	25	Quantitative	Academic	x	x	x		x	x	x	
(Watch 2001)	8	Qualitative	Ebook	x							
(Youssef 2004)	1	Qualitative	Academic	x							
(Yu and Chang 2012)	2	Qualitative	Ebook				x				
*(Bell et al. 1996)	6	Quantitative	Research								
*(Bradley et al. 2015)	7	Qualitative	Research								
*(DoD 2017)	7	Quantitative	Guidelines								
*(Office of Construction, VA 1977)	13	Quantitative	Guidelines								
*(The Comptroller General 1972)	14	Qualitative	Research								
*(U.S. EPA 2001) Fred Hutchenson	3	Quantitative	Case Study								
*(U.S. EPA 2001) Louis Stokes	2	Quantitative	Case Study								

Table 4.2 "IBS Database Reference" 2 of 2

Tables 4.3 – 4.6 below are organized with the author, in citation format, in the first column. The first row contains all of the thematic concepts captured from the spectrum of benefits. The tables use an "x" to identify when a cited source revealed qualitative data for a specific benefit. The tables use a "q" to identify when a cited source revealed quantitative data for a specific benefit.

Source	**Flexibility**	Modularity	Expandability	Adaptability	Modernization	Standardization	**< Life Cycle Cost**	Payback Period	Operations	Maintenance	Access	< Cost	< Staffing	>Efficient/<Time	**< $/time Design**	Late Design Changes	**< $ Change**	**System Coordination/ Design**	**Construction Control Measure**
(Allen and Rand 2016)																			
(Alvarez 1989)	q	q		x		q	q	x	x	x	x	q			q			q	
(Anastopoulos 1982)	x						q	q	q	q	x	q			x	x		x	
(Anonymous 1994)	x																		
(Anonymous 1995)														x					
(Anonymous 2000)	x			x															x
(Anonymous 2008)														x					x
(Anonymous 2014) Consulting Engineer		x																	
(Anonymous 2014) R&D Magazine																			
(Bachman 2003)	x				x														
(Bardwell and Saba 2005)	x																x		
(Barista 2003)	x																		
(Bonge 2002)				x															
(Briller 2014)																			
(Brown 1995)	x																		
(Cahnman and Kulka 1995)	x																		
(Carthey et al. 2015)	x		x																
(Cohen 2000)	x				x										x				
(Committee on Design, Construction 2000)	q				q					q	x								
(DeLauter and Roadarmel 1995)																			
(DiBerardinis et al. 2013)	x																		
(Domby 2012)	x																		
(Drickhammer 2003)	x																		
(Dussault and Nelson 2014)																		x	
(Eagle 2005)	x																		
(Eagle 2015)	q																		
(Faloon 2013)																			
(Gibson 1990)	x			x						x									
(Griffin 2004)																			
(Higginbotham and Studt 2001)	x																		
(Higgins 2007)																			x
(Holness 1987)	x			x															
(Howatson 2001)	x		x																
(Hrickiewicz 2012)	x																		
(Iselin and Lemer 1993)	x																		
(Keller 2002)	x																		
(Kelly and Borthwick 1985)	x					x					x	x					x		
(Kim 2001)								x		x									
(Landon 2006)					x														
(Leary and Meyer 2009)	x						x		x	x	x		x						
(Leveridge 2013)	q			q			x			x	x	x		x					

Table 4.3 "IBS Spectrum of Benefits" 1 of 4

Source	**Noise Control**	**Disruption**	**Infection Control**	**Access to Nature**	**> Views, Daylight**	**CNST Safety**	**Fire Safety**	**> Staff Productivity**	**Security for Systems**	**Schedule Compression**	Fast Tracking	Trade Stacking	< ladders/ scaffolding	Pre- Assembly	**Sustainable**	**Energy Efficiency**	Energy Efficicient Mechanical Layou	LEED	**> Facility Life Span**	**> Standard of Healthcare**
(Allen and Rand 2016)		x																		
(Alvarez 1989)	x	q	q					q		x		q	q			q				
(Anastopoulos 1982)		x								x	x	x		x						
(Anonymous 1994)									x											
(Anonymous 1995)		x																		
(Anonymous 2000)	x	x										x	x							
(Anonymous 2008)		x																		
(Anonymous 2014) Consulting Engineer		x																		
(Anonymous 2014) R&D Magazine															x					
(Bachman 2003)																				
(Bardwell and Saba 2005)																				
(Barista 2003)																				
(Bonge 2002)		x																		
(Briller 2014)		x	x																	
(Brown 1995)												x								
(Cahnman and Kulka 1995)																				
(Carthey et al. 2015)																				
(Cohen 2000)					x															
(Committee on Design, Construction 2000)		q																		
(DeLauter and Roadarmel 1995)							x													
(DiBerardinis et al. 2013)		x																		
(Domby 2012)																				
(Drickhammer 2003)																				
(Dussault and Nelson 2014)		x																		
(Eagle 2005)		x											x							
(Eagle 2015)																				
(Faloon 2013)		x													x					
(Gibson 1990)		x																		
(Griffin 2004)		x																		
(Higginbotham and Studt 2001)																				
(Higgins 2007)																				
(Holness 1987)		x																		
(Howatson 2001)		x																		
(Hrickiewicz 2012)																				
(Iselin and Lemer 1993)																				
(Keller 2002)		x																		
(Kelly and Borthwick 1985)		x								q		x		x						
(Kim 2001)		x																		
(Landon 2006)					x															
(Leary and Meyer 2009)		x			x	x				x		x	x							
(Leveridge 2013)		q	q							q		q								

Table 4.4 "IBS Spectrum of Benefits" 2 of 4

Source	Flexibility	Modularity	Expandability	Adaptability	Modernization	Standardization	< Life Cycle Cost	Payback Period	Operations	Maintenance	Access	< Cost	< Staffing	>Efficient/<Time	< $/time Design	Late Design Changes	< $ Change	System Coordination/ Design	Construction Control Measur
(Lombardi et al. 1997)										x									
(MacKenzie 1992)	x									x							x		
(Macmillan 2003)	x			x					x	x							x		
(Mathers and Haldenby 1979)			x	x						x	x					x	x		
(McCarthy 1995)	x																		
(MCW Consultants 2006)																			x
(Merkel 2006)	x																		
(Moe 2008)																			x
(Mudry 2001)				x													x		
(Nadel 1997)	x																		
(Neuman 2013)																			x
(Nitch 2006)	x				x														
(Odegard 1996)	x									x	x								
(Odegard and Justison 1996)	x									x									
(Pancham 2004)			x																
(Phillips 2005)	x																x		
(Phillips 2012)	x			x															
(Poirier 2012)				x			x		x										
(Rechel et al. 2009)	x																		
(Roulo 2010)																			
(Shahid 1993)	x	x		x	q		x			x	x			x		x	x	x	x
(Schatveta et al. 2017)	x			x					x	x						x			
(Schmidt 2002)																		x	
(Scholer Corporation 2000)	x																		
(Smallbridge 2004)	x	x							x										
(Starr 1997)	x																		
(Stillman and Graves 1998)				x			x												
(Streets 1995)	x			x						x		x							
(Teramura and Yomaru 1992)					x					x									
(Thompson 2009)	x				x														
(Thrun 2004)							x		x	x									x
(Tusler Jr. 2014)	x											q							
(Verderber 2015)	x																		
(Vondrak and Riley 2005)	q	q		q			q	x	x	x	x			q	q	q	q	x	
(Watch 2001)	x			x													x		
(Youssef 2004)	x																		
(Yu and Chang 2012)	x			x															
*(Bell et al. 1996)	q			q	q					q	x								
*(Bradley et al. 2015)	x		x							x								x	x
*(DoD 2017)	q			q		q			q	q	x								
*(Office of Construction, VA 1977)	q	q		q		q		q		q	q					q	q	q	
*(The Comptroller General 1972)	q			x	q		x		x	q				q	x		q		
*(U.S. EPA 2001) Fred Hutchenson													x						
*(U.S. EPA 2001) Louis Stokes																			

Table 4.5 "IBS Spectrum of Benefits" 3 of 4

Source	Noise Control	Disruption	Infection Control	Access to Nature	> Views, Daylight	CNST Safety	Fire Safety	> Staff Productivity	Security for Systems	Schedule Compression	Fast Tracking	Trade Stacking	< ladders/ scaffolding	Pre- Assembly	Sustainable	Energy Efficiency	Energy Efficicient Mechanical Layou	LEED	> Facility Life Span	> Standard of Healthcare
(Lombardi et al. 1997)																				
(MacKenzie 1992)	x	x										x								
(Macmillan 2003)										x										
(Mathers and Haldenby 1979)		x	x					x		x	x								x	x
(McCarthy 1995)										x		x								
(MCW Consultants 2006)		x																		
(Merkel 2006)																				
(Moe 2008)		x																		
(Mudry 2001)		x										x								
(Nadel 1997)																				
(Neuman 2013)		x																		
(Nitch 2006)																				
(Odegard 1996)																				
(Odegard and Justison 1996)																				
(Pancham 2004)																				
(Phillips 2005)		x																		
(Phillips 2012)																				
(Poirier 2012)		x																		
(Rechel et al. 2009)																				
(Roulo 2010)		x																		
(Shahid 1993)	x	x				x	x	x	x	q		x	x							
(Schatveta et al. 2017)		x								x										
(Schmidt 2002)																				
(Scholer Corporation 2000)		x																		
(Smallbridge 2004)																				
(Starr 1997)																				
(Stillman and Graves 1998)																				
(Streets 1995)		x																		
(Teramura and Yomaru 1992)																				
(Thompson 2009)				x	x															
(Thrun 2004)		x										x	x							
(Tusler Jr. 2014)		x										x							x	
(Verderber 2015)																				
(Vondrak and Riley 2005)		x				q			q	x		q	x	q	q	q	q	q		q
(Watch 2001)		x								x		x	x						x	
(Youssef 2004)																				
(Yu and Chang 2012)																				
*(Bell et al. 1996)																	q			
*(Bradley et al. 2015)		x				x														
*(DoD 2017)		q																		
*(Office of Construction, VA 1977)		q								q		q								
*(The Comptroller General 1972)		x								x		q							x	x
*(U.S. EPA 2001) Fred Hutchenson												q	q							
*(U.S. EPA 2001) Louis Stokes		q											q							

Table 4.6 "IBS Spectrum of Benefits" 4 of 4

Once the framework for the "IBS Spectrum of Benefits" was established, additional metrics were used to ascertain additional information. First, the sources were analyzed to determine the publication type. As previously discussed in the methodology, newspaper articles were removed via database configuration or filter. As illustrated, nearly half of the publications discovered during the systematic literature review were comprised of trade journals. This type of publication would typically reference or mention benefits associated with IBS, rarely substantiating the beneficial claim with cited literature.

The remaining literature sources varied in their detailing of benefits from a quantitative perspective; this is illustrated in the qualitative/ quantitative breakdown found in Figures 4.3 and 4.4. By and large, the publications that were contributed by U.S. governmental organizations established a robust foundation of supporting data. The research studies and reports provided by these organizations contain the majority of quantitative data, which in many cases is used by other publications as the premise for their research.

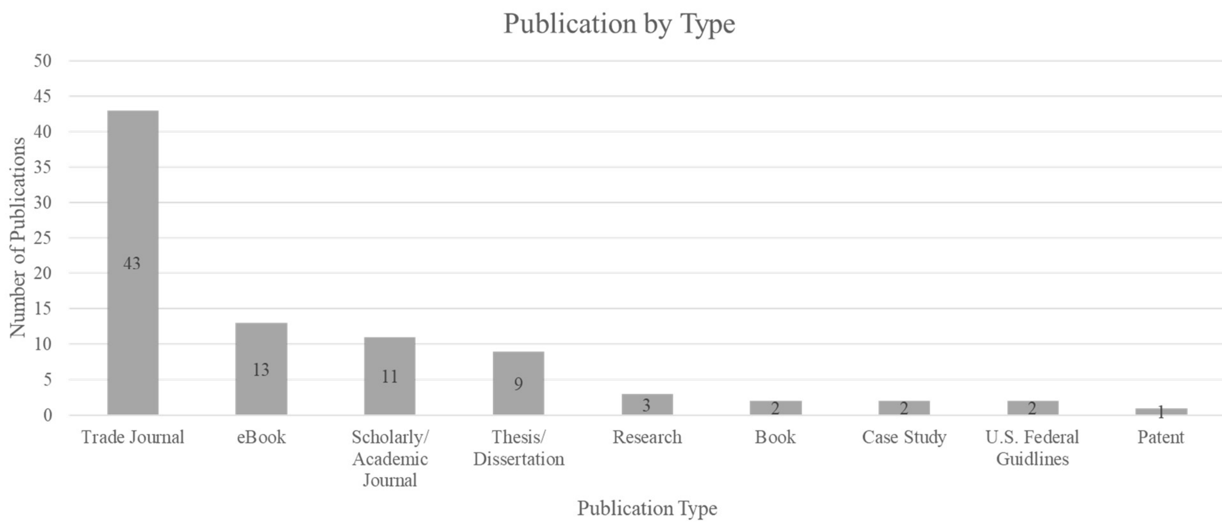

Figure 4.1 IBS Literature Review by Publication Type

Next, the publications were analyzed to determine the distribution of date ranges by year. The first publication was not found in the systematic literature review. Instead and as with the other non-systematic sources, was arbitrarily discovered through a snowball approach used during the initial exploratory stages of the research. This document was published in 1972 as a report to the U.S. Congress, by the Comptroller General which encompassed a compilation of innovations in hospitals and an analysis of their associated life-cycle costs.

In 1977, two documents were published: the first was released by the Department of Veterans Affairs (VA) and the second was a patent for a removable deck within the IBS. The "Hospital Building System" published by the VA serves as a foundational document referenced heavily within the IBS literature. The second, a patent, demonstrates a capitalistic response to an emerging innovation. After 1977, the distribution of publications containing foundational information is released at irregular intervals. As depicted in Figure 4.2, literature associated with the benefits of IBS was sporadic until the early 1990's.

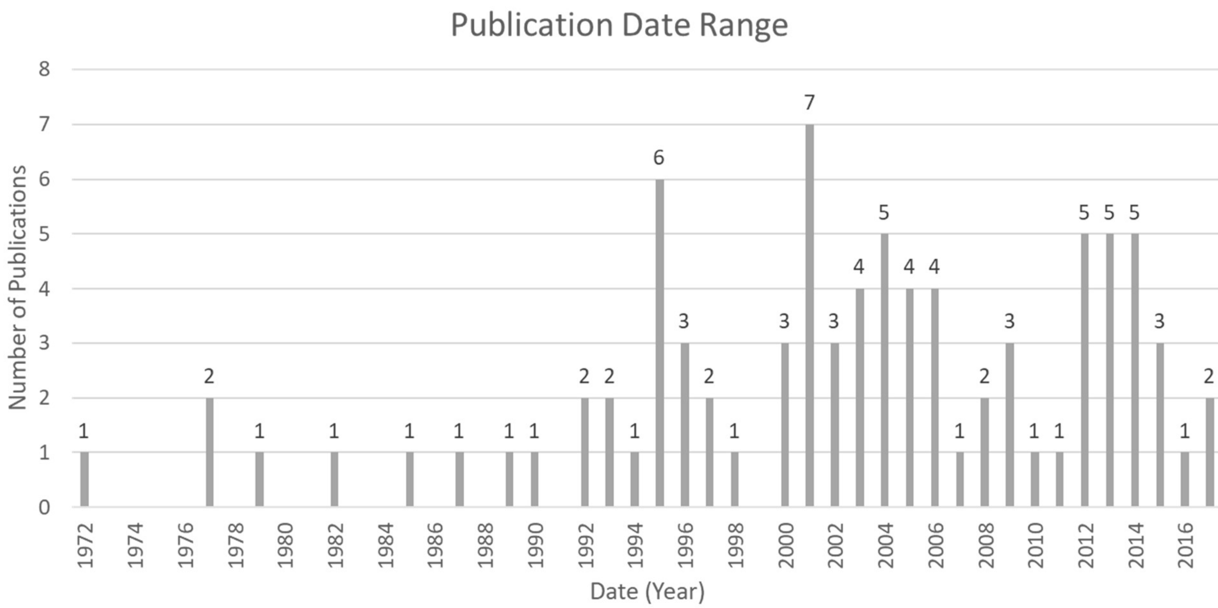

Figure 4.2 IBS Literature Review by Publication Date

Lastly the IBS spectrum of benefits were formatted into a chart that was able to capture the data presented in Tables 4.3 – 4.6 in a more meaningful way. A stacked column chart was selected to illustrate the total quantity of references made by the sources and identify the number of qualitative and quantitative references made for each benefit. It is important to recognize that the terms used to describe "IBS Spectrum of Benefits" are to be viewed as a benefit or improvement over traditional facilities without IBS. The ">" and "<" symbols are used traditionally to identify "greater (than)" or "less (than)" respectively.

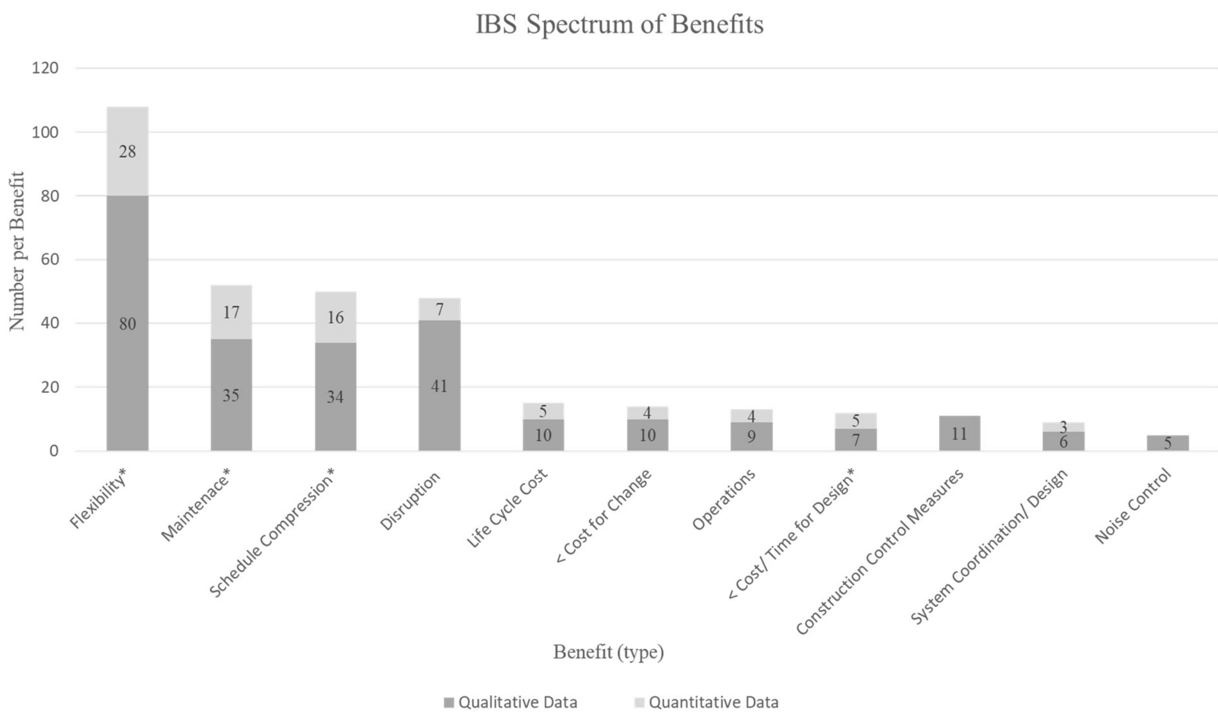

Figure 4.3 IBS Spectrum of Benefits, Qualitative vs. Quantitative 1 of 2

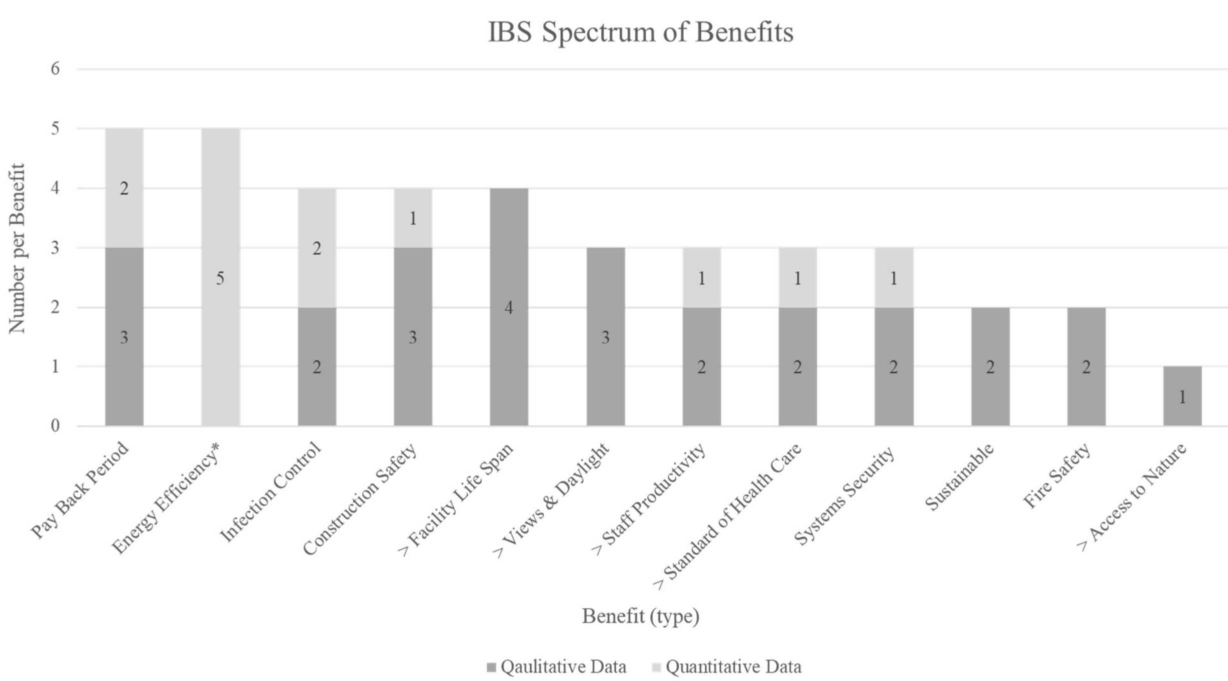

Figure 4.4 IBS Spectrum of Benefits, Qualitative vs. Quantitative 2 of 2

It was determined through the course of this research that there were several benefits offered by IBS which could be consolidated into a parent category. The parent categories are identified with an "*". Each identified parent category will have an additional chart associated with it that is able to further articulate nuanced terminology associated with it, which was referenced within the literature sources. It is important to note that the numbers associated with a parent category are an aggregate for the total number of results found within subsets of the parent category. Meaning, the number represented in a parent category could possibly exceed the number of sources used.

An example of this relationship can be illustrated with the benefit of flexibility. Within the literature, sources may have used one of the following terms. modularity, expandability, adaptability, modernization, or standardization to describe the concept of flexibility. Therefore, an additional chart (Figure 4.5) was created to segregated the terms selected by the sources. Additionally, if the term "flexibility" was used specifically by the author it was recorded under "flexibility". To summarize, the number represented under the term "flexibility" in the parent chart (Figure 4.5) illustrating the "IBS Spectrum of Benefits within Flexibility*" only corresponds to a reference made by an author directly to the term flexibility. It does not however, provide a sum of other terms used to describe flexibility within the chart.

The systematic literature review resulted in the production of a spectrum of benefits offered by IBS. The "IBS Spectrum of Benefits" is the outcome of the first objective and serves as a foundational component in the overall framework established by this research.

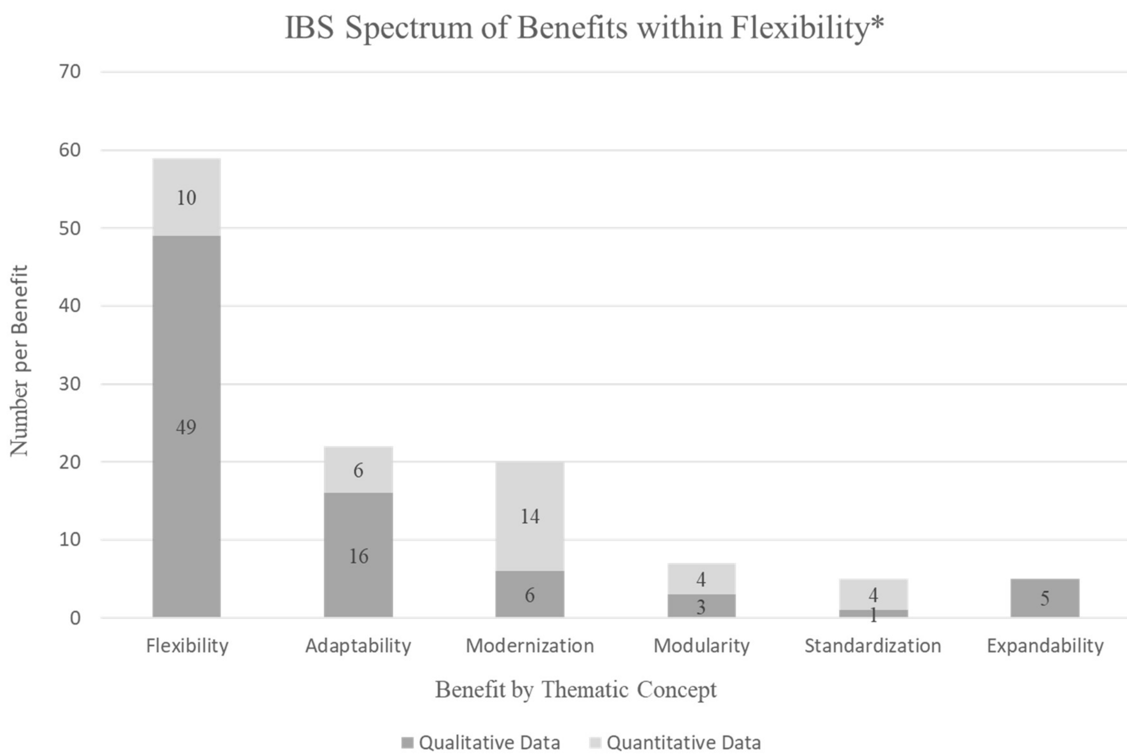

Figure 4.5 Flexibility Parent Category

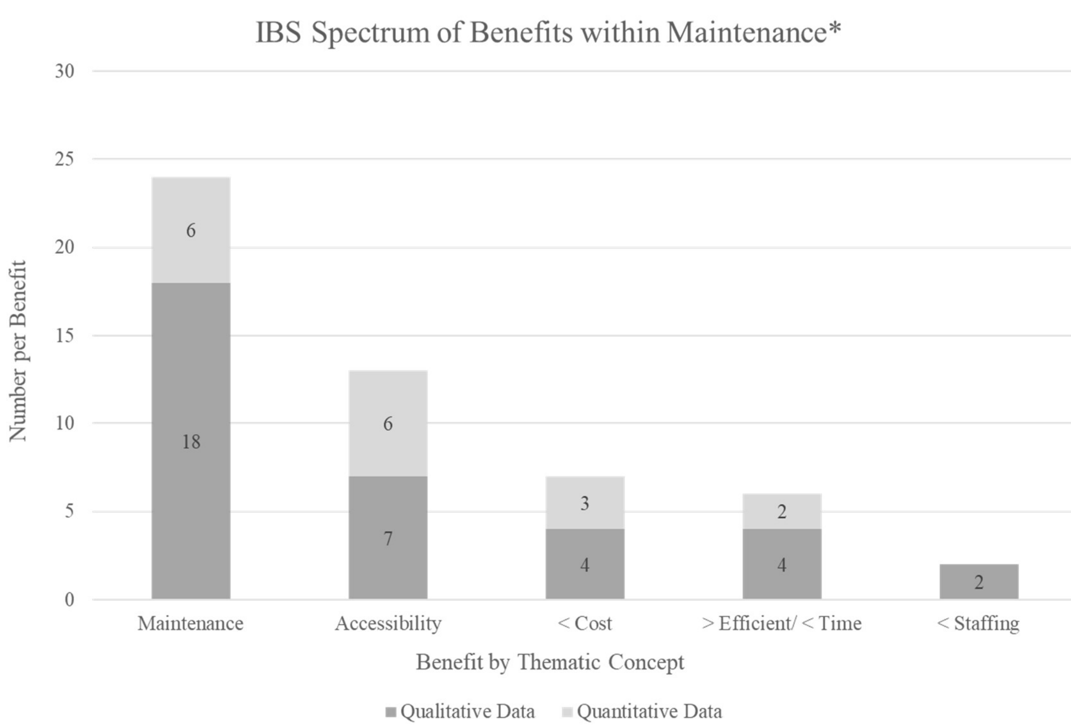

Figure 4.6 Maintenance Parent Category

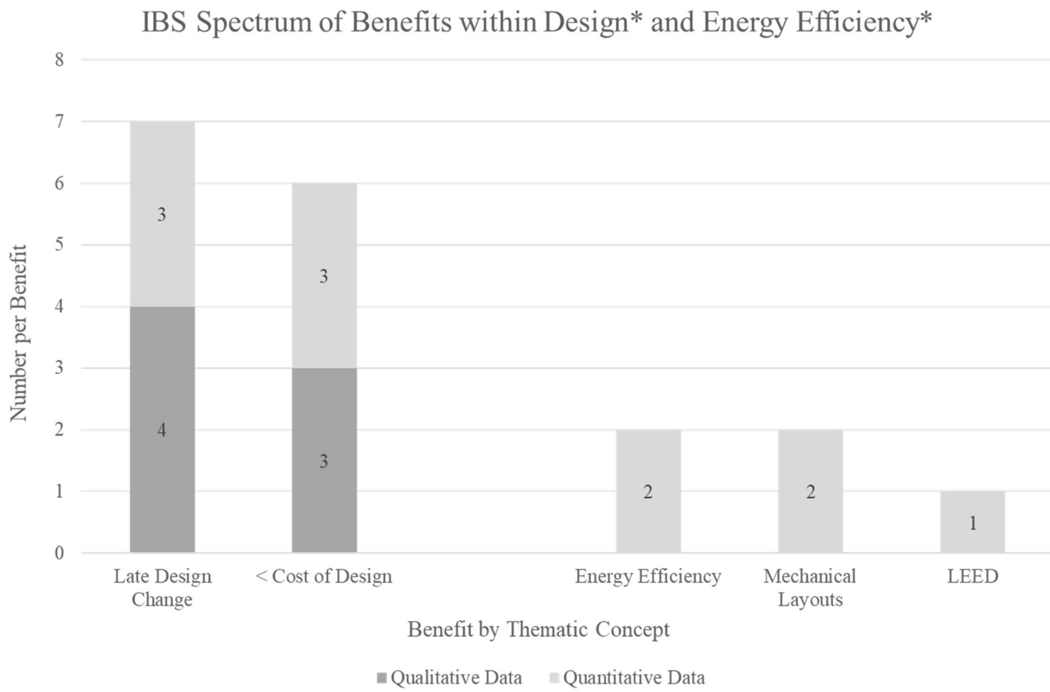

Figure 4.7 Design and Energy Efficiency Parent Categories

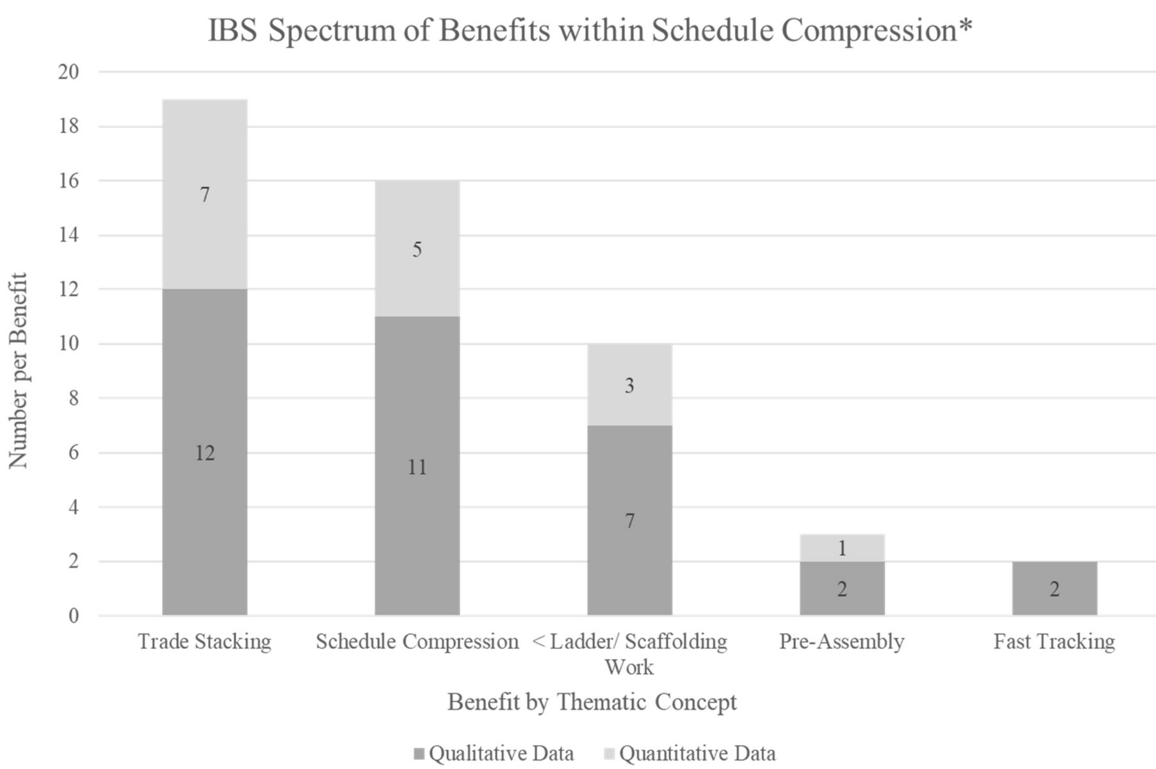

Figure 4.8 Schedule Compression Parent Category

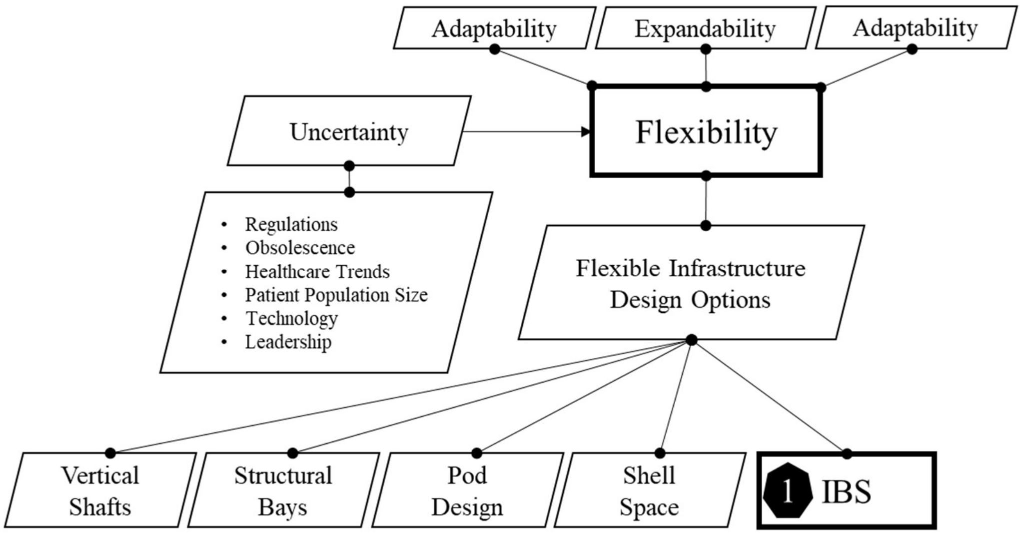

Figure 4.9 IBS Spectrum of Benefits within Framework

4.3 The Application of Flexibility to Evidence Based Design

Following the described methodology, this work established how the relationship between flexibility and EBD are rooted in existing literature. This relationship was initiated by nesting the two literature domains, flexibility and EBD, in order to draw possible conclusions as to the dependent nature flexibility has to EBD (Figure 4.10). This process illustrated the foundational and dependent nature flexibility has in acting as a driving mechanism for the successful implementation of specific EBD features or responses.

Again, it was not the intent of this research to provide an exhaustive or comprehensive matrix which documents all possibilities of this relationship. Instead, it is intended to serve as an observation, which documents select examples of this relationship. The selected and validated group of EBD features and responses originated by Noblis, when applied to de Neufville et al. (2008) concept of flexibility discussed in the methodology resulted in a unique perspective; illustrating an inherent foundational and dependent relationship between EBD and flexibility.

The establishment of this relationship gives rise to a continuum of flexibility which flows from the foundational elements of EBD to the organizational EBD principles established by the Military Health System (MHS). The concept for a continuum of flexibility nested within EBD is established through the introduction of flexibility into EBD features and responses (Figure 4.11). The application of flexibility at a foundational level incorporates flexible traits that are carried through the remainder of the framework. This is due to the MHS EBD framework which is structured as a linear flow and is predicated on the summation of previous building blocks. Once flexibility enters the system as an EBD feature or response, it then is incorporated into a goal. That same goal is aligned to support an associated principle. The flow of flexibility from the foundational elements of EBD features and responses comes to a head at each MHS EBD principle.

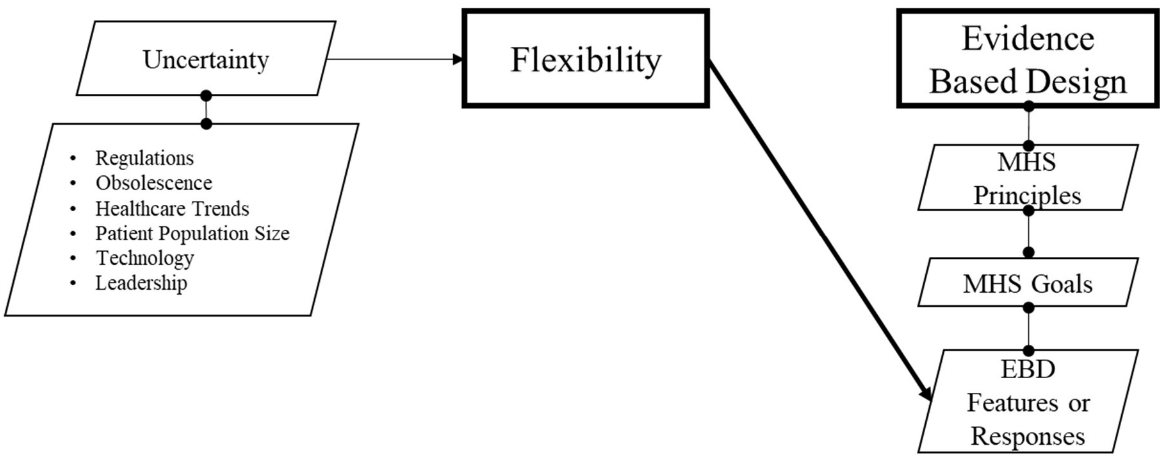

Figure 4.10 Flexibility Flow into EBD

The first four EBD principles endorsed by MHS are ever evolving, reliant on state-of-the-art features and responses. While each of the first four principles are interdependent from one another, there still is a common binding denominator, flexibility. The MHS fifth EBD principle states that facilities should be designed for maximum standardization, future flexibility and growth.

If flexibility has been incorporated as element of a feature or response, it then becomes an innate quality of each associated MHS EBD principle. Thus, providing direct support to the fifth principle. The five principles established by the MHS, while organizationally unique, are all derived from EBD. Therefore, flexibility in the context of the MHS, is part of EBD. The endorsement and commitment to flexibility within EBD by the MHS establishes a feedback loop flowing into and broadly supporting the concept of flexibility. This feedback loop creates the final component necessary to establish a continuum of flexibility present within the construct of EBD in the MHS.

The second objective of this research resulted in the production of a conceptual model (Figure 4.11) illustrating a relationship between flexibility and EBD and a continuum of flexibility enabled by this relationship. The "Flexibility-EBD Conceptual Model" also serves as a foundational component in the overall framework established by this research.

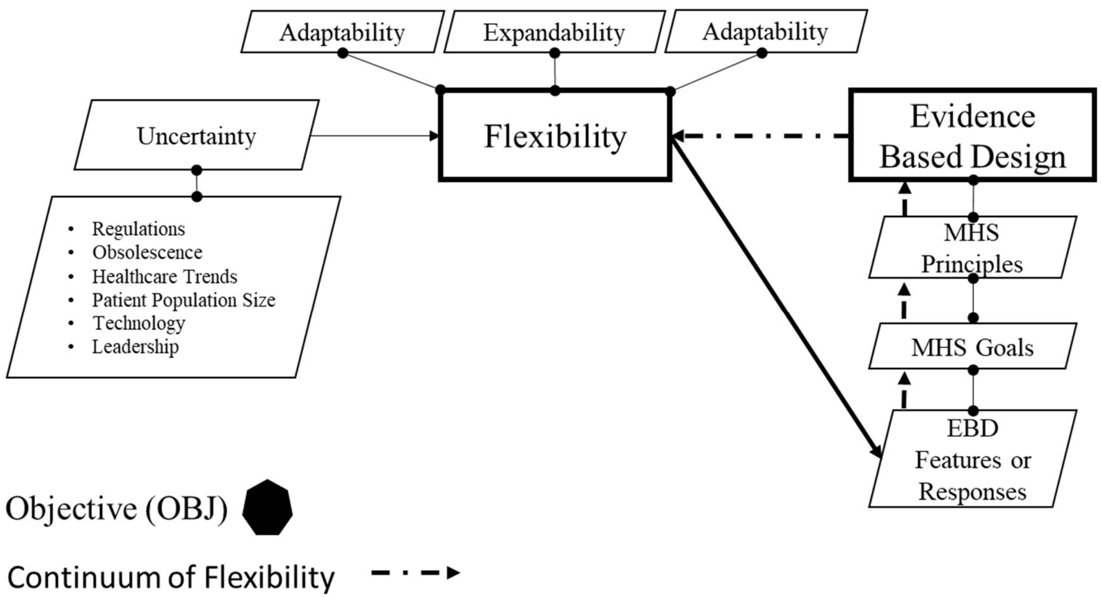

Figure 4.11 Flexibility-EBD Conceptual Model

4.4 Interstitial Building Space's Ability to Satisfy Evidence Based Design Components

The third objective within this research was to identify specific components of EBD embraced by the MHS which are satisfied by the use of IBS. This was accomplished by comparing the benefits conveyed in the "IBS Spectrum of Benefits" with the components of EBD. This comparison enabled conclusions to be drawn as to the dependent relationship EBD has to IBS.

The results of this comparison are not intended to be comprehensive. Instead, the comparison represents only a small population that is related to EBD components within the construct of the MHS. The outcome of the third objective is "IBS-EBD Component Mapping

Framework" which articulates the direct matches between the benefits associated with IBS and EBD components.

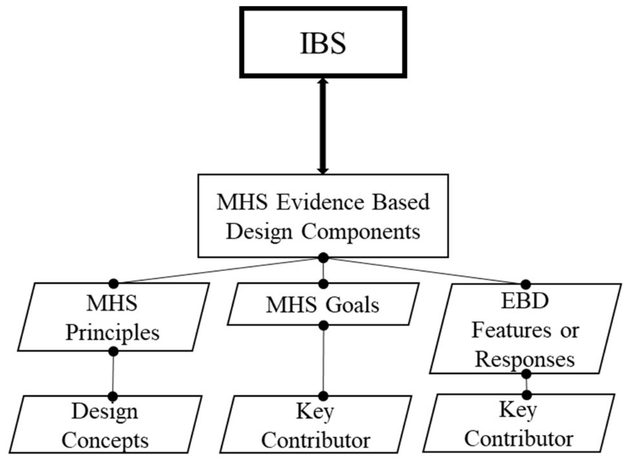

Figure 4.12 Objective 3 Framework

To illustrate the matches between the benefits of IBS and EBD components, the framework used in Figure 4.13 was adapted to create Figure 4.14. In Figure 4.14 the EBD components are situated along the left side in the first column. The boxes labeled "P1, P2, P3, and P4" were positioned respectively to serve as place holders, assisting with the alignment of EBD components under a specific principle. The layout was intended to resemble the structure used to illustrate the alignment of EBD features and responses under MHS EBD goals and MHS EBD principles (Figure 4.13). The formatting was amended to reflect the addition of design concepts under the MHS EBD principles, and key contributors aligned respectively under MHS EBD goals and EBD features and responses.

The text boxes within Figure 4.14 illustrate where an IBS benefit matched an EBD component. The matches are aligned along the x-axis with an EBD component and along the y-axis under an MHS EBD principle. Each match serves as a visual depiction that is used to build the mapping framework model.

The first match was directly with the MHS EBD's fifth principle, "design for maximum standardization, future flexibility and growth." The "IBS Spectrum of Benefits" table clearly articulates this match with the term's "flexibility" and "standardization". The term "growth" however, can be considered vague and left to reasonable interpretation.

Within the context of EBD and this research it was determined growth had two reasonable interpretations. First, the physical expansion of a facility, whether vertical or horizontal. Second, growth within the existing confines of physical space; but relating to reorganization or manipulation of space due to uncertainties.

The physical expansion of a facility directly corresponds to the EBD design concept of expandability, described by Malone, as the ability to add a new service or expand an existing service. The reorganization or manipulation of space aligns with the EBD design concept of adaptability, also described by Malone, as the ability to adjust quickly or respond to fluctuation in workload or technology (i.e. uncertainties). The concept of expandability and adaptability are both directly captured as an IBS benefit under the parent category of flexibility.

The next match was with two MHS EBD goals G2.A and G2.B: "Reduce Airborne Transmitted Infections" (G2.A) and "Reduce Infections Spread Through Contact" (G2.B). These two goals aligned with the IBS benefits of construction control measures and infection control.

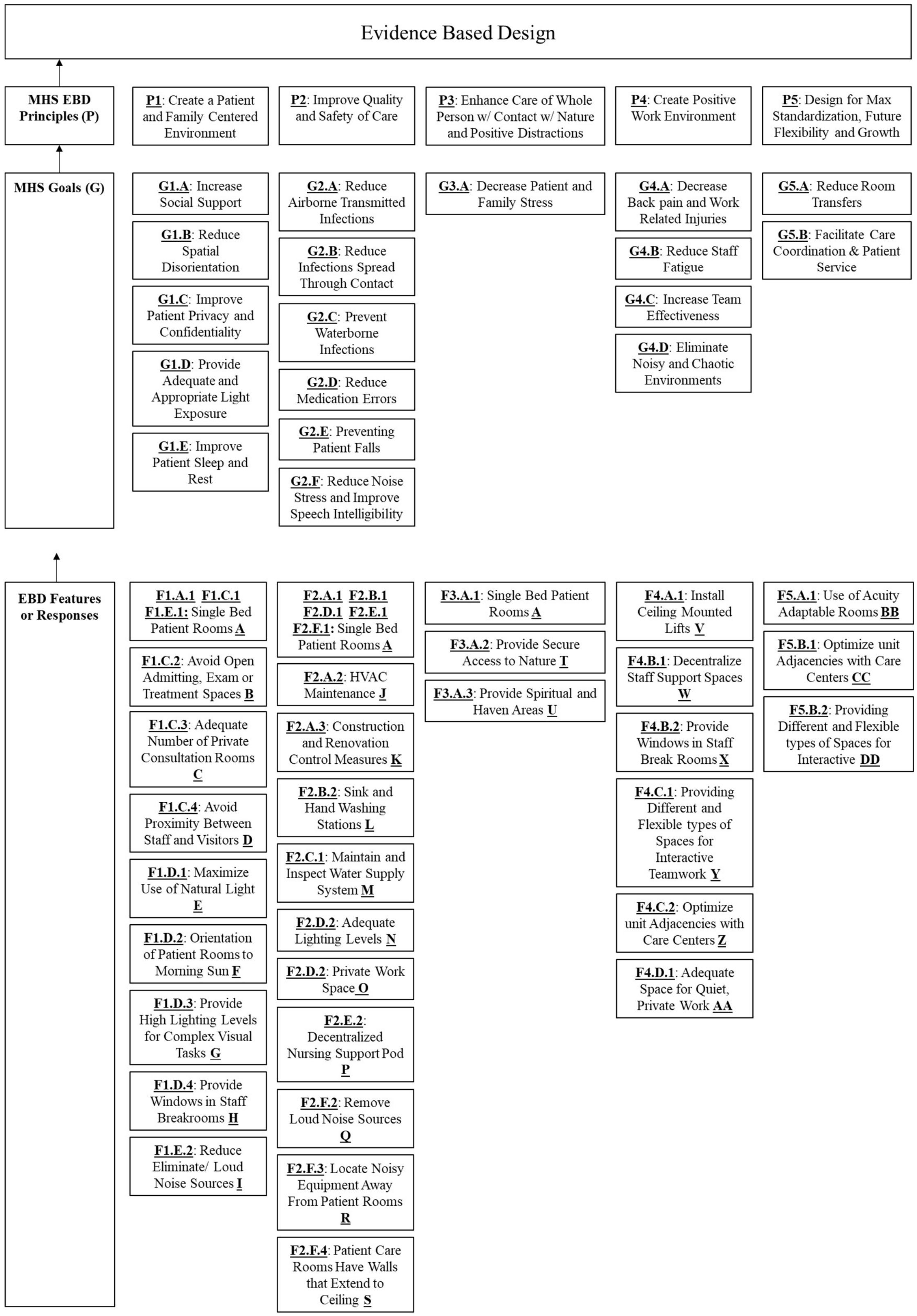

Figure 4.13 MHS EBD Alignment of Features/ Responses, Goals and Principles

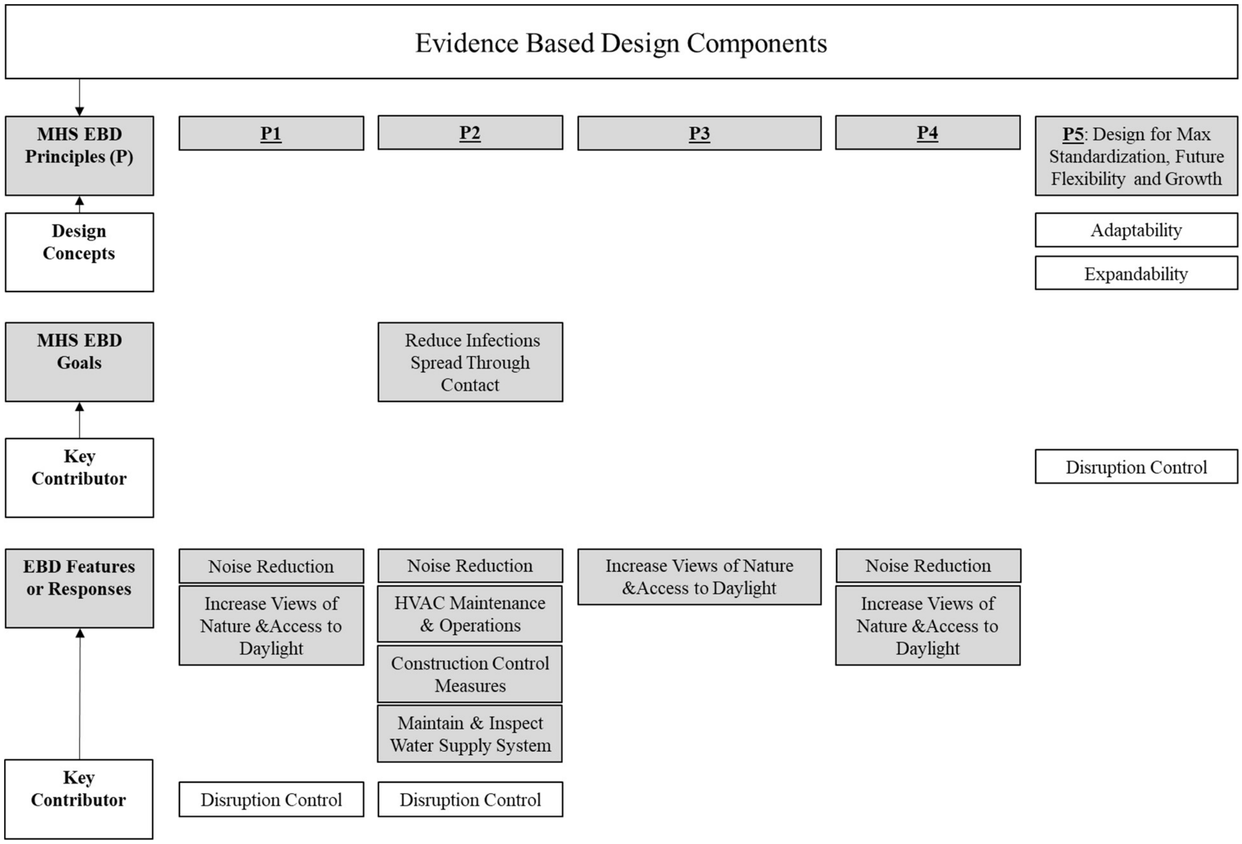

Figure 4.14 "IBS-EBD Component Mapping Framework"

There were three EBD features or responses matched for "Noise Reduction". The first was in support of response F1.E.2 "Reduce or Eliminate Loud Noise Sources". The second was in support of responses F2.F.2 and F2.F.3: "Remove Loud Noise Sources" (F2.F.2) and "Locate Noisy Equipment Away from Patient Rooms" (F2.F.3). The third was in support of the feature F4.D.1 "Adequate Space for Quiet, Private Work." All three of these examples aligned under the IBS benefit for noise control.

There were three matches for the key contributor "Disruption Control". The first was a key contributor to the MHS EBD goal G5.A "Reduce Room Transfers." The next two both served as contributors for the reduction of noise as previously mentioned under F1.E.2, F2.F.2 and F2.F.3. These three key contributors aligned themselves under the IBS benefit for disruption.

The next is a set of matches and is listed under three EBD features or responses as "Increase Views of Nature & Access to Daylight." The first match located under "P1" is in support of F1.D.1, F1.D.2 and F1.E.2: "Maximize Use of Natural Light" (F1.D.1), "Orientation of Patient Rooms to Morning Sun" (F1.D.2), and "Provide Windows in Staff Breakrooms" (F1.E.2). The next match is located under "P3" and supports F3.A.2 "Provide Secure Access to Nature." The third match is located under "P4" and supports F4.B.2 "Provide Windows in Staff Breakrooms." This set of matches aligns with the IBS benefits of increase access to nature and increases in views and daylight.

The grouping of matches is listed under "P2." The first is "HVAC Maintenance" and supports EBD response F2.A.2. This match is aligned with the IBS benefit of maintenance. The next match is "Construction & Renovation Control Measures" and supports EBD feature F2.A.3. This is aligned with the IBS benefit of construction control measures. The final match from this group is EBD response F2.C.1 "Maintain and Inspect Water Supply System." This aligns under the IBS benefit of maintenance.

The third objective of this research resulted in the production of the "IBS-EBD Component Mapping Framework" (Figure 4.14) articulating direct matches between IBS benefits and EBD components. This also serves as a foundational component in the overall framework established by this research.

4.5 Conclusion

The findings in this chapter presented the results for the three objectives of this research. The systematic literature review yielded a comprehensive "IBS Spectrum of Benefits" matrix (Tables 4.3 – 4.6) with an accompanying methodology allowing for a systematic reproduction of the process. The findings from the second objective resulted in the production of the "Flexibility-EBD Conceptual Model" (Figure 4.11) illustrating a relationship between flexibility and EBD as well as the continuum of flexibility enabled by this relationship. Finally, results of the third objective yielded a "IBS-EBD Component Mapping Framework" (Figure 4.14) which articulates the direct matches between the benefits associated with IBS and EBD components.

The combination of results from the three objectives resulted in a framework able to demonstrate the interrelated nature of flexibility, Evidence Based Design and Interstitial Building

Space. The framework illustrated in Figure 4.15 represents the aggregate relationship established within this research.

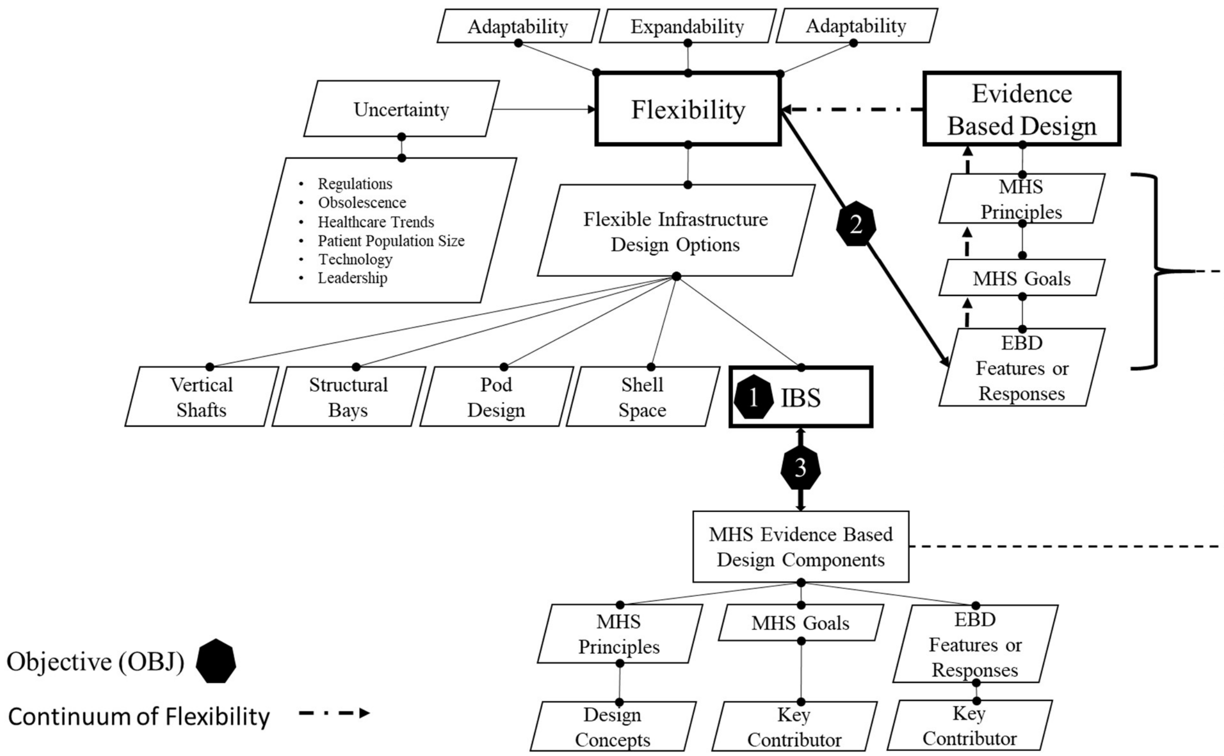

Figure 4.15 Resultant Framework

Chapter 5. Discussion

The systematic literature review produced a comprehensive "IBS Spectrum of Benefits" model. This model articulates the benefits of IBS described in literature from 1972 – present. The 1972 publication issued by the Comptroller General focused the discussion on innovations in hospitals and the associated life-cycle cost. Interestingly, IBS were first employed in the United Kingdom in the late 1960's, yet the 1972 publication was the earliest discovered that discussed IBS.

IBS' were first implemented experimentally as a response to the discovered need for flexibility. No formal research was conducted prior to its implementation, seemingly a foreshadow for the history of IBS. Even after numerous studies, reports and research were conducted to validate the beneficial claims made for IBS, organizations both public and private, have failed to maintain accurate records necessary for validation (Kendall et al. 2012).

This after the VA published the 1977 "Hospital Building System" which thoroughly analyzed and discussed the metrics necessary for the implementation and use of this system. Even today there are mixed claims as to the initial capital expenditure required to implement IBS design. The lack of accurate metric analysis and record keeping has created claims that range from: IBS facilities are less expensive than traditional facilities, "For combined hard and soft costs, Fred Hutchinson Cancer Research Center was 18% lower in overall costs against eight other conventional lab projects" (U.S. Environmental Protection Agency 2001a p. 4); to IBS facilities cost the same to construct as traditional facilities, "Studies have also been done which indicate that the concept is becoming more accepted, and that interstitial buildings do not necessarily require first-costs premiums." (Vondrak and Riley 2005 p. 2); to IBS cost more, "There is no denying that interstitial space itself adds to the buildings cost" (Kelly and Borthwick 1985 p. 17), "Disadvantages include the facts that the interstitial space adds to the ceiling height and to the gross space of the building, requires additional structures such as for floor access and may require additional sprinkling of the interstitial cavity, all of which add up to the fact that this system is more expensive; it can add 6 to 20 percent to the cost of the building (Ruys, 1990, 385)" (Gibson 1990 p. 216).

This issue persists into other qualitative benefits discussed within the literature, regardless the type of publication. While in aggregate, a collection of publications may have differing quantitative values associated with a specific IBS benefit, they still corroborate a similar claim e.g. a reduced construction schedule. It seems many of the values published were dependent on select discretionary factors and failed to comprehensively account for all considerations. "Of the research that does exist, few analyses include a comprehensive analysis of all building systems, or include the effects of interstitial space design on the construction process" (Vondrak and Riley 2005 p. 2). Therefore, only simple conclusions can be reached as to the true quantitative nature associated with each benefit.

In the pursuit of the second objective, an attempt was made to illustrate how a foundational and dependent relationship exists between flexibility and EBD. Furthermore, how flexibility acts as a driving mechanism for the successful implementation of specific EBD features or responses. The overlay between flexibility and EBD was structured within existing literature. Thus, driving the approach used to conceptually nest the two literature domains.

There was not a reference in the reviewed EBD literature which suggested a relationship similar in nature to the concept presented within this research. However, a thorough comparative literature review between EBD and flexibility should result in a strengthened argument in support of this concept. Additionally, the concept of a flexibility continuum being introduced as a foundational element within EBD would maintain its applicability as theorized, regardless of organizational or project specificities.

While the "IBS Spectrum of Benefits" is considered a comprehensive matrix, the selected EBD components were limited. This limitation was predicated first on the applicability to the MHS and second only to those recommendations of features and responses made by Noblis. The robustness of this comparison could be further exploited by the use of a comprehensive matrix of EBD components not limited by organizational preference.

5.1 Contributions and Impacts

The capstone of this research is the overall framework diagram (Figure 4.15) that articulates the dependent relationships between flexibility, IBS and EBD. The framework is comprised of three key elements: The "IBS Spectrum of Benefits" matrix, the "Flexibility-EBD Conceptual Model", and the "IBS-EBD Component Mapping Framework."

The expectation for the overall framework diagram is to serve as a foundational element that is able to serve as a point of departure for future research. The overall framework enables navigational clarity between the dependent relationships of the three key elements. The original intent of this research was to positively impact policy or decision making for healthcare facilities programming and design.

The EBD community extends beyond healthcare facilities and this framework can be applied to other facilities such as: educational, prisons, commercial and industrial. Thus, the framework can enabe stakeholders involved with complex projects to evaluate the importance of dependent relationships specific to their project. Furthermore, the framework highlights the importance flexibility has in assisting owners, builders and designers alike to efficiently allow for dynamic shifts within their circle of influence. Finally, the use of the relationship illustrated by the framework can be used as a foundation to expand the aperture for the inclusion of additional variables by the EBD community.

The "IBS Spectrum of Benefits" provides a comprehensive matrix that can be used as a point of departure or as a reference in future research. Also, the "IBS-EBD Component Mapping Framework" supports the addition of "enabling EBD" to be added as a benefit of IBS. The "IBS Spectrum of Benefits" can be used as a reference matrix in the determination of metrics from which to evaluate IBS facilities.

These metrics can be used to evaluate facilities that incorporate IBS as one component of a larger system such as: "integrated building systems" used by the private sector, the "Hospital Building System" used by the Department of Veterans Affairs, or the "Interstitial Building System" used by the Department of Defense.

Finally, the "IBS Spectrum of Benefits" identifies several benefits that when isolated from the context of IBS are by themselves a functional area i.e. sustainability and LEED. Sustainability and LEED, as benefits of IBS received minimal recognition within existing literature. However, this highlights an opportunity for the sustainability and LEED communities to determine the applicable benefits of IBS to their respective domains.

The "Flexibility-EBD Conceptual Model" illustrates a relationship between flexibility and EBD and a continuum of flexibility enabled by this relationship. Additionally, the data will prove valuable to stakeholder communities by articulating the ability of IBS to promote flexibility throughout the spectrum of a healthcare facilities lifecycle, while concurrently supporting EBD components. Furthermore, it suggests the continuum of flexibility serves as a foundational element in EBD. While this research strictly focused on the relationship of flexibility to EBD within the MHS, this conceptual model can be applied to the entire EBD community. The importance flexibility plays in a facilities life cycle should be solidified in to the EBD construct. The evolving nature of EBD itself validates the need for flexibility to become a core competency of EBD.

The “IBS-EBD Component Mapping Framework” articulates direct matches between IBS benefits and EBD components. It establishes a connection between flexible infrastructure design options, specifically IBS and its impact on EBD. The identification of this connection should prove impactful to the EBD community, the Department of Defense (DoD) and other organizations that subscribe to EBD as well as those that also operate facilities or are considering a facility with IBS.

The “IBS-EBD Component Mapping Framework” provides the validation that IBS is able to directly support EBD. Furthermore, the comparison used in the mapping framework suggests that additional, unexplored EBD components could likely be indirectly enabled with IBS. Using IBS as an example it raises additional questions as to the possibility of other flexible infrastructure design options exhibiting similar traits – suggesting that flexible infrastructure design options beyond IBS may innately assist EBD outside flexibility.

The “IBS-EBD Component Mapping Framework” can be used by the DoD through the Unified Facilities Criteria (UFC) to correlate the relationship between IBS a component of the “Interstitial Building System” and EBD a subset of a “World Class Health Facility.” The existence of this relationship suggests a possibility for other flexible infrastructure design options used by the “Interstitial Building System” to exhibiting similar traits in support of EBD.

Finally, the discovery of the relationship illustrated by the “IBS-EBD Component Mapping Framework” provides beneficial validation for how one flexible infrastructure design option such as IBS can support concurrent requirements such as EBD, LEED or sustainability. Thus, reinforcing the importance for the integration stakeholder and multidisciplinary experts on complex and dynamic construction projects.

5.2 Opportunities for Future Research

It appears there is significant room for quantitative research that can measure the benefits offered by IBS. Furthermore, a comprehensive spectrum of disadvantages for IBS does not exist. A comparison between the benefits and disadvantages of IBS using quantitative data is needed. This comparison can assist in the establishment of a comprehensive tool used to assist stakeholders in their evaluation of IBS. Additionally, this comprehensive tool can be expanded to incorporate other flexible infrastructure design options.

The EBD community can investigate how flexible infrastructure design options are able to support EBD. This relationship can be expanded through a comparative review of flexible infrastructure design options, resulting in the establishment of a decision matrix able to assist stakeholders with the incorporation of EBD. Additionally, a detailed analysis can be conducted comparing the "IBS Spectrum of Benefits" to all EBD components existing in current literature.

Finally, there is an ample amount of research and validation which can be conducted as it relates to the "Flexibility-EBD Conceptual Model" presented.

Chapter 6. Conclusion

In complex projects, such as healthcare facilities designers, builders, owners, interdisciplinary team members, users and other stakeholders must coordinate their efforts to effectively navigate project specific intricacies to ensure the best possible outcomes. Driven by the improvement of outcomes, science and technology continue to advance on numerous levels. Disciplines such as Evidence Based Design seek to improve patient, staff and resource outcomes; green building organizations seek to improve sustainability and lean programs aim to improve efficiencies. These improvements while often developed to assist or solve a particular goal, often have unanticipated ripple and interrelated effects on one another.

The interrelated effects paired with rapid evolution of science and technology necessitate coordination between stakeholders to produce effective outcomes. This coordination is especially important within the healthcare arena because health and wellbeing are reliant on it. However, the sheer amount of information as well as the continual progress and evolution of that information can become overwhelming and difficult to navigate. This contributing to the dynamic and ever-changing nature of healthcare facilities. Thus, creating uncertainties.

These uncertainties add to the complexities associated with the life cycle of construction projects. The concept of flexibility can be used to augment responses intended to combat these uncertainties. Flexibility is available in many forms one of which is through flexible infrastructure design, specifically Interstitial Building Space. The motivation of this research was initially predicated on how flexibility and Interstitial Building Space could assist with uncertainties specific to healthcare facilities. Furthermore, how improvements brought on by advancements of science and technology affecting stakeholders were interrelated with flexibility.

The purpose of this research was to examine Interstitial Building Space, Evidence Based Design and the concept of flexibility in order to compare and synthesize their relationships and create an overarching framework that is able to articulate these relationships. The first objective of this research was to establish and validate a current spectrum of benefits offered by Interstitial Building Space. This was necessitated by the lack of comprehensive and current literature detailing the benefits of IBS.

First, to achieve this, the research methodology used a systematic literature review to establish a current and comprehensive spectrum of benefits offered by IBS. This resulted in a matrix able to articulate the benefits, frequency, and the qualitative/ quantitative nature of IBS represented in existing literature.

The second objective aimed to demonstrate how flexibility may serve as a foundational mechanism that is able to support Evidence Based Design. This was motivated by realizing how healthcare facilities seemed to respond independently to the achieving specific goals i.e. sustainability, lean construction or EBD. EBD's focus is on implementing validated research that shows improved of outcomes; whereas, flexibility is focused on strategic decisions of capital investments which affect short-term, mid-range and long-term adaptability and or expandability. The intent was to benefit healthcare facility stakeholders by identifying interrelated qualities between flexibility and EBD.

For this, the methodology nested literature from the flexibility domain and EBD domain to correlate supporting concepts. This resulted in the establishment of a relationship between flexibility and EBD features and responses. The establishment of this relationship within the inherent structure of EBD supports a continuum of flexibility, demonstrating the dependent relationship between flexibility and EBD.

The third and final objective built upon the framework established by the first and second objectives. The intent was to identify specific components of Evidence Based Design within the construct of the Military Health System that are satisfied by the use of Interstitial Building Space. The purpose was to demonstrate, through the use of specific examples, how flexibility in the form of IBS is interrelated with EBD.

To achieve this, the methodology compared MHS EBD components to the IBS spectrum of benefits identified from this research to determine matching patterns. This resulted in the identification of specific MHS EBD components that are directly supported by the benefits offered by IBS.

This research resulted in three specific products: the "IBS Spectrum of Benefits", the "Flexibility-EBD Conceptual Model" and the "IBS-EBD Component Mapping Framework"; each independently provide findings toward their objective. However, these three products in aggregate comprise the foundational elements to the overall framework; articulating the relationships between flexibility, EBD and IBS.

The findings associated with this research demonstrate only a small portion of the relationships that stakeholders must consider throughout a healthcare facilities lifecycle. Furthermore, while the relationships presented within this research were framed within the healthcare construct, the applicability is pertinent to all types of construction projects. The continued progress and evolution of science and technology results in a moving target for stakeholders within the construction industry, challenging stakeholders to continually adapt and resist complacency. The framework presented within this research should, at a basic level, illustrate the interrelated complexities facing the construction industry. Bringing awareness to niches within the construction industry of the interrelated implications of their work.

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Appendix A

EBD Feature/ Response Reference Link to Figure 3.20	**MHS EBD Goal**	**EBD Feature or Response**	**Baseline Source (Noblis Study)**	**Validation Source**
A	Increase Social Support **G1.A**	Single Bed Rooms **F1.A.1**	"Both the American Institute of Architects Guidelines (2006) and DoD Space Planning Criteria (2006) recommend that most, if not all rooms on a unit be single-bed. DoD Space Planning Criteria for a single-patient room includes space for a sleeper chair and a side chair, which can be used by family members and visitors." p.27	"Single-occupancy rooms increase patients' privacy, which provides patients with control over personal information, an opportunity to rest, and an opportunity to discuss their needs with family members and friends.(Bobrow & Thomas, 1994; Burden, 1998; Morgan & Stewart, 1999)." (Chaundhury et al. 2004 p.7)
				"The majority of patients prefer single rooms because of

				greater privacy, reduced noise, reduced embarrassment, improved quality of sleep, opportunity for family members to stay, and avoidance of upsetting other patients (Douglas, Steele, Todd, & Douglas, 2002; Kirk, 2002; Pease & Finlay, 2002; Reed & Feeley, 1973)." (Chaundhury et al. 2004 p.8)
A	Improve Patient Privacy and Confidentiality **G1.C**	Single Bed Rooms **F1.C.1**	"Patient privacy and confidentiality is best supported in a single-bed room." (Malone et al. 2007 p. 30)	"Single-occupancy rooms increase patients' privacy, which provides patients with control over personal information, an opportunity to rest, and an opportunity to discuss their needs with family members and friends.(Bobrow & Thomas, 1994; Burden, 1998;

				Morgan & Stewart, 1999)." (Chaundhury et al. 2004 p. 7)
				"The majority of patients prefer single rooms because of greater privacy, reduced noise, reduced embarrassment, improved quality of sleep, opportunity for family members to stay, and avoidance of upsetting other patients (Douglas, Steele, Todd, & Douglas, 2002; Kirk, 2002; Pease & Finlay, 2002; Reed & Feeley, 1973)." (Chaundhury et al. 2004 p. 8)

B		Avoiding Open Spaces **F1.C.2**	"Avoid Open-Plan Cubicle Curtained Admitting, Examination and Treatment Spaces. Ensure that admitting, exams and treatments occur inside walled rooms. Current DoD Space Criteria includes open-plan rooms with cubicles separated by curtains: e.g., in the post-anesthesia care unit, primary care clinic treatment rooms. A ROI analysis is needed." (Malone et al. 2007 p. 30)	"According to Mlinek & Pierce [37] , overhearing conversations at the reception desk was the main problem in the waiting room. Mlinek & Pierce suggested achieving a more audibly secure area by changing the structural design. Thus, the addition of background music or the use of physical barriers could be used to limit noise transmission and overhearing of conversations." (Huisman et al. 2012 p. 5)
C		Adequate Number of Private Consultation Rooms **F1.C.3**	"Ensure that there are walled rooms for providers to conduct meetings with families and in public areas like reception and waiting rooms where private information may be	"According to Mlinek & Pierce [37] , overhearing conversations at the reception desk was the main problem in the waiting room. Mlinek & Pierce suggested achieving a

			discussed." (Malone et al. 2007 p. 30)	more audibly secure area by changing the structural design. Thus, the addition of background music or the use of physical barriers could be used to limit noise transmission and overhearing of conversations." (Huisman et al. 2012 p. 5)
D		Avoid Proximity Between Staff and Visitors **F1.C.4**	"Avoid Physical Proximity between Staff and Visitors Ensure that admission and reception areas are designed to avoid physical proximity between staff and visitors to minimize overhearing confidential telephone conversations and discussions." (Malone et al. 2007 p.30)	"According to Mlinek & Pierce [37], overhearing conversations at the reception desk was the main problem in the waiting room. Mlinek & Pierce suggested achieving a more audibly secure area by changing the structural design. Thus, the addition of background music or the use of physical barriers could be used to limit noise transmission and

				overhearing of conversations." Huisman p.5
E	Provide Adequate and Appropriate Light Exposure **G1.D**	Maximize Use of Natural Light **F1.D.1**	"Maximize Use of Natural Light throughout the Hospital." (Malone et al. 2007 p. 31)	"Access to daylight in HCF seems to have a significant impact on patients as well as on staff." (Huisman et al. 2012 p. 6)
				"Beauchemin & Hays [52,53] found that patients had shorter hospital stays when staying in sunny rooms compared with dimly lit rooms. Patients treated in sunny rooms had an average stay of 16.6 days compared with 19.5 days for those in dim rooms." (Huisman et al. 2012 p. 6)

F		Orientation of Patient Rooms to Morning Sun **F1.D.2**	"Orient the Greatest Number of Inpatient Rooms to Receive Early Morning Sun Exposure." (Malone et al. 2007 p. 31)	"Lewy et al. [51] compared both morning and evening light treatments of patients who were experiencing winter depression and established that morning light was at least twice as effective as evening light in the treatment of seasonal affective disorder." (Huisman et al. 2012 p. 6)
G		Provide High Lighting Levels for Complex Visual Tasks **F1.D.3**	"Key complex areas requiring bright light include medication preparation and procedure areas." (Malone et al. 2007 p. 31)	"In addition, natural and electrical light is also an important aspect to consider for avoiding errors [18]." (Huisman et al. 2012 p. 3)
H		Provide Windows in Staff Breakrooms **F1.D.4**	"Although more research is needed, it appears that maximizing access to natural light reduces staff stress and improves both	"Access to daylight in HCF seems to have a significant impact on patients as well as on staff." (Huisman et al. 2012 p. 6)

			circadian rhythms and staff satisfaction." (Malone et al. 2007 p. 31)	
A	Improve Patient Sleep and Rest **G1.E**	Single Bed Rooms **F1.E.1**	"Single-bed rooms are the most effective EBD response to reduce noise, setting the stage for better rest and sleep." (Malone et al. 2007 p. 31)	"The majority of patients prefer single rooms because of greater privacy, reduced noise, reduced embarrassment, improved quality of sleep, opportunity for family members to stay, and avoidance of upsetting other patients (Douglas, Steele, Todd, & Douglas, 2002; Kirk, 2002; Pease & Finlay, 2002; Reed & Feeley, 1973)." (Chaundhury et al. 2004 p. 8)
				"Single-occupancy rooms increase patients' privacy, which provides patients with control over personal information, an opportunity to rest,

				and an opportunity to discuss their needs with family members and friends.(Bobrow & Thomas, 1994; Burden, 1998; Morgan & Stewart, 1999).” (Chaundhury et al. 2004 p. 8)
I		Reduce or Eliminate Loud Noise Sources **F1.E.2**	“Plan for noiseless paging and alarms. No overhead announcing systems should be routinely planned or used. Educate staff, patients and visitors about noise and arranging care to maximize sleep. Achieve World Health Organization (WHO)-recommended noise decibel levels.” (Malone et al. 2007 p. 33)	“One of the main repercussions of a high noise level is the effect on patients’ quality and quantity of sleep [62] . Quality of sleep in a respiratory intensive care unit (ICU) was poor for all patients; no complete sleep cycles were experienced. Sources of disturbance were mainly therapeutic procedures, staff talking, and environmental noises.” (Huisman et al. 2012 p. 7)

				"In a survey of neurosurgery ICU patients, among those who reported sleep disturbance, 58% considered environmental noise a frequent disturbing factor (Ugras & Oztekin, 2007)." (Ulrich et al. 2008 p. 27)
A	Reduce Airborne Transmitted Infections **G2.A**	Single Bed Rooms **F2.A.1**	"Single-patient rooms reduce the proximity of contagious patients to non-infected patients." (Malone et al. 2007 p. 36)	"Infected patients or patients highly susceptible to infections need to be isolated in private rooms with proper ventilation systems and barrier protections in order to stop infection from spreading or to reduce the possibility of development of new infections. (Anderson et al., 1985; Muto et al. 2000; O'Connell & Humphreys, 2000; Sehulster & Chinn,

				2003).” (Chaundhury et al. 2004 p. 7)
				“Ongoing research is demonstrating that nosocomial infection rates are low in private rooms with proper design and ventilation systems (The Center for Health Design, 2003).” (Chaundhury et al. 2004 p. 7)
				“McManus et al. [31] compared common infections (Pseudomonas aeruginosa) and pneumonia (Pseudomonus bacteremia) in burn patients in single-bed

				rooms and in open wards. The study showed that single-bed rooms and good air quality substantially reduce infection incidence and reduce mortality." (Huisman et al. 2012 p. 5)
J		HVAC maintenance **F2.A.2**	"Ensure that HVAC Systems are Well-Maintained and Operated." (Malone et al. 2007 p. 36)	"Indoor quality. This subtopic encompasses elements such as ventilation, dust, smell, relative humidity, and air quality. A number of studies have focused on healing environments and ventilation. Smedbold et al. [32] , Arlet et al. [33] , and Panagopoulou et al. [34] described the indoor quality related to the content of indoor air that could affect the health and comfort of building occupants and to the

				building materials, ventilation, and activities conducted in HCF." (Huisman et al. 2012 p. 5)
				"McManus et al. [31] compared common infections (Pseudomonas aeruginosa) and pneumonia (Pseudomonus bacteremia) in burn patients in single-bed rooms and in open wards. The study showed that single-bed rooms and good air quality substantially reduce infection incidence and reduce mortality." (Huisman et al. 2012 p. 5)
K		Construction and Renovation Control Measures **F2.A.3**	"Ensure that effective control measures are used during construction and renovation. Such measures include: using portable HEPA	"Indoor quality. This subtopic encompasses elements such as ventilation, dust, smell, relative humidity, and air quality. A number of

			filters, installing barriers between the patient-care and construction areas, using negative pressure in construction/renovation areas relative to patient-care spaces, and sealing patient windows." (Malone et al. 2007 p. 36)	studies have focused on healing environments and ventilation. Smedbold et al. [32] , Arlet et al. [33] , and Panagopoulou et al. [34] described the indoor quality related to the content of indoor air that could affect the health and comfort of building occupants and to the building materials, ventilation, and activities conducted in HCF." (Huisman et al. 2012 p. 5)
				"The implementation of infection control measures during construction and renovation activities in a hospital significantly reduces the incidence of invasive aspergillosis." (Kim et al. 2014 p. 1)

				"Environmental dispersal of microorganisms during construction, resulting in nosocomial infections, has been described previously, and select examples are provided in Table I as a reminder that there is a solid, scientific basis for these concerns." (Bartley 2000 p. 1)
A	Reduce Infection Spread Through Contact **G2.B**	Single Bed Rooms **F2.B.1**	"Single patient rooms are easier to decontaminate than multi-bed rooms." (Malone et al. 2007 p. 38)	"Infections in burn patients ↓ HCV transmission between patients ↓ Transmission of hospital-acquired diarrhea↓." (Chaundhury et al. 2004 p. 9)

<u>L</u>		Sink and Hand Washing Stations **<u>F2.B.2</u>**	"Sink and Hand-washing Stations. Both AIA and DoD criteria specify rooms in which sinks and hand-washing stations should be located. What is not clear is where the ideal location for both to improve staff compliance." (Malone et al. 2007 p. 38)	"It is common knowledge that the chances of infection by bacteria on hands are lower if hands are washed more often. Larson et al. [30] discussed the effect of the use of an automated sink on the practice of hand washing and attitudes towards hygiene in high-risk units in two hospitals. Hands were washed better or more thoroughly but significantly less often using the automated sink." (Huisman et al. 2012 p. 5)
	Prevent Waterborne Infections **<u>G2.C</u>**	Maintain and Inspect Water Supply System **<u>F2.C.1</u>**	"To minimize stagnation and back flow and for temperature control, provide regular maintenance and inspection—or consider using a looped water system to minimize maintenance	"Water pressure "shock" may send a surge of debris when pressure loss is restored after a rupture. [78] Massive amounts of loosened scale may be released when domestic valves are returned to service

			requirements.” (Malone et al. 2007 p. 39)	after being off during construction or disruptions. If decontamination is necessary, systematic flushing of the water system assists in removing debris shaken loose by drilling or disruptions.” (Bartley 2000 p. 8)
				“plumbing disruptions or lack of preventive maintenance pose risks of contamination as well.” (Bartley 2000 p. 10)
A	Reduce Medication Errors **G2.D**	Single Bed Rooms **F2.D.1**	Not referenced in baseline source	“Universal rooms or acuity adaptable rooms are a current trend in design, especially in hospitals that are promoting patient-centered care and family participation in the patient’s healing program. These rooms are all private rooms. Results from a limited

				number of studies have indicated that medication errors, patient falls and procedural problems may be reduced in acuity adaptable rooms (Bobrow & Thomas, 2000; Gallant & Lanning, 2001; Hill-Rom, 2002; Spear, 1997). However, these results may be specific to the particular institutions studied." (Chaundhury et al. 2004 p. 8)
				"medication errors are reduced in single-occupancy rooms, resulting in reduced costs (Anonymous, 2000; Bilchik, 2002; Bobrow & Thomas, 2000; Hill-Rom, 2002; Morrissey, 1994)." (Chaundhury et al. 2004 p. 7)

N		Adequate Lighting Levels **F2.D.2**	"Assess the Adequacy of Lighting Levels in Staff Work Areas – especially the lighting in (the pharmacy and nursing) areas that support medication preparation, dispensing and administration. The need for light for visual task performance increases with age." (Malone et al. 2007 p. 40)	"Consequently, the rate of prescription dispensing errors was associated with the level of illumination." (Huisman et al. 2012 p. 5)
				"In addition, natural and electrical light is also an important aspect to consider for avoiding errors [18]." (Huisman et al. 2012 p. 3)
O		Provide Private Work Space **F2.D.2**	"Provide Private Space for Work to minimize interruptions and distractions." (Malone et al. 2007 p. 40)	"Crowded and poorly designed work spaces contribute to staff stress that increases the risk of medication errors." (Mahmood et al. 2011 p. 1)

<u>A</u>	Reduce Patient Falls **<u>G2.E</u>**	Single Bed Rooms **<u>F2.E.1</u>**	"Single-patient rooms invite the presence of more family, who can then assist with patient movement." (Malone et al. 2007 p. 41)	"Universal rooms or acuity adaptable rooms are a current trend in design, especially in hospitals that are promoting patient-centered care and family participation in the patient's healing program. These rooms are all private rooms. Results from a limited number of studies have indicated that medication errors, patient falls and procedural problems may be reduced in acuity adaptable rooms (Bobrow & Thomas, 2000; Gallant & Lanning, 2001; Hill-Rom, 2002; Spear, 1997). However, these results may be specific to the particular institutions studied."

				(Chaundhury et al. 2004 p. 8)
				"Most falls occur in patient rooms, among elderly patients, and when patients are alone or while attempting to go to the bathroom. (Hendrich et al., 1995; Langer, 1996; Pullen, Heikaus, & Fusgen, 1999). However, if provision is made for family members in patient rooms, falls may be reduced due to assistance from family. It is easier to accommodate family in private rooms than in semi-private rooms (Ulrich, 2003)." (Chaundhury et al. 2004 p. 7)
P		Decentralized Nursing Support Using a Pod Concept **F2.E.2**	"Provide charting space, clean materials and linen, soiled collection and automated medication dispensing close to	"a few of these environmental issues, for example, walking distance from nurses station to patient rooms, patient

			patient rooms, using a pod configuration to provide a cockpit-like approach. The recommended ratio of beds per pod is 2 beds in the ICU/IMCU units and 4-8 beds in acute medical/ surgical, pediatric and obstetric units. Most of the needed supplies and medications are available just outside the patient door and the nurse can chart or coordinate care without returning to a central nurses' station. The result is that nursing staff are more readily available to help move patients because they have less reason to leave the patient care area." (Malone et al. 2007 p. 42)	surveillance opportunity/lack of visibility, have been associated with staff effectiveness in the event of patient falls (Feldman & Chaudhury, 2008; Gulwadi & Calkins, 2008)." (Mahmood et al. 2011 p. 1)
				"There were no indications that either

				centralized or decentralized nursing station designs resulted in superior visibility." (Zborowsky et al. 2010 p. 1)
A	Reduce Noise Stress and Speech Intelligibility **G2.F**	Single Bed Rooms **F2.F.1**	"Most noise originates with the presence of a roommate." (Malone et al. 2007 p. 42)	"The majority of patients prefer single rooms because of greater privacy, reduced noise, reduced embarrassment, improved quality of sleep, opportunity for family members to stay, and avoidance of upsetting other patients (Douglas, Steele, Todd, & Douglas, 2002; Kirk, 2002; Pease & Finlay, 2002; Reed & Feeley, 1973)." (Chaundhury et al. 2004 p. 8)
				"Excess noise can lead to increased anxiety and pain perception, loss of sleep, and prolonged

				convalescence (Baker, Garvin, Kennedy, & Polivka, 1993; Cys, 1999; Hilton, 1985). Single rooms often afford more privacy, reduction of noise and less crowding. Control is greater in private rooms, as patients can adjust settings according to their needs (Shumaker & Reizensten, 1982).” (Chaundhury et al. 2004 p. 8)
Q		Remove Loud Noise Sources **F2.F.2**	“Typical offenders include overhead paging and personal pagers.” (Malone et al. 2007 p. 43)	“Blomkvist et al. [57] indicated that the improved acoustics had affected the psychosocial environment. The study showed that improved acoustic conditions in the healthcare environment reduce risks of conflicts and errors.” (Huisman et al. 2012 p. 7)

R		Locate Noisy Equipment Away from Patient Rooms **F2.F.3**	"The most notorious equipment offender is the ice machine." (Malone et al. 2007 p. 43)	"Table 1 Nursing care for patient±environmental incompatibility due to CCU noise." (Topf 2000 p. 6)
S		Patient Rooms Have Walls Extending to Ceiling **F2.F.4**	"Many patient care areas include multi-patient spaces, which are separated by a curtain –very common in the Primary Care Clinic Treatment rooms and Post Anesthesia Care Units. For all of the reasons described above, this creates a noisy environment, which may significantly contribute to poor patient outcomes. The walls need to extend all the way up to the structure above in order to fully block the noise between patient rooms and public spaces (e.g., hallways)." (Malone et al. 2007 p. 43)	"Private patient rooms with insulated walls and a sliding glass door facing the nurses' desk." (Topf 2000 p. 6)

<u>A</u>	Decrease Patient and Family Stress **<u>G3.A</u>**	Single Bed Patient Rooms **<u>F3.A.1</u>**	"Single-patient rooms facilitate greater individualization of the patient's environment." (Malone et al. 2007 p. 43)	"Sources of stress for patients are: perceived lack of control, lack of privacy, noise, and crowding (Shumaker & Pequegnat, 1989). Excess noise can lead to increased anxiety and pain perception, loss of sleep, and prolonged convalescence (Baker, Garvin, Kennedy, & Polivka, 1993; Cys, 1999; Hilton, 1985). Single rooms often afford more privacy, reduction of noise and less crowding. Control is greater in private rooms, as patients can adjust settings according to their needs (Shumaker & Reizensten, 1982)." (Chaundhury et al. 2004 p. 8)
				"Music can also help reduce patients' stress. Patients can listen to music in

				private rooms without disturbing their roommates (Cabrera & Lee, 2000)." (Chaundhury et al. 2004 p. 8)
T		Provide Secure Access to Nature **F3.A.2**	"Landscape designers employ many features that can provide patient access to nature, including healing gardens, planted atrium spaces, courtyards, and terrace gardens, to name a few." (Malone et al. 2007 p. 45)	"Keep et al. [43] confirmed previous studies showing that most ITU patients are conscious of their surroundings and retain some long-term memory of their stay. Patients who received care in a windowless ITU, in contrast to those in an ITU with windows, had a less accurate memory of the length of their stay and were less well orientated regarding time during their stay. The incidence of hallucinations and delusions reported by patients was more than twice as high in the windowless unit."

				(Huisman et al. 2012 p. 6)
				"Regarding the effects of the view from the window of the patient room, Ulrich [10] demonstrated that patients with a view of nature (trees) had shorter postoperative stays, took fewer potent pain drugs, and received more favourable comments about their condition in nurses' notes than did matched patients in similar rooms with a window facing a brick building wall." (Huisman et al. 2012 p. 6)
U		Provide Multiple Spiritual Spaces and Haven Areas **F3.A.3**	"Current DoD criteria include a chapel and consultation rooms, which—combined with good landscape design features, such as healing gardens—can	"The principle uses of the gardens were to relax, eat, talk, pass through, stroll, and wait; just over half mentioned some kind of therapeutic activity,

			provide spiritual and haven areas." (Malone et al. 2007 p. 45)	such as praying, meditating or taking a nap." (Marcus 2018 p. 3)
<u>V</u>	Decrease Back Pain and Work Related Injuries **<u>G4.A</u>**	Install Ceiling Mounted Patient Lifts **<u>F4.A.1</u>**	"Ceiling-Mounted Lifts should be provided in those rooms where patients are likely to require lifting or movement-such as ICU/ IMCU rooms, Operation Rooms, Emergency Department Trauma Rooms, and some portion of medical/ surgical and pediatric rooms- as part of a comprehensive Zero-Lift program." (Malone et al. 2007 p. 47)	"Caboor et al. [81] intro- duced an adjustable bed height during standard nursing tasks to enhance the quality of spinal motion, and Dariaseh et al. [82] examined musculoskeletal outcomes in multiple body regions and effects on nurses' work. The consequences of working conditions are thus known to some extent. However, the type of interventions to prevent these consequences appears to need exploration." (Huisman et al. 2012 p. 8)

<u>W</u>	Reduce Staff Fatigue **<u>G4.B</u>**	Decentralize Staff Support Spaces **<u>F4.B.1</u>**	"Locating staff support spaces such as supplies and charting space next to or in patient rooms should reduce staff walking, providing more patient care time and greater staff satisfaction. However, the space should be designed with privacy to minimize distractions that can result in errors." (Malone et al. 2007 p. 49)	"walking distances significantly decreased in the new multi-hub units." (Hua et al. 2012 p. 2)
<u>X</u>		Provide Windows in Staff Break Rooms **<u>F4.B.2</u>**	"As is true with patients, access to natural light may help staff with circadian rhythm adjustment, thereby improving staff fatigue. Natural light costs nothing once the window is provided." (Malone et al. 2007 p. 49)	"Studies on medical staff indicate an improved perceived quality of the work environment in association with windows, sunlight, or views. Nurses exposed to exterior nature views have reported improved perceived alertness and reduced acute stress, whereas nurses with no view or non-

				nature views have reported deteriorated perceived alertness and increased acute stress (Pati, Harvey Jr., & Barach, 2008)" (Zadeh et al. 2014 p. 3)
Y	Increase Team Effectiveness **G4.C**	Providing Different and Flexible types of Spaces for Interactive Teamwork **F4.C.1**	"Current inpatient DoD Space Criteria provide space for a workroom, which is intended for use by the whole team. Likewise, conference rooms, nurse's stations, consultation rooms, staff lounges, staff support space in a pod configuration and other generic staff spaces throughout a hospital are intended to support spontaneous team interaction." (Malone et al. 2007 p. 50)	"Each department has some department-specific space, access to spaces shared with one other department ('sub-share'), and access to spaces shared with many other departments ('main share'). This approach provides a 'home base' for departments, whilst also providing the ability to connect with their colleagues and across departments. Resources are well

				utilized and redundant space is avoided. Different tasks and activities can happen where it makes most sense. The medical cluster remains connected, with opportunities to work together, but still within their team bases." (Cawood et al. 2016 p. 844)
Z		Optimize unit Adjacencies with Care Centers **F4.C.2**	"Collocate teams who each play a vital role in caring for unique populations to create a patient-focused approach that should also improve staff communication and collaboration. This planning approach was used to program the New Fort Belvoir Community Hospital and WRNMMC	"Nurse communication did not change significantly when comparing the multi-hub versus the control traditional unit. Exception: a decrease occurred in overall information exchange between doctors and nurses in the multi-hub configurations (but specifically

			projects." (Malone et al. 2007 p. 50)	looking at pre- and post- figures for the moved units, communication experienced a rise, especially at the nursing stations), and also a significant reduction in social communication occurred among nurses." (Hua et al. 2012 p. 2)
AA	Eliminate Noisy and Chaotic Environments **G4.D**	Adequate Space for Quiet, Private Work **F4.D.1**	"To minimize distractions and interruptions, provide a quiet space to work. DoD Space Criteria includes a number of rooms that can provide the desired environment if designed appropriately: workrooms, consultation rooms, decentralized sub-nursing stations, and conference rooms." (Malone et al. 2007 p. 51)	"From the perspective of staff, noise levels were sufficiently high to interfere with their work and to affect patient comfort, and recovery." (Huisman et al. 2012 p. 8)

BB	Reduce Room Transfers **G5.A**	Use of Acuity Adaptable Rooms **F5.A.1**	"For the most part, this feature is only appropriate for medical centers that care for a large number of patients with high acuity." (Malone et al. 2007 p. 53)	"intra-hospital spread of infection may result from patients being transferred to more than one ICU or more than one floor during their hospitalization." (Chaundhury et al. 2004 p. 7)
				"reduction in transfers is particularly applicable with acuity-adaptable rooms (Hill-Rom, 2002; Ulrich, 2003)."(Chaundhury et al. 2004 p. 6)
CC	Facilitate Care Coordination and Patient Services **G5.B**	Optimize Unit Adjacencies with Care Centers **F5.B.1**	"Collocating teams who each play a vital role in caring for unique and vulnerable populations creates a patient-focused approach that should also improve staff communication and collaboration. This planning approach was used to program the New Fort Belvoir	"Clinical outcomes seemed not to change significantly." (Hua et al. 2012 p. 2)

			Community Hospital and WRNMMC projects." (Malone et al. 2007 p. 55)	
DD		Provide Different and Flexible Spaces for Interactive Teamwork **F5.B.2**	"Multiple, flexible spaces allow the care team to interact spontaneously as well as providing space for regular communications." (Malone et al. 2007 p. 55)	"Each department has some department-specific space, access to spaces shared with one other department ('sub-share'), and access to spaces shared with many other departments ('main share'). This approach provides a 'home base' for departments, whilst also providing the ability to connect with their colleagues and across departments. Resources are well utilized and redundant space is avoided. Different tasks and

				activities can happen where it makes most sense. The medical cluster remains connected, with opportunities to work together, but still within their team bases." (Cawood et al. 2016 p. 844)

Appendix B

EBD		**IBS**	
EBD Component	**EBD Component Description**	**IBS Benefit**	**IBS Validation Example**
Principle	Design for Maximum Standardization, Future Flexibility and Growth	Flexibility	"It is believed by many that interstitial space generally provides the greatest flexibility in the provision of services since it allows the services to be introduced at varied and changeable locations...the ultimate solution in providing flexibility." (Gibson 1990 p. 333)
		Standardization	"It should be noted that the consistency derived from the application of a universal interstitial space results in economy: all parts of the building complex are based on a single system of construction employing as much standardization as possible, in compliance sometimes with imposed contract procedures and programs for the project." (Alvarez 1989 p. 230)

Key Contributor	Adaptability	Adaptability	“Adaptability scored 5 out of 5 for the combination of modularity and access to utility distribution in the interstitial space greatly enhances the accommodation of change.” (Shahid 1993 p. 29)
	Expandability	Expandability	"Interstitial zones to accommodate ample systems distribution, expansion, replacement and maintenance." (Bradley et al. 2015 p. 23)
Feature or Response	Noise Reduction i.e. (Reduce Eliminate/ Loud Noise Sources, Locate Noisy Equipment Away From Patient Rooms, Remove Loud Noise Sources, Adequate Space for Quiet, Private Work)	Noise Control	"The uppermost interstitial space acts as a buffer for noise, vibration and construction." P.49 "Superior (acoustic benefit) due to added benefit of interstitial deck as a sound barrier, and due to larger and quieter HVAC ducts." (Shahid 1993 p. 60)
Key Contributor	Disruption Control	Disruption Control	"No areas adjacent, above or below the ICU were disrupted through systems down time, construction noise or other such circumstances. It can therefore be concluded that the impact of interstitial space on renovations, with respect to operational disruptions, is a positive one." (Mackenzie 1992 p. 6)

Feature or Response	Increase Views of Nature & Access to Daylight i.e. (Provide Windows in Staff Breakrooms, Orientation of Patient Rooms to Morning Sun, Maximize Use of Natural Light)	Access to Nature	"By locating major mechanical components on a central mechanical floor or within interstitial spaces, greater opportunity for connections to nature could occur. Collocating mechanical equipment in a mechanical floor will decrease the impact of visual barriers throughout the hospital." (Thompson 2009 p. 102)
		Increase Views/ Daylight	"This approach diminishes the impact of vertical visual barriers on occupied floors from mechanical, electrical, or HVAC chases. The resulting decrease in vertical chases and solid walls to accommodate mechanical distribution systems will increase the opportunities for views to nature and access to day light in interior spaces." (Thompson 2009 p. 75)
Feature or Response	HVAC Maintenance	Maintenance	"Maintenance is simplified: within the service floors engineers can work at any time on routine inspection and planned maintenance, modification or replacement of the services, with a minimum of disruption or interference from the associated

			noise and dirt." (Alvarez 1989 p. 222)
Feature or Response	Construction and Renovation Control Measures	Construction Control Measures	"The uppermost interstitial space acts as a buffer for noise, vibration and construction." (Shahid 1993 p. 49)
Feature or Response	Maintain and Inspect the Water Supply System	Maintenance	"It (IBS) can also promote greater ease of maintenance of services since they are generally more easily accessible." (Gibson 1990 p. 333)
Goals	Infection Control	Infection Control	"Since hospital renovation projects are part of the facility life cycle plan, and because zones of separation are required during the renovation (minor sustainment construction, modernization, or repair works), it appears that a type of interstitial space will be temporarily placed in different parts of the hospital at different times in the life cycle. Rather than many temporary interstitial spaces over time, a complete IBS design may offer in both cost savings and reduced risk of contamination due to problems such as have been discussed in the literature." (Leveridge 2013 p. 8)