ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL

BIM-BASED FACILITIES MANAGEMENT: A CONCEPTUAL FRAMEWORK FOR BIM IMPLEMENTATION OF THE FM INDUSTRY

Ph.D. THESIS

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İSTANBUL TEKNİK ÜNİVERSİTESİ ★ LİSANSÜSTÜ EĞİTİM ENSTİTÜSÜ

BIM-TABANLI TESİS YÖNETİMİ: TESİS YÖNETİMİ ENDÜSTRİSİNDE BIM UYGULAMA İÇİN KAVRAMSAL BİR ÇERÇEVE

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Ecem TEZEL, a Ph.D. student of ITU Graduate School student ID 502172403, successfully defended the thesis entitled "BIM-BASED FACILITIES MANAGEMENT: A CONCEPTUAL FRAMEWORK FOR BIM IMPLEMENTATION OF THE FM INDUSTRY", which she prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

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FOREWORD

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June 2023 Ecem TEZEL
(Architect, M.Sc.)

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ABBREVIATIONS

AEC : Architecture, Engineering and Construction
AI : Artificial Intelligence
AIM : Asset Information Model
AIR : Asset Information Requirements
AR : Augmented Reality
BAS : Building Automation System
BEP : BIM Execution Plan
BIFM : British Institute of Facilities Management
BIM : Building Information Modelling
CAD : Computer-Aided Design
CAFM : Computer-Aided Facilities Management
CDE : Common Data Environment
CIFM : Computer-Integrated Facilities Management
CM : Construction Management
CMMS : Computerized Maintenance Management System
COBie : Construction Operations Building Information Exchange
DFM : Danish Facility Management
EAM : Enterprise Asset Management
EMS : Energy Management System
EIR : Exchange Information Requirements
ERP : Enterprise Resource Planning
FGS : Focus Group Study
FM : Facilities Management
FMA : Facility Management Association Australia
GEFMA : German Facility Management Association
GIS : Geographic Information System
HVAC : Heating, Ventilating, and Air Conditioning
ICT : Information and Communication Technology
IFC : Industry Foundation Classes
IFMA : International Facility Management Association
IoT : Internet of Things
ISO : International Organization for Standards
IT : Information Technology
IWFM : Institute of Workplace and Facilities Management
IWMS : Integrated Workplace Management System
JFMA : Japan Facility Management Association
KPI : Key Performance Indicator
MEFMA : Middle East Facility Management Association
MEP : Mechanical, Electrical, Plumbing
MIDP : Master Information Delivery Plan
NIBS : National Institute of Building Sciences
O&M : Operation and Maintenance

OIR : Organizational Information Requirements
PDF : Portable Document Format
PIM : Project Information Model
PIR : Project Information Requirements
RFID : Radio Frequency Identification
RIBA : Royal Institute of British Architects
ROI : Return on Investment
SAFMA : South African Facilities Management Association
TIDP : Task Information Delivery Plan
TRFMA : Turkish Facility Management Association
WoS : Web of Science
VR : Virtual Reality
2D : Two-dimensional
3D : Three-dimensional

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BIM-BASED FACILITIES MANAGEMENT: A CONCEPTUAL FRAMEWORK FOR BIM IMPLEMENTATION OF THE FM INDUSTRY

SUMMARY

The Building Information Modelling (BIM) concept, which emerged in the early 2000s, contributes to the architecture, engineering and construction (AEC) industry by enhancing communication and coordination between stakeholders, detecting errors in advance to minimize rework, shortening project duration, reducing project costs and increasing quality. BIM, which is majorly used in the design and construction phases, has the ability to store a wide variety of information produced at different stages of the building life cycle in a digital data repository. Due to its data storage capability, many researchers and experts argue that the main benefit of BIM will emerge in the usage phase, which is the longest and most information-intensive phase by nature.

Buildings require several facilities management (FM) services to maintain their functionality, comfort, safety and efficiency during the operational phase, which starts right after the completion of the construction. BIM-based processes and applications that have caused a great transformation in the AEC industry, are undoubtedly changing the FM industry as well. Traditionally, building information is compiled as hard copy or electronic files that are, most of the time, incomplete, inaccurate, outdated or unavailable for further use. BIM can minimise these data-related problems and support facilities managers in decision-making processes through complete, reliable and available data. Therefore, BIM-based FM can be considered an information management methodology for the operational phase of the buildings.

Although BIM has an increasing adoption rate, especially in the design and construction phases, it is unexpectedly low utilised in the operational phase. Researches indicate that there are several factors inhibiting the BIM-FM integration. Recently, numerous international researchers and industry experts have been conducting various studies focusing on BIM-based FM. In addition to academic publications, the International Organization for Standardization (ISO) has published the ISO 19650 series of standards, which define the processes to identify and manage BIM-based information and exchange information among participants throughout the

building lifecycle. Although the ISO 19650 series provide a holistic roadmap for BIM-based information management, it encourages countries to develop and implement national procedures reflecting particular industry conditions.

Turkey has its own unique case in terms of the speed of BIM adaptation and implementation. BIM has been first mandated for the construction works of transportation projects in 2021. However, prior to this, companies that follow international trends and take initiative to implement BIM have enabled the Turkish AEC industry to achieve BIM Level 2 competence, parallel to other BIM-implemented countries. BIM Level 3, which refers to the highest level attainable in terms of BIM maturity, represents the state of full collaboration between teams on a common data medium. The rare examples for BIM Level 3 in Turkey consist of a few subway and airport projects, still Level 2 competence is more frequently observed. Industry reports and academic studies have revealed that the BIM-based data transfer to the operational phase is very limited. Yet, in the light of this information, it is expected to see the influence of BIM-based transformation experienced in the Turkish AEC industry on the FM sector practices. In this context, it is seen that there is a need for a holistic study to guide the FM sector during the BIM transition and implementation process.

The aim of the doctoral thesis entitled "BIM-BASED FACILITIES MANAGEMENT: A CONCEPTUAL FRAMEWORK FOR BIM IMPLEMENTATION OF THE FM INDUSTRY", is to propose a conceptual framework that will guide the BIM adaptation process and BIM-based applications of the managers of the FM service provider companies and the building owners and/or tenants. In the Introduction section, which is the first section of the thesis, first of all, the subject, purpose, scope and method of the thesis study are explained. The second part of the thesis includes the existing literature on the subject field. This chapter firstly introduces various definitions of the FM concept, then examines the evolution of the FM industry on a global scale, and briefly introduces frequently used FM technologies and software. Then, using the science mapping method, it identifies the articles published in international peer-reviewed journals in the fields of BIM and FM, categorizes them according to the journal in which they were published, authors who prepared the publication, and keywords. In addition to identifying influential scientific journals, researchers and keywords in BIM and FM, this classification identifies areas that have not yet been adequately researched and reveals potential future research areas in BIM-

FM. After examining for what purposes BIM can be used in FM, what are the challenges to BIM transition of the FM industry, and what are the required BIM information for various FM services, this thesis study introduces the 19650 series of standards developed by ISO for BIM-based information management.

The third part of the thesis study includes field studies conducted to determine BIM awareness and BIM use levels within the Turkish FM industry. Firstly, a quantitative research was conducted to measure the BIM awareness and usage levels of industry professionals, to identify the information requirements necessary for making BIM-based FM, and to identify the barriers for the sector to provide effective and efficient service. An online survey invitation was sent to the leading companies of the sector to participate in the survey. Then, semi-structured interviews were conducted with individuals running FM services in various building types in Turkey to discuss the factors that led to the limited use of BIM within the sector. The research conducted on the Turkish FM sector not only revealed the problems in the current business processes of the sector, but also showed that the sector has various expectations for BIM adaptation. In this context, in the fourth part of this thesis, a conceptual framework proposal is introduced that aims to facilitate the transition of FM companies to the BIM-based working process. The framework reflects on the ISO 19650 family of standards and proposes a BIM implementation roadmap considering the unique conditions of the Turkish FM industry. This is, to the best of the author's knowledge, the first attempt to develop a holistic guideline to implement BIM procedures and applications in the local FM sector, which is dominated by traditional business models, has old building stock and is developing its technological infrastructure. The two main principles advocated by the proposed conceptual framework are; the involvement of the FM team in the projects as early as possible and the BIM transition process to be advanced with a collaborative systematic with the building owner and/or tenant.

The focus group study, which was carried out with the participation of industry professionals, in order to measure the applicability and validity of the proposed conceptual framework by the FM sector, takes place in the fifth part of the thesis. Finally, in the conclusion section, which is the sixth chapter of the thesis, the studies carried out within the scope of the thesis are summarised, the conceptual framework proposed for BIM-based FM is demonstrated and the contributions of the proposed framework to the BIM transition process of the FM sector are disclosed.

BIM-TABANLI TESİS YÖNETİMİ: TESİS YÖNETİMİ ENDÜSTRİSİNDE BIM UYGULAMA İÇİN KAVRAMSAL BİR ÇERÇEVE

ÖZET

Yapı Bilgi Modellemesi (Building Information Modelling - BIM), proje yaşam döngüsü boyunca iletişim ve koordinasyonu kolaylaştırıp verimliliği arttıran teknoloji, süreç ve kurallar bütünü olarak tanımlanır. 2000'li yılların başında ortaya çıkan BIM kavramının mimarlık, mühendislik ve yapım sektörüne yaptığı temel katkılar; paydaşlar arası iletişim ve birlikte çalışabilirliği arttırmak, hataları önceden tespit etmek ve bu hatalara bağlı yeniden yapım ihtiyacını azaltmak, proje süresini kısaltmak, proje maliyetlerini düşürmek ve kaliteyi arttırmak olarak sıralanabilir. Ağırlıklı olarak tasarım ve yapım evrelerinde kullanılan BIM, bina yaşam döngüsünün farklı aşamalarında üretilen çok çeşitli bilgilerin bir arada tutulduğu dijital bir veri deposu özelliğine sahiptir. Bu özelliğinden dolayı pek çok araştırmacı ve uzman, BIM'in esas faydasının, bina yaşam döngüsünün, doğası gereği en uzun ve en bilgi-yoğun evresi olan kullanım evresinde ortaya çıkacağını savunmaktadır.

Yapımın tamamlanmasının ardından başlayan kullanım evresi boyunca, binaların işlevselliğinin, konforunun, güvenliğinin ve verimliliğinin sağlanması ve sürdürülmesi için çeşitli tesis yönetimi (facilities management - FM) hizmetlerine ihtiyaç duyulur. FM kavramı, bir organizasyonun temel hedeflerine ulaşmasını sağlayacak koşulları yaratmak için, binaları ve altyapısını işletmek, sürdürmek, iyileştirmek ve uyarlamak için gerekli olan entegre faaliyetleri içeren bir yaklaşımı ifade etmektedir. Günümüzde FM hizmetleri; bakım ve onarımdan temizlik ve atık yönetimine, alan planlama ve yönetiminden enerji yönetimine, acil durum planlama ve yönetiminden mimari ve mühendislik projeleri yönetimine, personel hizmetlerinden stratejik planlamaya, yönetim ve ofis hizmetlerinden gayrimenkul ve varlık yönetimine, çevre ve peyzaj düzenlemesinden catering hizmetlerine kadar geniş bir yelpazeye yayılmaktadır.

Mimarlık, mühendislik ve yapım sektöründe büyük bir dönüşüme neden olan BIM-tabanlı süreç ve uygulamalar, şüphesiz ki FM sektörünü de değiştirmektedir. FM bakış açısıyla BIM, dijital varlık oluşturma, yapıyı ve yapıya ait elemanları 3 boyutlu olarak görselleştirerek gerçek konumlarına yerleştirme, bakım-onarım takibi ve kontrolü, alan planlama ve yönetimi, bina performans takibi, FM personeline yönelik eğitim verme gibi amaçlarla kullanılabilen bir platform olarak görülmektedir. BIM-tabanlı FM, geleneksel olarak basılı veya elektronik kopyalar halinde derlenen bilginin tamlığı, doğruluğu, güncelliği ve erişilebilirliği ile ilgili sorunları en aza indiren ve FM'in karar verme süreçlerini veri ve bilgiye dayalı olarak yürütmesine destek olan bir bilgi yönetimi metodolojisi olarak ele alınabilir. BIM, özellikle tasarım ve yapım evrelerinde artan bir benimsenme oranına sahip olsa da, işletme evresinde şaşırtıcı derecede az kullanılmaktadır. Araştırmalar, BIM-FM entegrasyonunu engelleyen çeşitli faktörler olduğuna işaret etmektedir. FM amacıyla BIM kullanımının düşük olmasının temel nedenleri: BIM'in FM alanında kullanılabileceğine dair sektör farkındalığının düşük olması, BIM bilgi gereksinimlerini tanımlamanın zor olması, BIM-FM entegrasyonuna yönelik yönetmelik, standartlar ve prosedürlerin eksikliği, FM hizmetlerinin parçalı ve multidisipliner yapısı, farklı FM yazılımları arasındaki birlikte çalışabilirlik (interoperability) sorunları ve BIM modelinin kim tarafından, nasıl, ne zaman oluşturulacağı ve güncelleneceğinin belirsiz olması olarak özetlenebilir. Son yıllarda uluslararası pek çok araştırmacı ve endüstri paydaşı, BIM-tabanlı FM konusuna odaklanan çeşitli çalışmalar yürütmektedir. Akademik yayınlara ek olarak, Uluslararası Standardizasyon Teşkilatı (ISO), bina yaşam döngüsü boyunca BIM-tabanlı enformasyon gereksinimlerini belirlemek, yönetmek ve katılımcılar arasında enformasyon değişimini gerçekleştirmek için gerekli yönetimsel süreçleri tanımladığı ISO 19650 standart serisini geliştirip yayınlamıştır. ISO 19650 serisi, BIM-tabanlı enformasyon yönetimi için bütüncül bir yol haritası sunmasına rağmen, ülkelerin sektör koşullarına bağlı olarak ek prosedürler geliştirip uygulamaları konusunda teşvik etmektedir.

Mimarlık, mühendislik ve yapım sektörünün dünyanın farklı ülkelerinde farklı karakteristiklere sahip olması, bu sektörlerin BIM adaptasyon ve uygulama hızlarında da farklılıklar görülmesine yol açmaktadır. Türkiye'nin de kendine özgü bir karakteristiği vardır. Türkiye'de BIM kullanımı ilk olarak 2021 yılında ulaştırma projelerinin yapım işlerinde zorunlu kılınmıştır. Ancak bu tarihten önce, önde gelen mimarlık, mühendislik ve yapım firmaları BIM teknoloji ve süreçlerini, büyük ölçekli projelerde çoğunlukla tasarım ve yapım amaçlı kullanmaya başlamıştır. Uluslarası trendleri takip eden firmaların bu girişimleri, Türkiye mimarlık, mühendislik ve yapım sektörünün, BIM sistemine geçmiş diğer ülkeler ile benzer düzeyde BIM Seviye 2 yetkinliği kazanmasına olanak tanımıştır. BIM Seviye 2 yetkinliği, ekiplerin projelerini 3B modeller kullanarak olarak ürettiği, üretilen modellerin süre ve maliyet gibi yapıma bilgilerle zenginleştirildiği, ve ortak bir veri formatında diğer ekiplerle paylaşıldığı olgunluk düzeyini ifade eder. BIM olgunluğu anlamında ulaşılabilen en üst seviye olan BIM Seviye 3 ise ekipler arasında ortak veri ortamı üzerinde tam işbirliği durumunu idafe eder. Metro ve havalimanı gibi nitelikli bazı projelerde BIM Seviye 3 düzeyinde çalışmalar olmasına rağmen, Seviye 2 uygulama düzeyinin daha yaygın olduğu gözlemlenmektedir. BIM-tabanlı üretilen bilgilerin bina yaşam döngüsünün kullanım evresine aktarımının ise oldukça kısıtlı olduğu sektör raporları ve akademik çalışmalar tarafından ortaya konmuştur. Ancak bu bilgiler ışığında, Türkiye mimarlık, mühendislik ve yapım sektöründe yaşanan BIM-tabanlı dönüşümün, operasyonel evrede etkin rol alan FM sektör pratiklerine yansıması beklenmektedir. Bu kapsamda, FM sektörünün BIM adaptasyonu ve BIM uygulamalarına geçiş sürecine kaynaklık edecek, mevcut sektör parametrelerini dikkate alan kapsamlı bir çalışmaya ihtiyaç duyulduğu görülmektedir.

"BIM-TABANLI TESİS YÖNETİMİ: TESİS YÖNETİMİ ENDÜSTRİSİNDE BIM UYGULAMA İÇİN KAVRAMSAL BİR ÇERÇEVE" başlıklı doktora tezinin amacı, FM hizmetleri sunan firmaların yöneticileri ve hizmet alan bina sahipleri ve/veya kullanıcılarının BIM adaptasyon süreci ve BIM-tabanlı uygulamalarına rehberlik edecek bir kavramsal çerçeve önerisinde bulunmaktır. Tezin ilk bölümü olan giriş bölümünde, öncelikle tez çalışmasının konusu, amacı, kapsamı ve yöntemi yer almaktadır. Tezin ikinci bölümü, konu ile ilişkili mevcut literatüre yer vermektedir. Bu bölüm öncelikle FM kavramının çeşitli tanımlarını ortaya koyar, ardından FM endüstrisinin küresel ölçekte geçirdiği gelişim sürecini inceler ve endüstri profesyonelleri tarafından sıklıkla kullanılan FM teknoloji ve yazılımlarını kısaca tanıtır. Böylelikle, FM hizmetlerinin bina yaşam döngüsü içerisinde üstlendiği rolü kapsayıcı bir bakış açısıyla ele alır ve bu hizmetlerin etkin bir şekilde yürütülmesi için ilgili teknolojilerin kullanımının önemini vurgular. Daha sonra, bilim haritalama (science mapping) yöntemini kullanarak BIM ve FM alanlarında uluslararası hakemli dergilerde yayınlanmış olan makaleleri; yayınlandığı dergi, yayını hazırlayan yazarlar ve anahtar kelimelere göre sınıflandırır. Bu sınıflandırma, BIM ve FM alanında etki yaratan bilimsel dergileri, araştırmacıları ve anahtar kelimeleri tespit etmenin yanında, BIM-FM konusunda henüz yeterince araştırmamış olan alanları belirler ve BIM-FM konusunda ileriye dönük potansiyel araştırma alanlarını ortaya koyar. Bu bölümde yer alan bilim haritalama çalışması, uluslararası hakemli bir bilimsel kitap içinde kitap bölümü olarak yayınlanmıştır. Ardından, BIM'in FM'de hangi amaçlarla kullanılabileceği, FM endüstrisinin BIM geçiş süresince karşılaştığı zorlukların neler olduğu ve çeşitli FM hizmetleri için ihtiyaç duyulan BIM bilgi gereksinimlerinin neler olduğunu inceleyerek BIM-tabanlı bilgi yönetimi için ISO tarafından geliştirilen 19650 standart ailesini tanıtır.

Tezin üçüncü bölümü, Türkiye FM endüstrisinde BIM farkındalığı ve BIM kullanım durumunu tespit etmeye yönelik olarak yürütülen alan araştırmalarını içerir. Burada öncelikle, sektör profesyonellerinin BIM farkındalık ve kullanım seviyelerini ölçmek; BIM-tabanlı FM yapabilmek için gerekli olan bilgi gereksinimlerini tespit etmek ve sektörün etkin ve verimli hizmet sağlaması önünde engel teşkil eden noktaları belirlemek için nicel bir araştırma yürütülmüş ve sektörün önde gelen firmalarına internet üzerinde hazırlanan anket çalışmasına katılmaları için davetiye gönderilmiştir. Ardından, sektörde BIM kullanımının kısıtlı ölçüde kalmasına neden olan etmenleri tartışmak üzere, Türkiye'de çeşitli bina türlerinde FM hizmetleri yürüten bireyler ile yarı-yapılandırılmış mülakatlar gerçekleştirilmiştir. Elde edilen nitel veriler ışığında FM endüstrisinin iş yapma biçimleri, FM ekibinin yapısı ve FM hizmetleri için gerekli bilgi ve belgelere ulaşma sürecinde yaşanan zorluklar irdelenmiş, sektörün FM için geliştirilen güncel metodoloji ve teknolojilere olan yaklaşımı tespit edilmiştir. Bu bölümde yer alan nicel ve nitel araştırma sonuçları, uluslararası hakemli bir dergide makale olarak yayınlanmış ve uluslararası iki farklı konferansta sözlü olarak sunulup bildiriler kitabında yer almıştır.

Mimarlık, mühendislik ve yapım sektöründe yaşanan BIM-tabanlı dönüşümün tasarım ve yapım süreçlerini derinden etkilediği gibi binaların işletme süreçlerini de etkilemeye başladığı görülmektedir. Türkiye FM sektörü üzerinde yürütülen araştırma, sektörün mevcut iş yapma süreçlerindeki sorunları ortaya koymakla kalmamış, aynı zamanda sektörün BIM adaptasyonuna yönelik çeşitli beklentiler içinde olduğunu göstermiştir. Uzmanlar, BIM-tabanlı FM konusunda istekli olduklarını ancak BIM geçiş sürecini anlamaları ve başarıyla uygulamaları için çeşitli kılavuz ve standartlara ihtiyaç duyduklarını dile getirmektedir. Bu kapsamda, tezin dördüncü bölümünde, FM firmalarının BIM-tabanlı çalışma sürecine geçiş yapmalarını kolaylaştırmayı hedefleyen bir kavramsal çerçeve önerisi getirilmektedir. ISO 19650 standart ailesini temel alan bu öneri; Türkiye FM endüstrisinin kendine özgü koşullarını göz önünde bulundurarak geleneksel iş yapma modellerinin hakim olduğu, eski yapı stoğuna sahip ve teknolojik altyapısını geliştirmekte olan sektörün BIM-tabanlı FM uygulamaları için ihtiyaç duyduğu yol haritası görevini üstlenen ilk çalışma olma niteliği taşımaktadır. Önerilen kavramsal çerçevenin savunduğu iki temel prensip; FM ekibinin projelere mümkün olduğunca erken dahil olması ve BIM geçiş sürecinin bina sahibi ve/veya kullanıcısı ile ortak çalışmaya dayalı bir sistematikle ilerletilmesidir.

Tez çalışması kapsamında önerilen kavramsal çerçevenin FM sektörü tarafından uygulanabilirliği ve geçerliliğini ölçmek için, sektör profesyonellerinin katılımıyla gerçekleştirilen odak grup çalışması, tezin beşinci bölümünde yer alır. Son olarak, tezin altıncı bölümü olan sonuç bölümünde, tez kapsamında yapılan çalışmalar özetlenerek, BIM-tabanlı FM için önerilen kavramsal çerçeve ortaya konmuş ve önerilen çerçevenin FM sektörünün BIM'e geçiş sürecine yapacağı katkılar anlatılmıştır.

1.INTRODUCTION

Design, construction, and operations represent the three principal phases in the building life cycle. Decisions taken by the Architecture, Engineering and Construction (AEC) professionals in the design and construction phases have a substantial influence on building operations which refers to the longest stage and corresponds up to 85 per cent of the cost incurred in a building's entire life (Munteanu and Mehedintu, 2016; Abideen et al., 2022). The relationship between building delivery and building operations is more than a mere time flow. The operational phase begins immediately after the construction is completed and necessitates several facilities management (FM) services to guarantee that the constructed facilities function efficiently, comfortably, and safely (IFMA, 2019; Atkin and Brooks, 2021). FM activities carried out in this phase rely on the information scattered throughout the entire life cycle of a building (Wijekoon et al., 2016; Alnaggar and Pitt, 2019). Discontinuities in the information flow between building delivery and building operations result in inefficiencies in the later stages. Because the majority of project information created during design and construction are invaluable assets for FM professionals (Yu et al., 2000) and vice versa.

Conventional practices for delivering and managing building information cause the loss of a significant amount of data between the principal phases (Patacas et al., 2015). Besides, utilising unsystematically delivered data usually necessitates additional effort (Becerik-Gerber et al., 2012; Kasprak and Dubler, 2012; Patacas et al., 2015). As a result, all the actors of the AECO industries need a solution that is sensitive to the mentioned vulnerabilities of conventional methods. As a response to this call, the 2000s introduced building information modelling (BIM) as an innovative technological development in the AEC industry (Penttila et al., 2007). Throughout the years, several BIM definitions are proposed. Today, the most refereed BIM definition promotes BIM as the use of a shared digital representation of an asset to facilitate design, construction, and operation processes to form a reliable basis for decisions (ISO, 2018). The benefits of BIM involve but are not limited to simultaneous work of all disciplines on a 3D model to coordinate discipline-specific models, insight sharing, and recording digital building data which in return decreases the risk of cost and time overruns due to rework while increasing communication, efficiency, and overall quality of the project (Suermann and Issa, 2009; Azhar, 2011; Bryde et al., 2013; Love et al., 2013; Zhou et al., 2017). Even though BIM arises a promising method for efficient information management in the whole building life cycle, mostly the AEC industries across the world are the ones adopting BIM for delivering buildings. Evidence indicates that BIM adoption is progressing faster in countries that mandate BIM for public projects, such as the United Kingdom, United States, Norway, Finland, Denmark, Germany, Australia, and Singapore (Ariono et al., 2022; Tan et al., 2022). However, most of the BIM mandates focus on the use of BIM in design and construction phases rather than operational phase.

BIM offers certain benefits for FM practices including; building component locating, real-time facility data access, visualization and marketing, maintainability checking, digital asset creation and update, space management, planning and feasibility studies for noncapital construction, emergency management, energy monitoring and controlling and personnel training and development (Sabol, 2013; Becerik-Gerber et al., 2012). As FM practices require complete, accurate and available information, BIM emerges as a beneficial tool for efficient information handling during the operational phase (Pärn et al., 2017; Wong et al., 2018; Gao and Pishdad-Bozorgi, 2019; Matarneh et al., 2019a).

Studies reviewing the BIM implementation in FM practices coordinately emphasize; the lack of BIM benefit awareness, lack of knowledge transfer between design and FM teams, lack of standards and specifications, inaccurate and incomplete BIMs and data integration, exchange and interoperability difficulties as the main challenges (Dixit et al., 2019; Gao and Pishdad-Bozorgi, 2019; Matarneh et al., 2019; Wong et al., 2018; Naghshbandi, 2016; Yalcinkaya and Singh, 2014). These studies also emphasize the need for more real-life cases to increase the BIM benefit awareness, early involvement of FM teams in projects to increase collaboration and knowledge transfer between disciplines, standard and guideline development not only to define how, when and by whom the required information will be delivered, but also to solve interoperability problems.

1.1 Problem Statement

BIM is extensively employed by the AEC industries across the world due to its numerous benefits, including improved coordination and communication, increased productivity and reduced cost and time overruns (Zhou et al., 2017; Bryde et al., 2013; Love et al., 2013; Azhar, 2011; Suermann and Issa, 2009). Countries that have achieved a certain level of maturity in using BIM during the design and construction phases are now shifting towards utilising BIM during the operational phase (Gao and Pishdad-Bozorgi, 2019; Matarneh et al., 2019c). Over the past few years, BIM adoption has become an increasingly prevalent trend among design and construction firms in Turkey as well (Ozener et al., 2020; Tan et al., 2022; Karacigan et al., 2023). In addition to the increasing number of young professionals equipped with BIM competencies (Isonavic and Colakoglu, 2020), public authorities are encouraging and mandating BIM for specific public investments. All these developments accelerate the adoption and implementation of BIM across a broader range of stakeholders for building delivery. However, in contrast to the growing BIM influence in design and construction phases, building operations do not fully leverage BIM for FM purposes.

Turkey has a young yet emerging FM industry with an anticipated annual business volume of $12-15 billion (TRFMC, 2021). However, the industry lacks a profound set of standards for building operations. FM experts are often pressured to find short-term solutions to minimise operational costs when investors fail to recognise the value of the operational phase in the entire building life cycle. The use of BIM-based approaches in FM is emerging as a promising phenomenon for ensuring data-driven decision-making processes and achieving efficiency in building operations (Ashworth et al., 2019, 2023). Evidence shows that the success of BIM implementation relies on well-established standards and stakeholder commitment (Ariono et al., 2022; Karacigan et al. 2023). While the 19650 series of standards developed by ISO provides a well-founded basis to define procedures for the collaborative production of information and its management in the entire life cycle of buildings, adapting these procedures to fit national conditions is highly recommended (Ashworth et al., 2023).

This thesis study initially highlights the need for a strong collaboration between the two major actors of building operations, namely, building owners and facilities managers for a successful BIM transition of the industry. Then, the study proposes a conceptual framework to guide the BIM adoption and implementation process by examining ISO 19650 procedures from the perspectives of FM experts.

1.2 Purpose of the Thesis

The overall purpose of this thesis study is to guide developing FM industries during their BIM transition and implementation movement. This is achieved by proposing well-structured processes to introduce BIM-based methods and manage building information with a data-driven mindset in the operational phase. The characteristics of the Turkish FM sector set a typical example for developing FM industries. Hence, this study examines the current practices of the Turkish FM sector as a representative case. The proposed framework reconciles profound information management standards of ISO and unstandardised methods of the industry for building operations to draw a managerial roadmap tailored to the unique conditions of the industry. The two fundamental pillars of the proposed approach are the collaboration between the critical actors, building owners and FM representatives, and the early involvement of FM, respectively.

1.3 Scope and Limitations of the Thesis

Overall, the proposed framework places a higher priority on managing data and information throughout the entire life cycle of buildings. The suggested approach promotes the maximum utilisation of existing technology infrastructure without setting a particular preference for any specific software. Nevertheless, BIM-based principles employed in the framework play a complementary role in implementing a data-driven approach to the longstanding business practices of the FM industry. This particular aspect of the proposed study serves to integrate the well-established information management standards and unstructured practices of FM, rather than bringing about a dramatic change for FM professionals. Given the managerial perspective within this thesis study, the conceptual framework is represented in four consecutive phases and explained in detail. Topics such as the potential application of BIM in specific FM tasks, information requirements for BIM-FM integration, and interoperability between BIM-FM software are not covered.

1.4 Structure of the Thesis

The main objective of this thesis study is to guide FM organisations to adopt a data-driven mindset for building operations and implement a BIM-based approach for various FM services conducted in the operational phase of the building life cycle. To achieve this objective, the thesis study employs a variety of research and data collection methods as introduced in Figure 1.1 below.

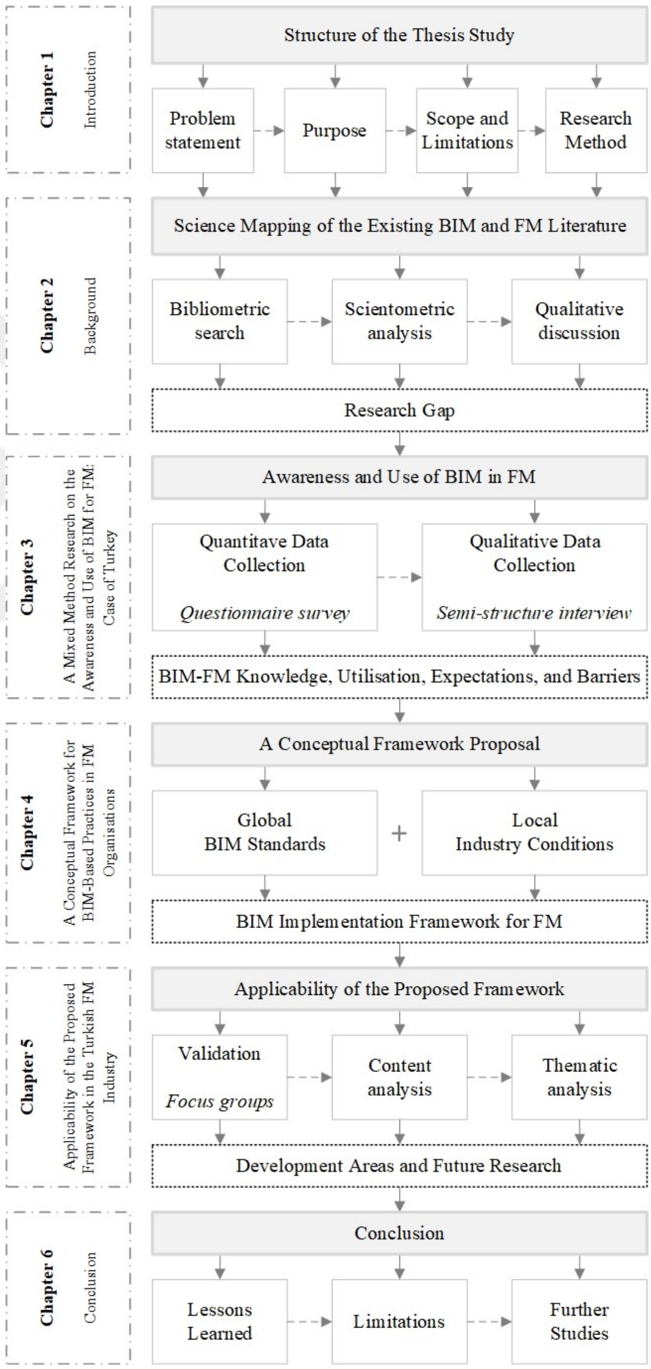


Figure 1.1: Overall structure of the thesis study.

Firstly, an in-depth review of the existing literature in the BIM and FM field is conducted to explore the state-of-the-art knowledge and research gaps in BIM-based FM studies. The literature review process applies a bibliometric search in scientifically reputable databases and employs scientometric analysis to identify the most influential publications, journals, scholars, and highly investigated topics in the BIM-FM domain. Then, mixed-method research involving the collection of quantitative and qualitative data from the FM industry professionals in Turkey is carried out. The data collected at this stage represents the current awareness and utilisation level of BIM among the industry actors, identifies information required for BIM-based FM practices, highlights the major problem areas of the prevalent practices, and discusses the reasons for limited BIM implementation in the FM industry. Based on these findings, this study proposes a conceptual framework for implementing BIM in FM practices by tailoring the international BIM-based information management standards of ISO to respond to the distinct requirements of the FM industry in Turkey. Finally, a focus group session is carried out to assess how the proposed framework can be applied within the context of the FM industry in Turkey.

2. BACKGROUND

This chapter initially defines the facilities management (FM) concept, presents the historical evolution of the FM industry, and introduces widely used FM technologies and software systems. The purpose is to provide a comprehensive perspective on the role of FM services within the building lifecycle and the importance of associated technologies in the delivery of efficient FM services. Then, the science mapping study provides a comprehensive review of the existing knowledge on building information modelling (BIM) and FM fields. The purpose is to analyse the most influential scientific journals, scholars, and keywords, identify research gaps, and propose future research directions in the BIM-FM domain. The following sections introduce BIM application areas in the FM services together with implementation challenges. Finally, BIM information requirements for different FM services and implementation standards are presented.

2.1 Facilities Management

Design, construction, and operations are the three major life cycle phases of any constructed facility (Succar, 2009). Equivalent to Stage 7 in the RIBA Plan of Work by the Royal Institute of British Architects (RIBA, 2020), the operational phase spreads through the longest period in the building life cycle and refers to the use, operations, and maintenance of the constructed facilities. Between 60% to 85% of the whole building life cycle costs are acknowledged to occur in the operational phase (Munteanu and Mehedintu, 2016; Abideen et al., 2022). Thus, FM services play a significant role in the efficient and effective use of buildings of all kinds.

2.1.1 Definition of FM

The efforts of defining facilities management date back to the 1990s. Initially, Becker and Steele (1990) said FM is responsible for coordinating all efforts related to planning, designing and managing buildings and their systems, equipment and furniture to enhance the organization's ability to compete successfully in a rapidly changing world. After their notion, Alexander (1996) defined FM as "*the process by* *which an organization ensures that its buildings, systems and services support core operations and processes as well as contribute to achieving its strategic objectives in changing conditions.*" According to Nutt (1999), FM "*covers the management structures, operations and procedures that serve to integrate decisions across the physical, human and financial areas of concern, all for the improved use, performance and productivity of facilities in all sectors*". Later, Barrett and Baldry (2003) referred FM as "*an integrated approach to operating, maintaining, improving, and adapting the buildings and infrastructure of an organization in order to create an environment that strongly supports the primary objectives of that organization*". Over the years, several FM definitions have been proposed, each acknowledging the supporting role of FM for the core business of organisations yet failing to provide an exclusive explanation of what exactly FM is (Nutt, 2004; Chotipanich, 2004; Noor and Pitt, 2009; Nor et al., 2014; Atkin and Brooks, 2021). Today, the most preferred FM definition by International Organization for Standards (ISO) suggests that "*FM is an organisational function which integrates people, place and process within the built environment with the purpose of improving the quality of life of people and the productivity of the core business*" (ISO, 2017).

Core business refers to "*the activity that is the main source of a company's profits and success, usually the activity that the company was originally set up to carry out*" (Url-1). The remaining activities, which are not the primary source of the company's profits yet essential for the business to run, are the non-core business. As the definition of core and non-core business differs regarding organisational objectives, the scope of FM functions differs from one organisation to another (Chotipanich, 2004). In the past, it was not unusual for organizations to form in-house teams employing internal personnel and resources to carry out FM services (Atkin and Brooks, 2021). However, competitive market conditions force organizations to direct their resources on value creation. Organizations can no longer rely on their resources for activities that do not directly add value. Moreover, buildings are recognized as important assets for organisations as they provide a physical medium for business activities and significantly impact occupants' well-being and productivity. Therefore, Price (2004) advises organisations to procure critical services from other organisations that have expertise in that field.

In most cases, organisations design, lease, or purchase buildings considering the needs and requirements of their personnel and operations, still, various FM practices are carried out throughout the buildings' occupational period. In addition to the efforts on FM definition, several researchers identify the extent of FM operations as well (Springer, 2001; Chotipanich, 2004). Typically, FM services are divided into two categories: soft FM services and hard FM services. Soft FM refers to the services that contribute to the quality, safety, and comfort of the organisation's physical environment. Examples of soft FM services are cleaning and housekeeping, catering, security, hospitality and reception services, landscaping and pest control, and waste management. On the other hand, hard FM refers to the services that are essential for the functionality and safety of the buildings and all physical components. Examples of hard FM services involve building maintenance, MEP systems (i.e., heating, ventilating, air conditioning, lighting, plumbing), fire safety systems, and emergency planning and safety equipment. The primary goal of soft services is to ensure the comfort and well-being of the occupants, which in return boosts employee motivation and business performance. Meanwhile, hard services are directly concerned with the safety and hygiene of the physical aspects, therefore mostly required by laws and regulations. Both soft and hard services are equally essential for holistic and successful FM operations (Atkin and Brooks, 2021).

A comprehensive list of soft and hard FM services includes but is not limited to:

- Maintenance operations and repair (i.e., building shell, fabric, plant and equipment, building performance monitoring, etc.)
- Buildings services (i.e., cleaning and housekeeping, MEP systems, energy and environmental management, waste disposal, pest control, disaster prevention, etc.)
- Space management (i.e., space configuration, space allocation, utilisation and relocation, space use monitoring, etc.)
- Architectural and construction services (i.e., new building design and construction, alteration, demolition, refurbishment, etc.)
- Facility planning and programming, administrative and office services (i.e., resource planning for short/mid/long terms, security, communication and mail services, hospitality and reception, transportation and car parking, storage and distribution, etc.)

- Real estate and property management (i.e., portfolio management, property investments, leasing, sub-letting and renting, etc.)
- Health and safety management (i.e., health, safety and welfare measures, hazard prevention, emergency routes, safety signs and equipment, first aid, etc.)
- Financial management (i.e., budgeting, purchasing, cost control, etc.)
- Human resources services (i.e., catering, employee support, recreation, training, etc.)

(Thomson, 1990; Springer, 2001; Chotipanich, 2004; Atkin and Brooks, 2021). As previously highlighted, the scope of the FM services differs regarding organisational needs. Thus, a set of services for one company might not fit the other. In other words, FM is an organisation-specific function that organisations are most likely to require only a few of the wide range of services listed above. The multi-disciplinary nature of the FM profession enables tailored solutions for organisations. Further discussions advocate FM to evolve from daily caretaking and maintenance delivery to strategic support for business (Pitt and Goyal, 2004; Noor and Pitt, 2009). Yet, proposing a universal explanation of the scope of FM exceeds the limits of this thesis study. The essence of this section stresses the importance of identification and prioritisation of the organisation-specific needs for effective FM.

2.1.2 History of FM

In the 1970s, the scope of FM practices was limited to two major services: cleaning buildings and maintaining building equipment (Atkin and Brooks, 2021; FMA, 2012). In the 1980s, the foundation of the International Facility Management Association (IFMA) in the United States provided a formal recognition to the FM profession (Nor et al., 2014; Url-2). The following decades introduced several FM associations across the world. This being said, in 1987 Japan Facility Management Association (JFMA) was established, followed by the Facility Management Association (FMA, Australia) in 1988, the German Facility Management Association (GEFMA) in 1989, the Danish Facilities Management (DFM) in 1991, the Institute of Workplace and Facilities Management (IWFM, former British Institute of Facilities Management-BIFM) in 1993, South African Facilities Management Association (SAFMA) in 1998, the Middle East Facility Management Association (MEFMA) in 2009, and Turkish Facility Management Association (TRFMA) in 2017, respectively. In addition to the listed regional organizations, a few multi-national communities, such as European Facility Management Network (EuroFM) and Global FM were founded by the leading FM associations, in 1993 and 2006. Figure 2.1 illustrates the establishment of these organizations on a timeline. Mentioned societies organize local and global meetings, develop practice guidelines and standards, and provide training to support the progress of the FM profession and experts.

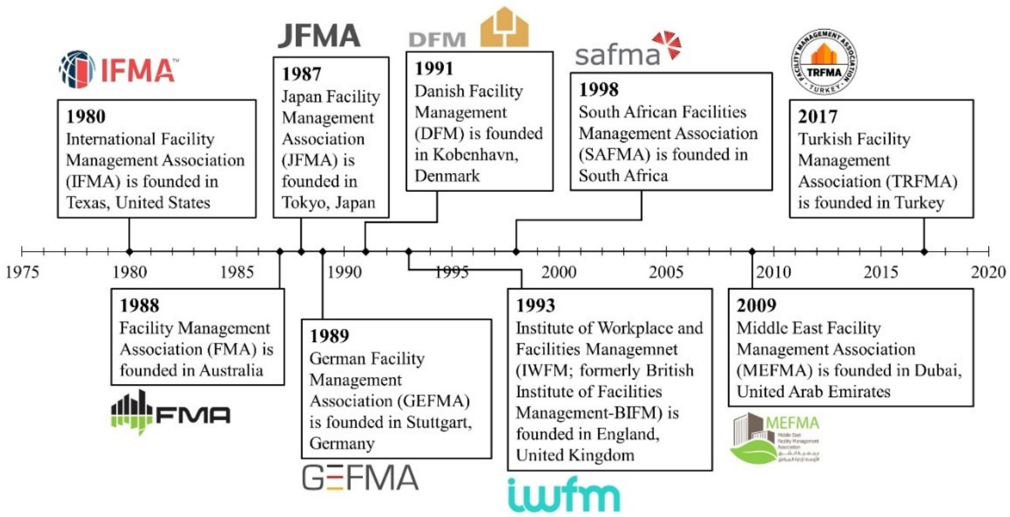


Figure 2.1: Historical development of FM associations across the world.

As a long-lasting profession, FM has been experiencing continuous changes for decades. Its scope has evolved from daily cleaning and maintenance operations to strategic support for organisations. Progress in the scope of FM practices consequently transforms the extent of FM professionals' duties. The survey by the National Institute of Building Sciences (NIBS) reports a comprehensive job task analysis of building operations professionals and categorises these tasks into five groups (NIBS, 2015). According to the report, building operations professionals spend 50% of their time on building operations tasks, 20% on facility optimization activities, 15% on planning activities, 8% on personnel supervising, and 7% on budgeting (NIBS, 2015). The distribution of job tasks is illustrated in Figure 2.2 and a detailed explanation of each of the five task groups is given below:

- Building operations tasks group involves maintaining the facility and systems, implementing an energy management program, conducting daily rounds, equipment checks, facility repair activities, investigating indoor environmental quality, coordinating normal and abnormal facility operations, managing work order process, conducting risk management activities, managing building securities, responding to tenant requests and building emergencies, managing outside service providers and third-party inspections, managing the personal protective equipment program, performing building hazard assessments, participating in emergency drills, and coordinating and conducting occupant training.

- Optimizing the facility group involves analysing and optimizing system performance, conducting measurement and verification activities, identifying cost-saving measures, responding to changing energy costs, and identifying sustainability opportunities.
- Conducting planning activities group involves developing equipment operations plans and planned maintenance schedules, updating procedures (i.e., standard operating procedures, building operating procedures, operating plans, emergency plans, etc.), contributing to capital renewal plans, construction standards and guidelines, and conducting data management activities.
- Supervising personnel group involves supervising building staff, developing workload analyses, analysing staff productivity and securing outside service providers.
- Contributing to the budgeting activities group involves contributing to the facility operations budget, capital improvement budget and long-term facility budget plans.

Figure 2.2: Job task analysis of building operations professionals.

As seen in Figure 2.2, FM embodies a wide spectrum of activities for the efficient and effective operations of built environments. Facilities managers today are expected to have strong technical knowledge regarding buildings and associated systems, understand organisational dynamics and demonstrate successful communication skills to coordinate multiple disciplines (Atkin and Brooks, 2021). The Workplace and Facilities Management Professional Standards by IWFM (2018) define ten functional areas of FM (see Figure 2.3). As stated by IWFM (2018), a workplace and facilities manager should:

- Understand the value-adding role of workplace and facilities management for organisations, improve organisational culture, and utilize information and knowledge in the decision-making process,
- Establish an FM strategy and develop policies that are aligned with the organisation's strategic objectives and corporate social responsibility statement,
- Develop, manage and lead highly motivated and skilled FM teams,
- Establish risk management strategies and build business resilience,
- Deliver business support services that are innovative and tailored according to the current and future needs of the organisation,
- Manage properties, assets and spaces, and maintain buildings utilizing BIM,
- Fulfil quality requirements and customer expectations,
- Optimise the use of technology and financial resources,
- Ensure transparency and prioritise value during the procurement and contracting process,
- Implement sustainable practices to use resources efficiently and minimise the environmental impact.

Figure 2.3: Key functional areas performed by FM professionals (adapted from IWFM, 2018).

FM professionals take different job titles depending on their roles and responsibilities during the operational phase of the buildings. Evidence shows that many facilities managers have an educational background in architecture, engineering, management, or real estate programs (Steenhuizen et al., 2014; Atkin and Brooks; 2021). Although scholars highlight the need for a structured FM curriculum (Sullivan et al., 2010), the multidisciplinary characteristics of the FM profession is challenging the efforts of establishing FM as an academic discipline (Junghnas and Olsson, 2014).

2.1.3 FM technologies and software

Traditionally, facilities managers received the majority of the building data as paper-based documents (Yalcinkaya and Singh, 2014). These professionals had to rely on blueprints, printed manuals, and records packed in binders to understand the building and make further decisions. Parallel to the diffusion of technological developments into the AEC practices, buildings are becoming more complex and technology-oriented environments. Naturally, buildings require the use of advanced technologies not only in the design and construction phases but also in the operational phase. Furthermore, escalating operational costs, the limited number of qualified FM staff, increasing competition and decreasing profits within the FM market oblige facilities managers to give priority to efficient and effective solutions. As a result, the FM industry has started to leave conventional approaches and employ modern technologies including computer-integrated facilities management (CIFM) environments (Yu et al., 2000).

The FM literature involves sophisticated technologies in complex acronyms. A broad list of software and technologies employed in the operational phase includes computerized maintenance management system (CMMS), computer-aided facilities management (CAFM), integrated workplace management system (IWMS), building automation system (BAS), energy management system (EMS), enterprise asset management (EAM), enterprise resource planning (ERP), building information modelling (BIM), digital twins, internet of things (IoT) and sensors, virtual reality (VR) and augmented reality (AR), and artificial intelligence (AI). Each of the listed technologies serves a specific FM function and contributes to efficient FM practices. A previous study by Ebbesen (2016) classifies the listed technologies into seven categories and illustrates the relationship among them in Figure 2.4.

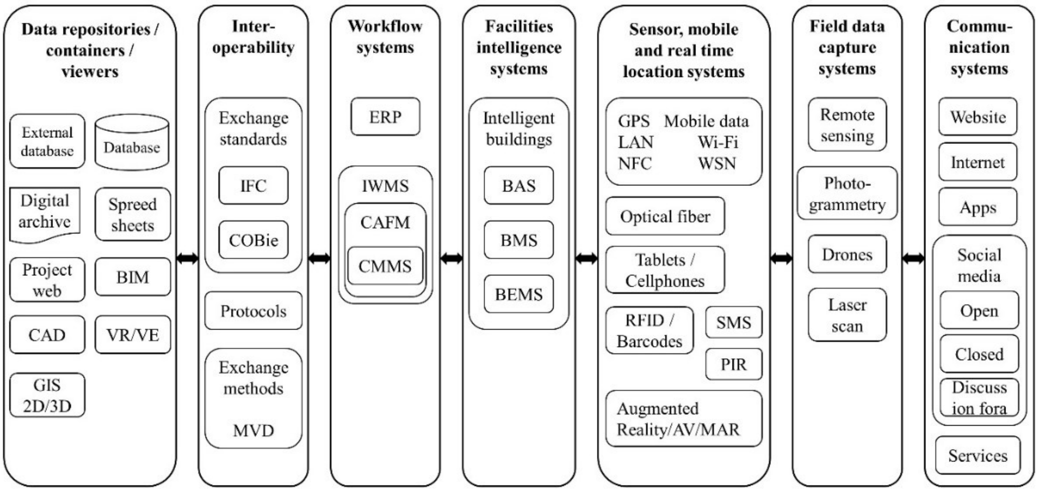


Figure 2.4: FM technologies (adapted from Ebbesen, 2016).

As illustrated in Figure 2.4, facilities managers utilize workflow systems to plan and monitor numerous tasks, but before doing that they have to transfer previous building data to the system. However, different data repositories keep different types of building data. For example, construction drawings such as as-built floor plans are created using CAD platforms and transferred to the FM team as digital CAD files. Other than that, equipment lists and O&M manuals for the equipment are kept as PDF files in a digital archive, vendor information and contact details for the equipment are kept as spreadsheets or Excel files, work orders, scheduled tasks and task status are kept in project web, and so on. Interoperability protocols and data exchange standards (i.e., COBie, IFC, etc.) enable data transfer between these systems and provide reliable data for FM decisions. Typically, any dysfunction of building equipment or unexpected issue is detected by the inspecting staff or data capturing systems (i.e., sensor, laser scan, etc.) and issued as a work request. Assigned FM staff arrives at the problem point, use hand-held devices (i.e., cell phone, tablet, etc.) to scan the barcode or RFID tag and detect the deficient asset and obtain specific information (i.e., equipment type, manufacturer, link to the O&M manual, etc.). Once the necessary intervention is done, the staff marks the task status as complete. The facilities manager controls the system to check whether the deficiency is solved and whether all building system is adequately functioning. Depending on the frequency or criticality of the problem, the facilities manager schedules a preventive maintenance task using the workflow systems as well.

FM services are notably fragmented and multiple technologies are simultaneously utilized for smooth and efficient facilities operations. Several commercial software is available for the use of FM professionals, each employing different data and serving a specific function. Among these software solutions are the CMMS, CAFM, and IWMS are the fundamental and most prevalent ones.

A computerized maintenance management system is one of the core software that essentially supports the maintenance of key equipment within facilities. According to IFMA, a CMMS allows facilities managers to plan, assign and track maintenance and repair work orders, control inventory, and report labour and material expenditures (Url-3). The CMMS database stores asset registers (i.e., manufacturer, model, serial number, class, equipment type, location, position, O&M manuals, warranty, etc.), maintenance tasks (work order number, description, priority, responsible personnel, etc.), resource and labour information (i.e., personnel shifts, crew information, etc.), material inventory (i.e., available materials and spare, storage areas, etc.), and report and analysis (i.e., material use, labour cost, etc.). Facilities managers use the CMMS to schedule preventive maintenance based on maintenance histories, which in return help to lower the hidden costs of maintenance (Wienker et al., 2016).

The second well-known FM software solution is computer-aided facilities management. Although the major purpose of the CAFM is to support operational and strategic FM, in practice, it is mainly used for space management purposes (Abel and Lennerts, 2005). Yet, it also includes maintenance management (i.e., planned, reactive and corrective) for critical equipment (Whittaker, 2017; Maslesa, 2019). A CAFM system incorporates CAD and GIS to store floor plans, therefore it is used for planning and allocating space (i.e., strategic areas, meeting rooms, etc.), tracking furniture, equipment and technical assets, and monitoring space occupancy (Mohanta and Das, 2016; Zvirbule & Kirikova, 2018; Url-4). Implementing a CAFM system improves FM practices simply because of the proper definition and documentation of the processes and responsibilities (Abel and Lennerts, 2005).

An integrated workplace management system, as the name suggests, integrates facilities management, real estate management, maintenance management, energy management, and project management functions within a single platform (Url-5). An IWMS mostly referred to as the developed CAFM, is an FM automation tool that relates assets, people, and space (Keller, 2013) and supports organisations to optimize the use and administration of workplace resources (Madritsch and May, 2009). Facilities managers utilize IWMS to make space management decisions, assign and track maintenance work orders, monitor energy metrics and carbon emissions, and design and construct new facilities or remodel existing ones. When integrated with the building management system, IWMS can support sustainability goals as it enables energy and water consumption tracking. Evidence highlights the increased efficiency, improved productivity and reduced operational costs due to the IWMS implementation (Hanley and Brake, 2016).

2.2 The Link Between BIM and FM

The vast majority of project information created during design and construction becomes invaluable for FM professionals (Yu et al., 2000). Although the design and construction phases utilize numerous computer software to create building information, most of the information is delivered in either a non-digital or unstructured format (Yalcinkaya and Singh, 2014; Patacas et al., 2015). On top of that, the manual data transfer process from discrete sources into the FM software is labour-intensive, tedious, time-consuming, error-prone, and most importantly vulnerable to data loss (Becerik-Gerber et al., 2012; Kasprak and Dubler, 2012; Patacas et al., 2015). As represented in Figure 2.5 below, significant data is lost between different phases of the building life cycle due to the conventional approach. Each data loss leads to information discontinuity throughout the project life cycle and costs the building owner, especially for further phases such as the operations phase.

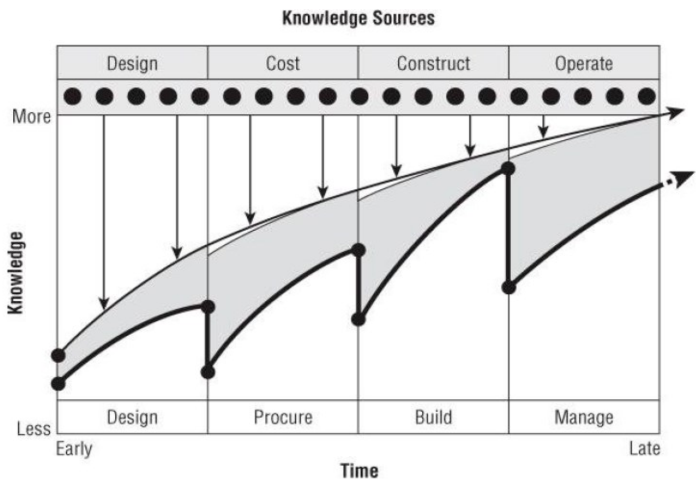


Figure 2.5: The BIM curve shows loss of data without interoperability in project milestones (Source: Bernstein, [adapted from Read et al., 2012]).

FM practices in the operational phase are inherently information-intensive (Alnaggar and Pitt, 2019), and the information required for smooth FM practices is dispersed across the whole building life cycle (Wijekoon et al., 2016). Common documents that are handed over from construction to FM are 2D as-built drawings, equipment lists, O&M manuals, and vendor and warranty information (Ghosh and Chasey, 2013). Successful FM operations undeniably rely upon the completeness, accuracy, and availability of the information (Song et al., 2002; Matarneh et al., 2019a; Atkin and Brooks, 2021). At this point, BIM arrives as an auspicious tool for better information management in building operations (Pärn et al., 2017; Wong et al., 2018; Gao and Pishdad-Bozorgi, 2019; Matarneh et al., 2019a).

Gu and London (2010) define BIM as "an IT-enabled approach that involves applying and maintaining an integral digital representation of all building information for different phases of the project life cycle in the form of a data repository". In the early 2000s, BIM entered the AEC industry and changed the conventional practices of design and construction (Penttila et al., 2007). Since then, project stakeholders experience better communication and coordination, which in return decrease errors and omissions, reduce project duration, decrease costs, increase quality, and improve overall project performance (Suermann and Issa, 2009; Azhar, 2011; Bryde et al., 2013; Love et al., 2013; Ghaffarianhoseini et al., 2017; Zhou et al., 2017). By the 2010s, BIM has started to transform FM practices as well. BIM supports FM practices by means of intelligent as-built models of buildings. These models assist commissioning, repair or replacement decisions, support maintenance planning and inspections, monitor building performance, visualise building space for renovation decisions or emergency planning, and keep building life cycle information digital and up-to-date (Becerik-Gerber et al., 2012; Pärn et al., 2017). In addition to the listed benefits, BIM implementation in FM implies a certain level of adversaries. A brief list of these adversaries involves a lack of BIM-FM information requirements standards, fragmented FM data requirements, interoperability problems between BIM and FM software, incomplete and outdated building information models, limited BIM-FM demand of building owners, and shortage of BIM-experienced FM personnel (Becerik-Gerber et al., 2012; Korpela et al., 2015; Patacas et al., 2015; Pärn et al., 2017). Despite the great potential of BIM for FM, BIM-enabled FM practices are still lacking compared to design and construction applications. Yet, the latest reviews on BIM studies confirm the shifting research interest towards BIM-based FM (Pärn et al., 2017; Gao and Pishdad-Bozorgi, 2019; Matarneh et al., 2019c; Tezel and Giritli, 2021).

2.2.1 Science mapping of BIM and FM literature

This section adapts the science mapping approach by Jin et al. (2019) to disclose the existing knowledge on BIM and FM integration. The details of the research procedure are illustrated in Figure 2.6.

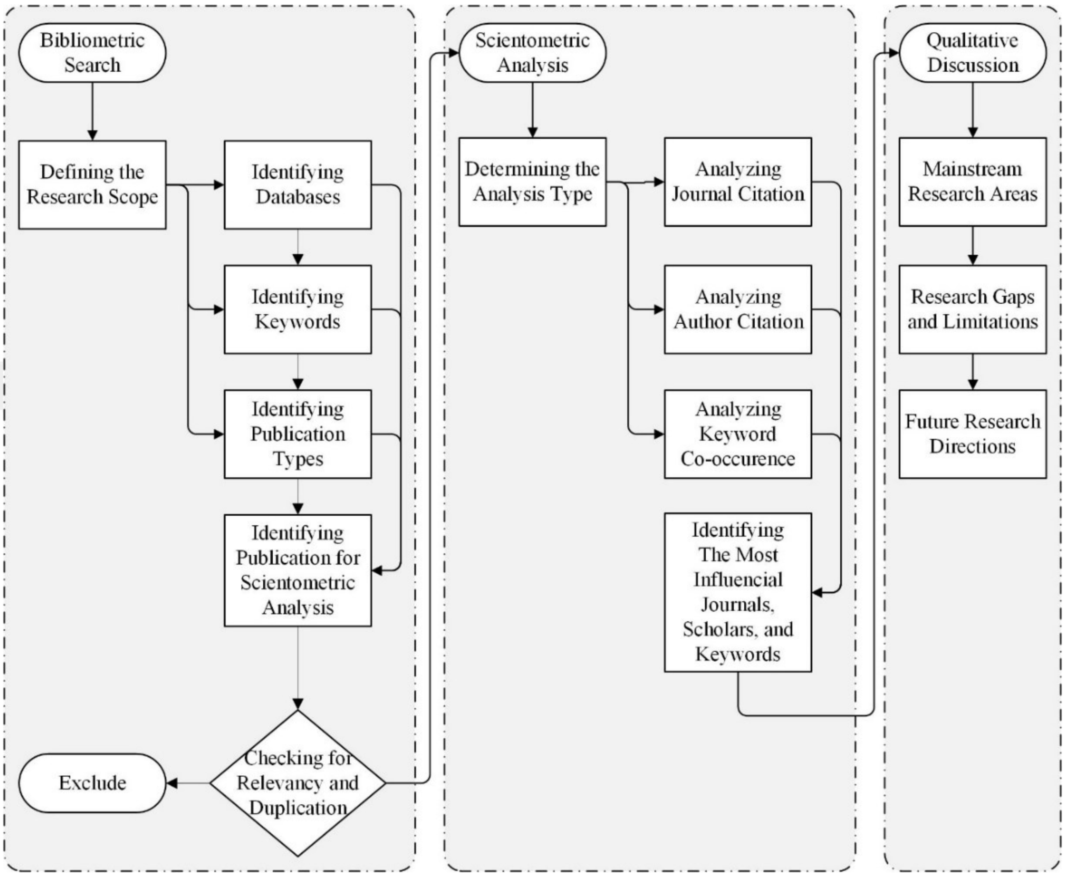


Figure 2.6: Research procedure for science mapping of BIM and FM literature (adapted from Jin et al., 2019).

In the first step, a bibliometric search within the Web of Science (WoS) and Scopus databases determine the journal articles published between 1998 and 2019 containing ("BIM" OR "building information model" OR "building information modeling" OR "building information modelling") AND ("FM" OR "facility management" OR "facilities management") words in title/abstract/keyword fields. The initial search identifies 477 journal articles, which are then screened to remove duplicates and irrelevant ones. In the end, a total of 150 articles were selected for the second step which is the scientometric analysis. Figure 2.7 shows the detailed distribution of articles throughout the years.

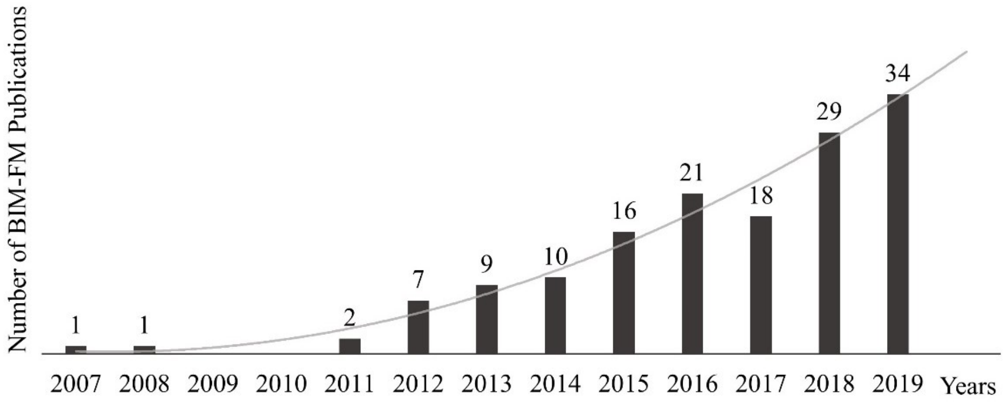


Figure 2.7: Distribution of BIM-FM journal articles over the years.

In the second step, a scientometric analysis identifies the influential keywords, articles, scholars and journals in the domain of BIM and FM using VOSviewer software. As journals, documents, cited references, authors and descriptive terms-keywords as the fundamental units of scientometric analysis (Börner et al. 2003), this study proceeds with the journal citation analysis to determine the most productive and influential journals of BIM and FM studies, author citation analysis to determine the influential scholars of the field and keyword co-occurrence analysis to identify the mainstream research topics of BIM-FM integration.

In the final step, an in-depth qualitative discussion describes the mainstream research topics in BIM-FM integration, discusses the limitations or gaps of existing research in the BIM-FM integration, and proposes future directions for further scholarly and research work.

2.2.1.1 Journal analysis

Journal articles are published after a detailed peer review process, therefore, they are accepted as reliable knowledge sources. The 150 articles analysed in the scope of this study were published in 57 distinguished journals between 2008-2019. Table 2.1 shows the journal names, number of publications (No. of Pubs.), number of citations (Total Cit.), normalized citation (Norm. Cit.), average citation (Avg. Cit.) and average normalized citation (Avg. Norm. Cit.) values.

As seen in Table 2.1, Automation in Construction is the most productive journal with 26 articles and the most influential journal in BIM-FM integration studies due to the highest average normalized citation value of 1.76. Facilities is the second most productive journal with 16 articles and followed by Advanced Engineering Informatics with 8 articles, Journal of Computing in Civil Engineering with 7 articles, and Buildings with 7 articles.

Table 2.1: Most productive journals in the BIM-FM research field.

Journal Name	No of Publ.	Total Cit.	Norm. Cit.[a]	Avg. Cit.	Avg. Norm. Cit.[b]
Automation in Construction	26	946	45.89	36.38	1.76
J of Management in Engineering	4	99	6.63	24.75	1.66
J of Computing in Civil Engineering	7	146	7.95	20.86	1.13
Buildings	7	79	7.23	11.29	1.03
Built Env Project and Asset Management	5	110	5.11	22.00	1.02
Advanced Engineering Informatics	8	181	7.24	22.63	0.90
Facilities	16	92	13.71	5.75	0.86
J of Performance of Constructed Facilities	5	32	2.34	6.40	0.47
J of Information Technology in Construction	6	52	2.22	8.67	0.37

Notes: [a] Norm. Cit. denotes the normalized number of citations of a document that equals the number of citations of the document divided by the average number of citations of all documents published in the same year and included in the data that is provided to VOSviewer.
[b] Avr. Norm. Cit. represents the normalized number of citations received by the documents in which a keyword or a term occurs or the average normalized number of citations received by the documents published by a source, an author, an organization, or a country.
The normalization corrects for the fact that older documents have had more time to receive citations than more recent documents (van Eck and Waltman, 2018).

Although the Journal of Management in Engineering has a relatively limited number of articles on BIM-FM integration, it is the second most influential journal in this field with an average normalized citation value of 1.66, followed by the Journal of Computing in Civil Engineering with the average normalized citation value of 1.13.

2.2.1.2 Author analysis

The author citation analysis determined the most influential scholars in the BIM-FM community according to the number of articles they published and citations they received. Figure 2.8. below illustrates the whole community of BIM-FM research with

405 scholars. In the figure, node and font sizes are associated with the total number of publications. If an author is represented with a bigger node, this means that the author has more publications compared to the others.

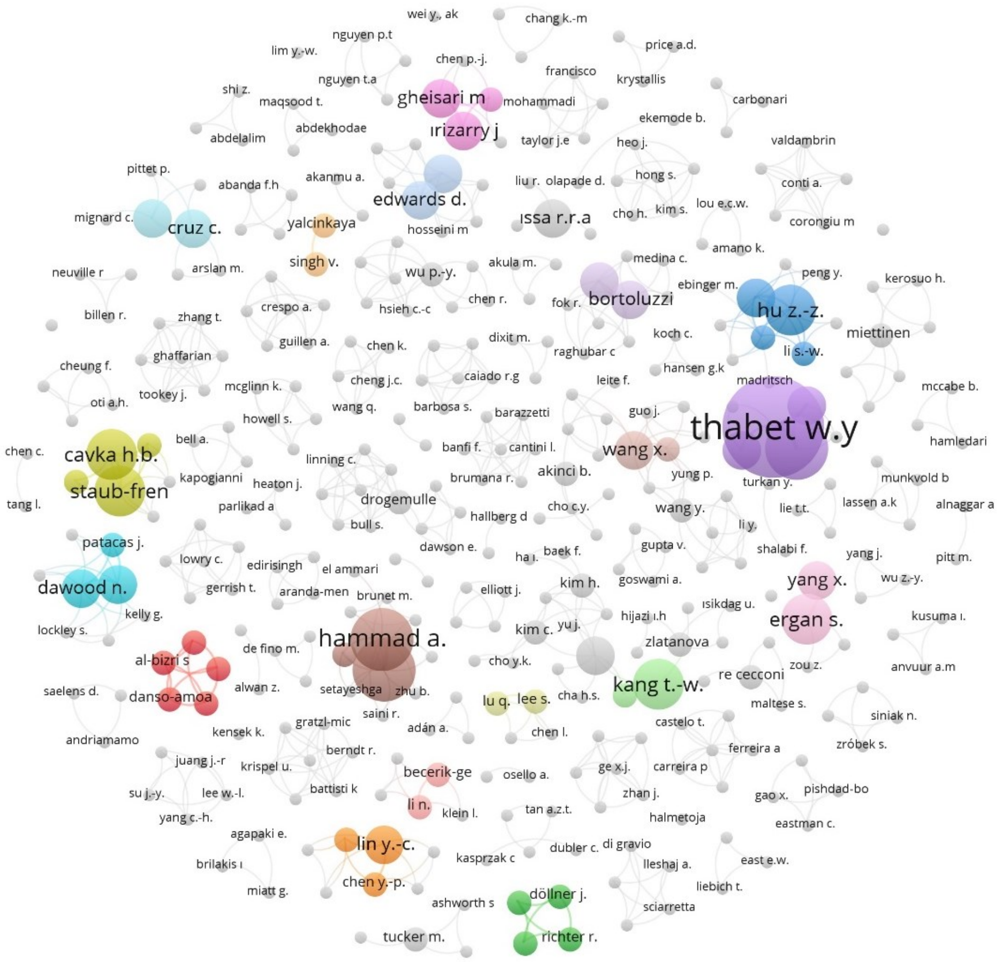


Figure 2.8: BIM-FM research community.

The results reveal 24 pioneering scholars in the BIM-FM domain with at least 3 publications and 20 citations. The remaining majority have either less number of publications or citations. A detailed summary of the most influential authors including the total number of publications (No. of Pubs.), number of citations (Total Citation), normalized citation (Norm. Citation), average citation (Avg. Citation) and average normalized citation (Avg. Norm. Cit.) values are shown in Table 2.2.

As seen in Table 2.2, Issa, R.R.A. is the most influential author with the highest average normalized citation value of 1.91, followed by Zhang, J.P. (1.41), Dawood, N.N. (1.40), and Kassem, M. (1.40).

Table 2.2: Most influential scholars in the BIM-FM research field.

Author Name	No of Publ.	Total Cit.	Norm. Cit.[a]	Avg. Cit.	Avg. Norm. Cit.[b]
Issa, Raja Raymond A.	3	77	5.73	25.67	1.91
Zhang, Jian-Ping	3	45	4.23	15.00	1.41
Dawood, Nashwan N.	3	124	4.20	41.33	1.40
Kassem, Mohamed	3	124	4.20	41.33	1.40
Motemadi, Ali	5	159	6.68	31.80	1.34
Gheisari, Masoud	3	86	3.50	28.67	1.17
Irizarry, Javier	3	86	3.50	28.67	1.17
Edwards, David John	3	41	3.47	13.67	1.16
Hammad, Amin	5	158	5.34	31.60	1.07
Hu, Zhen-Zhoung	4	45	4.23	11.25	1.06
Wetzel, Eric Michael	3	77	2.88	25.67	0.96
Nicolle, Christophe	3	235	2.88	78.33	0.96
Cavka, Hasan Burak	4	54	3.38	13.50	0.84
Staub-French, Sheryl	4	54	3.38	13.50	0.84
Yang, Xue	3	26	1.92	8.67	0.64
Thabet, Walid Y.	8	148	5.04	18.50	0.63
Ergan, Semiha	4	28	2.17	7.00	0.54
Bulbul, Tanyel	3	59	1.30	19.67	0.43
Cruz, Christophe	3	179	1.28	59.67	0.43
Lucas, Jason D.	6	71	2.16	11.83	0.36

Notes: [a] Norm. Cit. denotes the normalized number of citations of a document that equals the number of citations of the document divided by the average number of citations of all documents published in the same year and included in the data that is provided to VOSviewer.
[b] Avr. Norm. Cit. represents the normalized number of citations received by the documents in which a keyword or a term occurs or the average normalized number of citations received by the documents published by a source, an author, an organization, or a country.
The normalization corrects for the fact that older documents have had more time to receive citations than more recent documents (van Eck and Waltman, 2018).

It can be concluded that the most influential studies in the BIM-FM domain focused on FM requirements and maintainability problems (Liu and Issa, 2016), owner BIM competencies and information requirements (Giel and Issa, 2016; Mayo and Issa, 2016; Patacas et al., 2016), use of open data standards-such as IFC and COBie (Patacas et al., 2015) challenges in BIM adoption in FM (Kassem et al., 2015), efficient MEP management (Hu et al., 2016, 2018), and data mining for information extracting (Peng et al., 2017).

The remaining studies covered a wide variety of issues such as safety applications during the O&M phase (Pärn et al., 2019), augmented reality (AR) integration (Williams et al., 2015; Gheisari and Irizarry, 2016) or equipment localization with RFID tags (Motamedi et al., 2013).

2.2.1.3 Keyword analysis

Keywords represent the main concepts of existing studies. Keyword co-occurrence analysis shows how frequently a specific keyword took place in literature and what are the relationships among different keywords. Additionally, the average normalized citation value of each keyword refers to how influential of that concept is in the research community. Figure 2.9. represents 38 out of 418 unique keywords that have at least 3 occurrences. Once again, node and font sizes are associated with the number of occurrences for each keyword. This being said, when a keyword occurs multiple times in the dataset, then its corresponding node is shown bigger compared to the others. In addition, the connecting lines between each keyword represent the inter-relatedness between those concepts.

The results of the keyword co-occurrence analysis identified 7 clusters according to their inter-relatedness. The focus of each cluster is briefly explained below:

- Cluster 1 focuses on the integration of various information systems (i.e., BIM, CMMS (Computerized Maintenance Management System) and GIS (Geographic Information System) for maintenance practices.
- Cluster 2 focuses on the data transfer/information exchange among different systems and facilities (i.e., safety-related purposes or healthcare facilities).
- Cluster 3 focuses on the corrective maintenance activities and covers the visualization of HVAC (Heating, Ventilation and Air Conditioning) systems and their energy performance.

- Cluster 4 focuses on maintenance management activities and related technologies such as RFID (Radio Frequency Identification) tags, mobile AR (Augmented Reality) applications, etc.
- Cluster 5 focuses on the use of BIM and other technologies such as laser scanners for obtaining the as-built model of historical/heritage buildings.
- Cluster 6 focuses on interoperability problems which is one of the biggest challenges against BIM-FM integration.
- Cluster 7 focuses on the case study method for real-life examples of automation in O&M practices

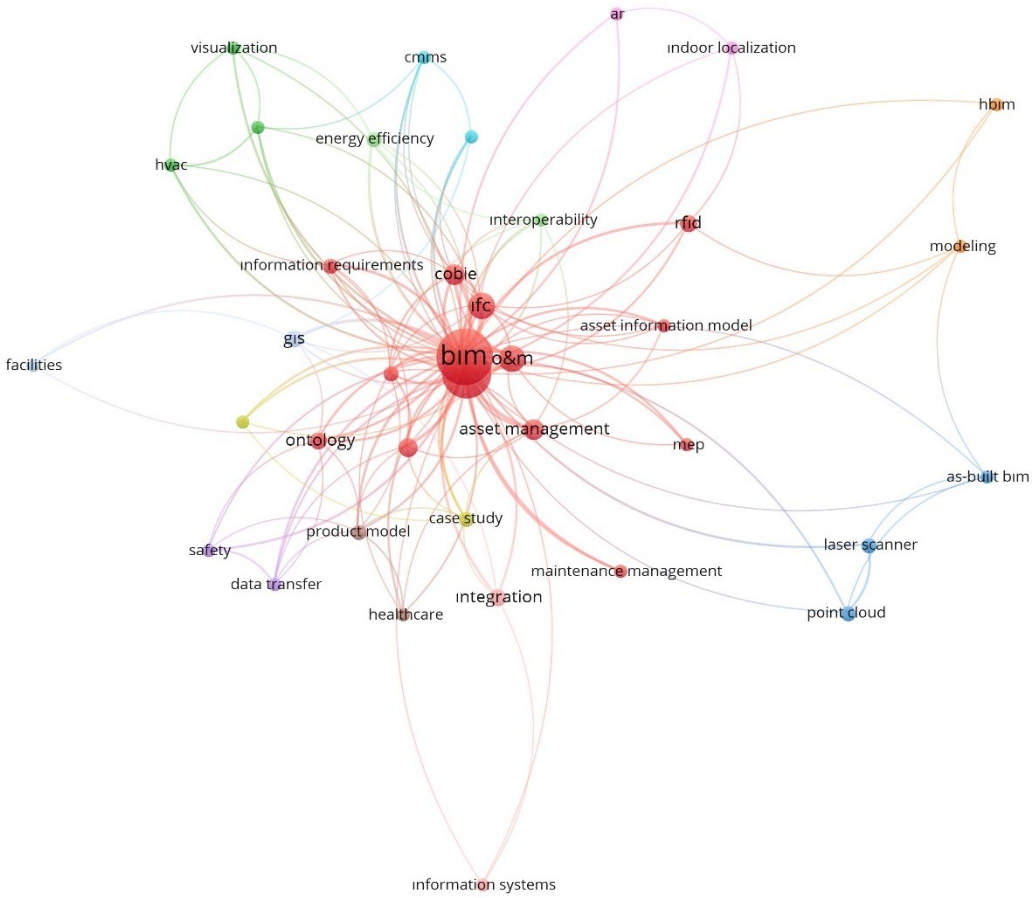


Figure 2.9: Major BIM-FM research keywords.

Table 2.3. lists the keywords including their occurrence frequency (Occur. Freq.), average citation (Avg. Citation), average normalized citation (Avg. Norm. Citation) and average publication year (Av. Pub. Y.) values.

Table 2.3: Most influential keywords in the BIM-FM research field.

Keyword	Occur Freq	Avg. Cit.	Avg. Norm. Cit.[b]	Avg. Pub. Year
Artificial intelligence (AR)	3	9.00	2.60	2018
Maintenance management	3	30.67	2.47	2016
Indoor localisation	3	6.67	2.19	2018
Point cloud	4	45.75	2.17	2016
Laser scanner	4	46.00	2.11	2015
HBIM	3	16.00	2.00	2018
Facilities	3	108.33	1.78	2015
Ontology	5	40.00	1.51	2014
Modelling	3	14.67	1.43	2017
Operation and maintenance (O&M)	15	16.20	1.29	2017
As-built BIM	3	39.33	1.25	2015
Automation	3	3.67	1.24	2018
Asset information model	3	3.33	1.21	2018
MEP	3	11.67	1.17	2018
Asset management	9	11.89	1.16	2018
Facilities management (FM)	86	21.17	1.10	2016
COBie	8	20.38	1.08	2017
IFC	16	30.81	1.03	2015
GIS	5	29.60	1.00	2016
Information management	6	24.67	1.00	2016

Average normalized citation prevents the dominance of older publications due to their time advantage in getting citations (van Eck and Waltman, 2018). On the other hand, the average publication year refers to how old or new each keyword is. Table 2.3. includes the keywords with Av. Norm. Citation over 1.00, and because the BIM keyword a has lower Av. Norm. Citation value (0.98), isn't listed in the table.

As seen in Table 2.3, AR applications are the most influential and popular research subject based on their average normalized citation, followed by maintenance management, indoor localization, point cloud, laser scanner and HBIM. On the other hand, keywords referring to the data standards such as COBie, IFC, and information management subjects are the least popular ones.

2.2.1.4 Mainstream research topics and future directions

Based on the clusters obtained in keyword co-occurrence analysis, the qualitative discussion process determines four mainstream research topics in the BIM-FM field, identifies the research gaps in each category, and proposes further research directions.

- BIM implementation in FM: Studies on this topic measure the existing BIM adoption level within the FM industry (Becerik-Gerber et al., 2012), and analyse BIM implementation benefits and challenges (Kassem et al., 2015; Pishdad-Bozorgi et al., 2018). A limited number of case studies is the major problem for higher BIM adaptation within the industry. Therefore, future research should capture and analyse more real-life examples of BIM-based FM practices.

- Information requirements, exchange and management: Studies on this topic identify BIM information requirements for the O&M phase (Becerik-Gerber et al., 2012; East et al., 2013; Korpela et al., 2015; Mayo and Issa, 2016), propose information management framework (Alnaggar and Pitt, 2019), and improve the information exchange process (Matarneh et al., 2019b). The two major study gaps are the quality of handover information and interoperability between different software. Future studies should propose an information management guideline that identifies the required information for FM in different building types, parties responsible for the management of information, and data/information exchange processes between different software platforms. A second direction may focus on FM data capturing and conveying operational knowledge to the design phase.

- FM operations in buildings: Studies on this topic deal with corrective maintenance (Shalabi and Turkan, 2017), energy consumption monitoring (Oti et al., 2016), emergency planning (Isikdag et al., 2013) and visualization of FM work orders (Williams et al., 2015). Further studies should contribute to efficient maintenance operations with BIM and AR/VR integration.

- Existing/heritage buildings: Studies on this topic focus on the automatic as-built data generation of existing buildings via point clouds (Wang et al., 2015) or other image-based technologies (Lu and Lee, 2017), and BIM-based performance assessment of historic buildings (Bruno et al., 2018). The number of studies is limited due to the lack of fully automatic and accurate as-built BIM generation. Thus, future studies using different recognition techniques to generate rich semantic data and automatic data transfer from site to the central BIM model are encouraged.

2.2.2 Application areas of BIM in FM

Due to the information-intensive nature of the operational phase, BIM is argued to be an advantageous tool for FM (Becerik-Gerber et al., 2012; Mayo and Issa, 2016; Wijekoon et al., 2018; Dixit et al., 2019). This argument derives from the geometric and non-geometric information storage capability of BIM in the building lifecycle. Geometric information refers to the graphical representation of the building information. Typical examples of geometric information of a building component involve its shape, length, width, height, angle, and so on. On the other side, non-geometric (or alphanumeric) information refers to the textual representation of the building information. Typical examples of non-geometric information about a building component involve its ID, manufacturer name, installation date, cost, and so on. A BIM model provides a collaborative platform to create and coordinate both geometric and alphanumeric information of each building component in the early stages and stores the information available for later stages which then can be maintained and transferred to other systems throughout the building lifecycle (Becerik-Gerber et al., 2012; Pärn et al. 2017). Table 2.4 summarises the BIM application areas in FM.

A complete as-built BIM model helps FM personnel to detect the precise location of a deficient component. An inspection record that is attached to the associated equipment in the BIM model supports maintenance, repair or replacement decisions. Data critical for space management such as spatial location, type, name, and area calculations can be retrieved from the BIM model and enable facilities managers to allocate and manage building spaces according to the needs of the occupants and business. BIM models allow for the creation of new assets as well as updating the existing ones.

Table 2.4: BIM application areas in FM.

Category	Description
Asset creation, real-time data access, and update	Early implementation of BIM ensures critical building information is created in the design and construction phases and transferred to the operational phase. Intelligent models store a vast amount of data regarding each component (name, type, location, manufacturer, installation/replacement date, cost, O&M manual, specification, warranty, work order history, test report, sensor information, etc.) that is available and open to update throughout the entire building life cycle
Locating building components	As-built 3D models show the exact locations of MEP equipment, associated components, and furniture (HVAC system components, water line, gas line, electric wires, meeting tables, work stations, etc.)
Renovation and refurbishment	3D models provide an advanced visual representation of renovation or refurbishment alternatives in terms of geometry, dimension, material, texture, and light attributes. Moreover, BIM models support feasibility studies by automatically generating quantity take-off for required building material and labour together with their cost
Maintenance and repair management	Intelligent as-built 3D models support FM personnel to reach component-specific information (i.e., location, O&M manual, failure and repair log, work order history, etc.) when performing preventive, predictive or corrective maintenance activities
Energy and indoor environmental quality monitoring	Linking sensors to the 3D visual models of buildings and HVAC equipment enhance real-time energy consumption, carbon dioxide emission monitoring through BAS, enables unnecessary energy use tracking and supports energy conservation procedure development
Space management	3D models visualize building spaces with critical attributes (space location, number, name, description, boundaries, area calculations, etc.) and support space allocation decisions, monitor space utilisation status, and move management
Emergency management	Spatial information stored in BIM models help responsible personnel to make decisions through seeing the location of hazard/emergency, identifying the closest emergency response equipment (i.e., hydrant, fire extinguisher, first aid kit, etc.), and determining escape routes in case of emergencies. BIM models can be used for emergency simulations and emergency planning as well
Personnel training and development	Walking through visual models replace site-visits and presentations and provide a virtual training platform for FM personnel to get familiar with the building spaces, equipment and surrounding environment without visiting the physical building

In other words, BIM models are virtual or digital replicas of actual buildings. This helps FM personnel to get familiar with the building even before physically being there, conduct personnel training, and enable them to simulate different emergency scenarios to develop genuine action plans. Another application area of BIM in FM is to capture data regarding indoor environmental conditions. With the help of sensors, captured indoor data such as temperature, carbon dioxide, humidity and noise is visualized and monitored in real-time to ensure comfort conditions and control energy use.

2.2.3 Constraints to BIM implementation in FM

There is no doubt that the operational phase lasts significantly longer compared to the design and construction phases in the building life cycle. In this long period, FM practices not only require accurate and up-to-date information to perform efficiently but also generate more information regarding building operations. It is fair to say that building owners and facilities managers benefit the most from BIM implementation (Eadie et al., 2013). Nonetheless, the literature reveals that design and construction professionals are taking the most advantage of BIM. Despite the great potential of BIM for FM, BIM-enabled FM practices are still lacking compared to design and construction applications. Table 2.5 below summarises the reasons for low BIM implementation in FM. The most prominent barriers to BIM implementation in FM are limited BIM awareness and poorly defined BIM execution procedures, lack of owner demand, limited BIM experience of FM personnel, interoperability problems and data transfer between different software systems, fragmented nature of FM data, incomplete and/or inappropriate BIM data for FM, ambiguities in data and model maintenance, lack of evidence quantifying efficiency gains using BIM for FM, and late involvement of FM discipline in projects, respectively (Becerik-Gerber et al., 2012; Korpela et al., 2015; Patacas et al., 2015; Pärn et al. 2017; Dixit et al., 2019; Gao and Pishdad-Bozorgi, 2019).

In addition, a recent study claims that short-term FM contracts as another hindrance to the low use of BIM (Tezel et al. 2021). Building owners as well as facilities managers are not fully aware of what is BIM and how BIM can be utilized in the operational phase. In most cases, BIM is accepted as another brand-new high-cost technology investment.

Table 2.5: BIM implementation barriers in FM.

Category	Description
Unclear benefits of BIM for FM	There is a lack of proof of productivity gains, reduction in equipment failure, reduction in maintenance cost or better energy use within buildings due to the use of BIM in the operational phase
High technology investment cost	BIM requires cutting-edge technology investment in both hardware and software. BIM hardware and software need frequent updates to ensure their functionality. Continuous employee training is also required so that the invested technologies are utilised in an efficient manner
Lack of owner demand	Building owners or clients are not aware or fully convinced about the productivity gains that BIM promises, therefore although they request BIM-based design and construction, they do not particularly request the use of BIM in the operational phase
Unspecified FM information needs	It is harder to define what information is needed, which model element is necessary or how to prepare that model in the maintenance phase compared to the design and construction phases
Late involvement of FM in projects	It is important to involve FM as early as possible to identify information requirements for the operational phase and ensure the appropriate information handover, however, in most cases FM teams arrive to the project at the compliance
Unstructured, incomplete and late delivery of information	All information regarding building and its systems are often delivered just before the building is commissioned which leaves no room for building owners or facilities managers to control whether the information they require for the operational phase is included or not
Lack of standardized FM tools and processes	The FM services are naturally fragmented and FM professional use numerous software systems each requesting different type of data for different purposes
Lack of interoperability and data standards	There is a lack of interoperability and data standards to ensure automatic or semi-automatic data transfer between BIM models and FM software systems, in addition, existing data transfer procedures are manual, costly, time consuming, and vulnerable to data loss
Lack of clarity about responsibility on information production, delivery, and maintenance	BIM models go through several modifications during the whole life cycle, and it is important to define which information will be delivered by whom, when, how, and who will be responsible for the overall maintenance of the information within BIM models

Table 2.5 (continued): BIM implementation barriers in FM.

Category	Description
Limited BIM technology experience of FM staff	FM embodies multiple disciplines to ensure the functionality, comfort, safety, and efficiency of built assets. Most FM personnel do not have expertise in the architecture and construction fields, consequently they do not have experience in BIM technology
Lack of real-life examples	Both building owners and facilities managers require real-life examples and best practice guides to understand and implement BIM into FM practices

As discussed in the BIFM forum (2018), there is a lack of cost-based benefit evidence of BIM in FM, which is attributed to the primary reason for the disconnection between expected and actual BIM-FM integration. To accelerate BIM implementation within the industry, facility managers first need to understand for what purposes they can utilise BIM and what benefits they would expect from BIM.

2.3 BIM Implementation for FM

Identifying, retrieving and processing proper data for efficient FM practices has been one of the main competencies of FM teams (IFMA, 2018) and one of the primary concerns of BIM-FM researchers. Every day, FM professionals utilise a variety of software for numerous tasks and activities. However, each FM task in each building requires different information depending on the scope of service and building complexity. The fragmented nature of FM data and services makes it harder to propose a one-size-fits-all solution. BIM-enabled FM practices promise complete, accurate, and automated data handling and information management processes. Still, identifying the information requirements of FM tasks and defining the data exchange process between different software is the major difficulty of BIM-FM integration (Wijekoon et al., 2018).

2.3.1 Information requirements

An early study by Becerik-Gerber et al. (2012) proposes a structure for non-geometric BIM data requirements based on the existing FM data capture process and interview results with FM professionals. Their classification adopts a sequence-based approach for information creation and proposes a responsibility distribution for involved parties to ensure building information is provided and maintained throughout the building life cycle. Likewise, Lucas et al. (2013a, 2013b) develop sequence diagrams of FM tasks in a healthcare facility by documenting information needs, interactions and communications between different actors. Later, Thabet and Lucas (2017) employ spreadsheets to collect and transfer information of a large educational institution. Their framework is open to variations for different FM tasks. Patacas et al. (2015, 2016) evaluate the existing open BIM standards (IFC and COBie) and propose a framework to identify, validate and visualise different data types from different models and databases. In their studies, they use three data categories: graphical data, non-graphical data, and documentary data. Mayo and Issa (2016) carry out a Delphi survey with FM experts to develop a list of basic deliverables for building owners. Another study by Cavka et al. (2017) focuses on the owner information requirements in BIM-enabled project delivery and develops a conceptual framework to connect digital and physical products to the owner's requirements. Their framework has three data categories: space, system and components. In the same year, Rodriguez-Trejo et al. (2017) identify and prioritise sustainable FM KPIs and propose a decision support system for building owners. They recommend including six KPIs namely, cost, space, energy, sustainability, quality, safety, security and well-being within the BIM Execution Plans. A recent study by Ashworth et al. (2019) cooperates with BIFM to develop an employer's information requirements (EIR) template. The six sections included in their guideline are purpose and scope, BIM and asset management strategy and objectives, project details, management requirements, technical requirements, and commercial requirements, respectively. Apart from the previous studies, the workflow by Abdirad et al. (2020) enables reliable and verifiable data collection for asset management purposes.

In addition to the studies focusing on BIM and FM integration in general, several studies identify required data for particular FM services. In terms of energy management, Mousa et al. (2016) receive building information (i.e., spatial, electricity use, natural gas use, and measurement time) from the BIM model and integrate them with carbon estimation models to visualise carbon dioxide emission within buildings. Moreover, Mantha et al. (2016) identify static and dynamic parameters (data types) that have a significant effect on building energy consumption levels. In terms of maintenance and repair, Yang and Ergan (2017) identify necessary data for HVAC troubleshooting namely, work order characteristics, complaint logs, static information, dynamic information, historical information and space-related information. In terms of emergency management, Jung et al. (2020) propose an information breakdown structure and develop a fire information management system for first emergency responders in buildings. A further study by Matarneh et al. (2019b) employs a task-based approach to identify required data for multiple FM tasks and proposes a data identification, compliance and exchange process using COBie.

2.3.2 Implementation standards

Information production, information delivery, and information management are district yet strongly related concepts (ISO, 2018). The information management process spreads throughout the building life cycle and it is only natural for the quantity of information to increase as buildings move into the later phases of their life cycle. Thus, identifying, producing and transferring the only relevant information to the operational phase is pivotal.

Between 2018 and 2022, ISO published the ISO 19650 series called "Organizing and digitization of information about buildings and civil engineering works, including building information modelling (BIM) - Information management using building information modelling" to provide a standardised information management framework for all actors of the building life cycle (see Figure 2.10). Although this series of standards delivers a foundation for internationally agreed terminology and principles for BIM-based production and management of information, they strongly encourage the development of national annexes for better practices.

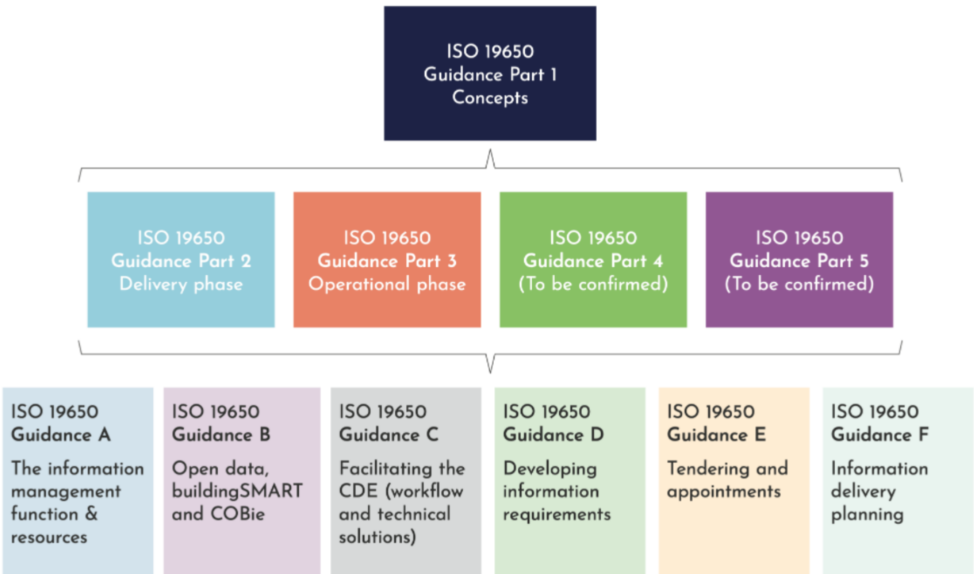


Figure 2.10: ISO 19650 series of standards (adapted from UK BIM Framework).

The actors, their roles and their relationship within the building life cycle are given in Table 2.6 and Figure 2.11 based on ISO 19650 series. As listed in Table 2.6, appointing party is the client, asset owner or employer who is responsible for the management of information. Appointing party determines information requirements, identifies all the principles and procedures about the delivery of information, sets up a common data environment (CDE), reviews the delivered information models, and archives information for future use. The lead appointed party coordinates the information between appointing party and the delivery team. It is the lead appointed party's responsibility to establish BIM Execution Plan (BEP) and other resources showing, the delivery team's capability and capacity, mobilization, and risks. The appointed party is the supplier of services and provider of information together with one or more task teams. The appointed party assesses the task team's capability and capacity, prepares delivery plans for information, and creates the requested information.

Table 2.6: ISO 19650 actors and their roles within the building life cycle.

Actor	Definition
Appointing party	Receiver of information concerning works, goods or services
Lead appointed party	Coordinator of information between appointing party and delivery team
Appointed party	Provider of information concerning works, goods or services
Project team	Appointing party and all delivery teams
Delivery team	Lead appointed party and their appointed parties
Task team	Individuals assembled to perform a specific task

Further groups identified by ISO 19650 involve the task team, delivery team and project team, respectively (see Figure 2.11). Among them, the task team is responsible to perform a specific task within the whole information management process that often involves one person. The delivery team is responsible to deliver the information and comprises the lead appointed party and their appointed parties. Lastly, the project team is the biggest entity involving all actors in the information management process.

The first part of the 19650 series, BS EN ISO 19650-1:2018 provides recommendations to develop an information management framework including information exchanging, recording, versioning and organizing. According to ISO 19650-1:2018, collaboration is the key to success during the operational phase. In the beginning, the building owner and FM service provider should identify what information is required for the FM services during the operational phase.

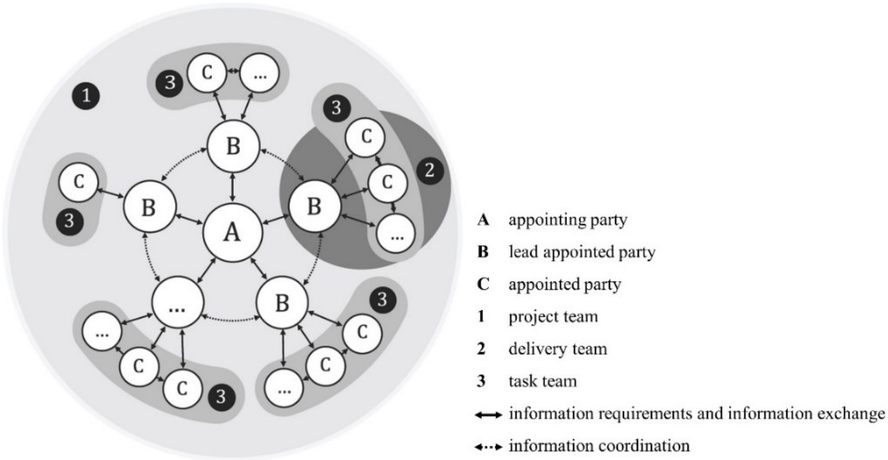


Figure 2.11: ISO 19650 actors and their relationship within the building life cycle.

Figure 2.12 below illustrates the different types of information and their relationship. The asset information model (AIM) and project information model (PIM) are the information repositories and include both structured (i.e., geometrical models, schedules, databases, etc.) and unstructured (i.e., documentation, video clips, sound records, etc.) information. The organizational information requirements (OIR), project information requirements (PIR), asset information requirements (AIR), and exchange information requirements (EIR) should define the level of information need in terms of information quality, quantity, and granularity.

As highlighted earlier, the quantity of information tends to increase throughout the building life cycle. Therefore, it is important to consider the value of information and deliver only the minimum amount of information needed to respond to each requirement. Other than that will be a waste of time, effort, and money for all parties.

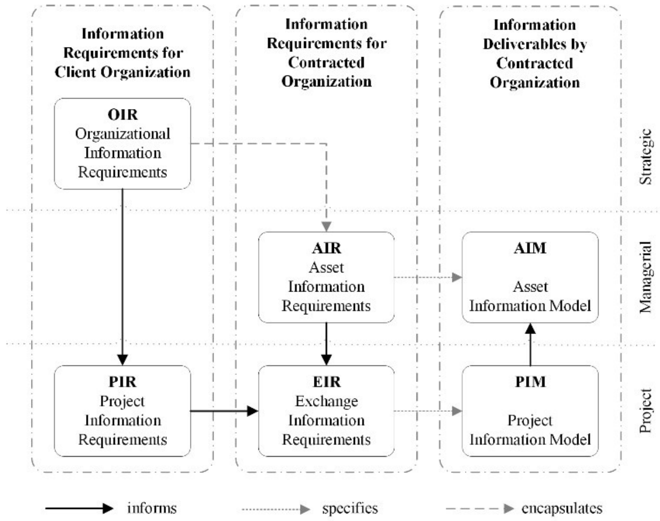


Figure 2.12: Different types of information by BS EN ISO 19650-1:2018.

Then, the information delivery cycle should be planned in terms of who delivers the information how and when, and who will approve the delivered information before transferring or exchanging (see Figure 2.13). Thus, it is recommended to implement a common data environment (CDE) to ensure all actors can produce, manage, share and exchange information whenever necessary. Information should be delivered based on pre-defined information exchange and each information container should be directly related to one or more pre-defined information requirements. All parties are responsible for the timely delivery of appropriate information. The overall process of information management proposed by ISO is seen in Figure 2.14 below.

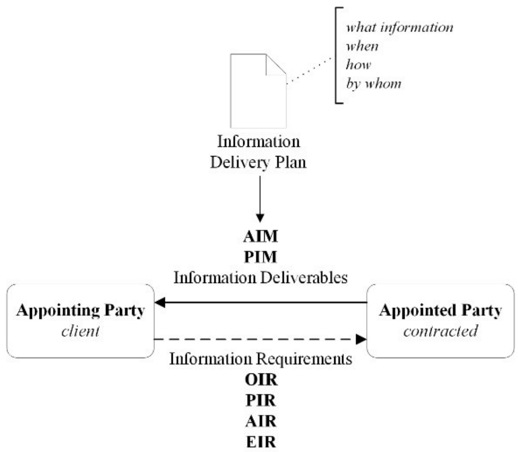
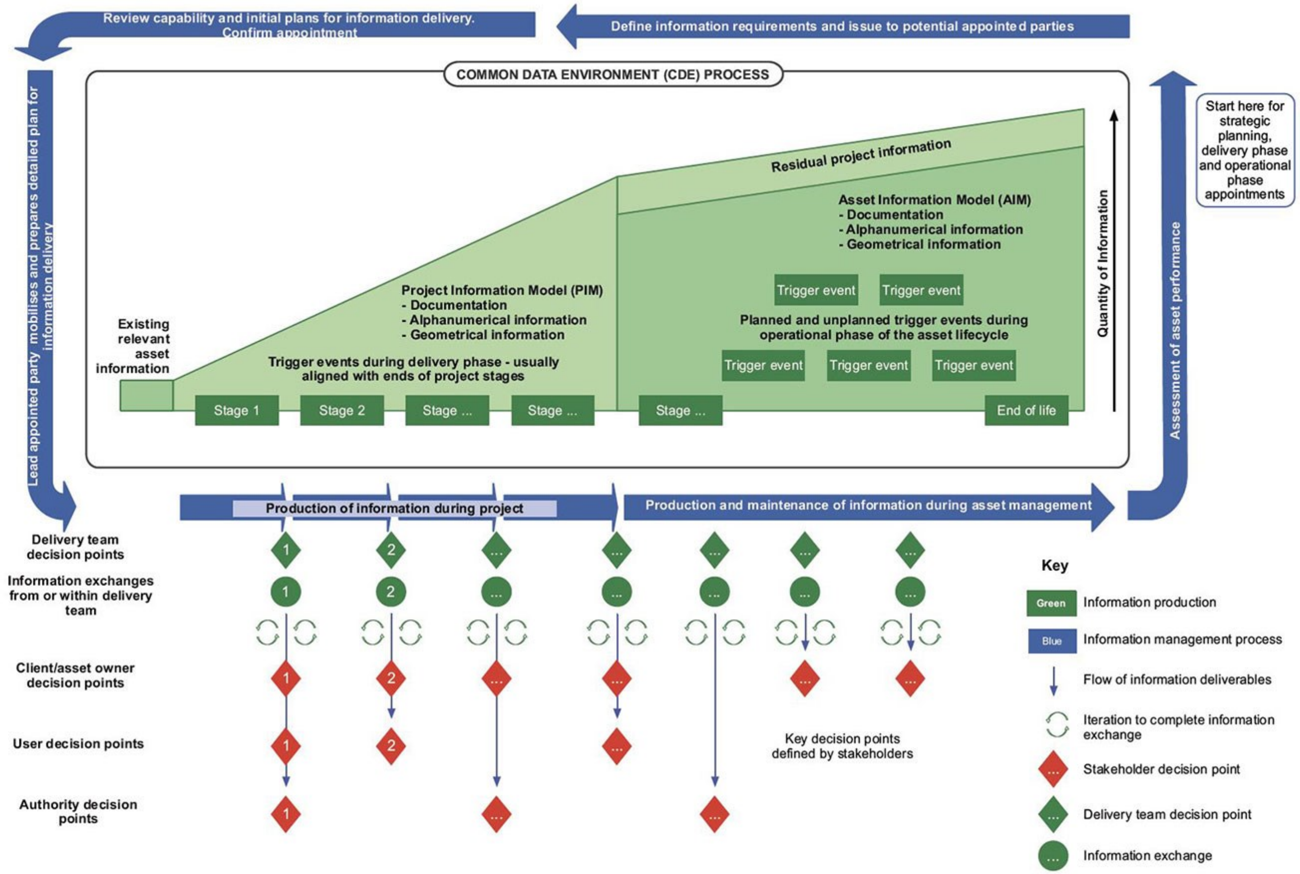


Figure 2.13: Information delivery cycle by BS EN ISO 19650-1:2018.

The second part of the 19650 series, BS EN ISO 19650-2:2018 specifies an effective and efficient information management process using BIM during the delivery phase of built assets. Building owners or their representatives are responsible for providing IT infrastructure such as CDE and technology training such as information standards to the FM service providers. Figure 2.15 illustrates the 8 steps of the information management process by ISO 19650-2:2018 which are (1) assessment and need, (2) invitation to tender, (3) tender response, (4) appointment, (5) mobilization, (6) collaborative production of information, (7) information model delivery, and (8) project close-out, respectively. See Appendix A for a detailed representation.



b) BS EN ISO 19650-1:2019, Figure 1

Figure 2.14: Information management process by BS EN ISO 19650-1:2018.

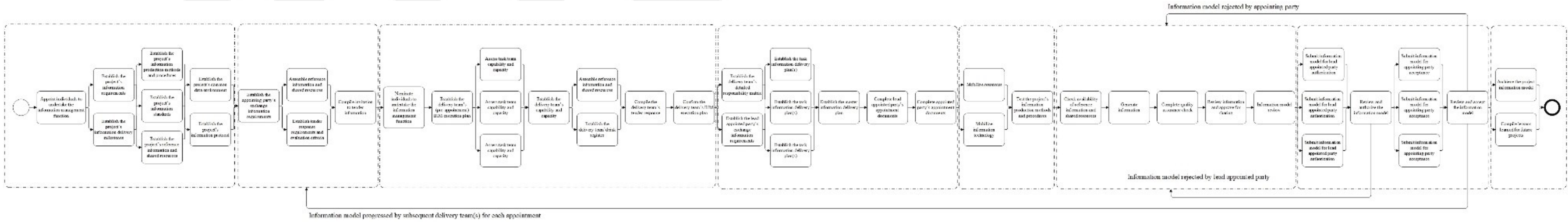


Figure 2.15: Steps of information management by BS EN ISO 19650-2:2018.

As a first step, assessment and need step guides appointing party to assign individuals to carry out the information management process within the organization. Here, appointing party establishes the project's information requirements and relevant procedures for the production and delivery of the information (i.e., information delivery milestones, information standards, procedures and methods, CDE, etc.). Next, in the invitation to tender step, appointing party prepares the exchange information requirements (EIR) and invites organizations to provide service. The tender response step helps appointing party to assess the information delivery teams in terms of BIM execution plan (BEP), team capability (ability to produce and manage information) and capacity (timely delivery of information), mobilization plan, and risk assessments prepared by prospective lead appointing party and associated information delivery teams. The lead appointed party confirms the BEP and establishes a detailed responsibility matrix for information delivery teams to identify what information is to be produced by whom and when it is exchanged with whom during the appointment step. Meanwhile, task teams prepare task information delivery plans (TIDPs) that are later aggregated into a master information delivery plan (MIDP) by the lead appointed party. In the mobilization step, the lead appointed party tests and activates resources including IT infrastructure and CDE to serve the collaborative production of information. The collaborative production of information step enables the production of project information in accordance with the previously defined standards, methods and procedures. Control measures ensure the appropriate information is shared within the CDE. The information model delivery step defines the procedures for the lead appointed party to review, authorize and accept information models developed by task teams. As the final step, the project close-out step requests appointing party to archive the project information model (PIM) within the CDE and suggest capturing lessons learned throughout the entire project.

The third part of the 19650 series, BS EN ISO 19650-3:2020 enables the appointing party to establish their information requirements during the operational phase of built assets. This document specifies the information management process for both foreseen or scheduled events such as annual maintenance tasks, and unforeseen events such as new projects or unexpected equipment breakdowns and accidents. Figure 2.16 illustrates the 8 activities of the information management by ISO 19650-3:2020 which are (1) assessment and need, (2) invitation to tender/request to provide service, (3) respond to invitation to tender/request to provide service, (4) appointment, (5) mobilization, (6) production of information, (7) information model acceptance, and (8) AIM aggregation, respectively. See Appendix B for a detailed representation.

Assessment and need guides the appointing to assign individuals to carry out the information management process, establish organizational information requirements (OIR) and asset information requirements (AIR), identify the assets to be managed, and set up the procedures and technology infrastructure for the production of information. In the invitation to tender/request to provide service step, appointing party prepares the exchange information requirements (EIR) and arranges a formal tendering process or requests to provide service for the delivery of information. The response to invitation to tender/request to provide service process helps the prospective lead appointed party to assess the information delivery team in terms of BIM execution plan (BEP), team capability and capacity, mobilization plan, and risk assessments. During the appointment process, the lead appointed party confirms the information delivery team's BEP and establishes a responsibility matrix clarifying what information is to be produced by whom and when to be exchanged with whom. Meanwhile, task teams develop task information delivery plans (TIDP) that are later aggregated into master information delivery plan (MIDP) by the lead appointed party. The mobilization process guides the lead appointed party to test and activate necessary resources including IT infrastructure and CDE for the production of information according to TIDPs. Once the information is delivered by delivery teams and authorized by the lead appointed party, appointing party reviews the information model to control its appropriateness to previously defined information production methods and procedures. This process is called information model acceptance and it leads to the asset information model (AIM) aggregation process. Appointing party either accepts the information model and transfers it to the "published" state within the CDE or rejects it and requests changes and resubmission. Finally, the AIM aggregation process defines the procedures for information reconciliation and maintenance of the AIM.

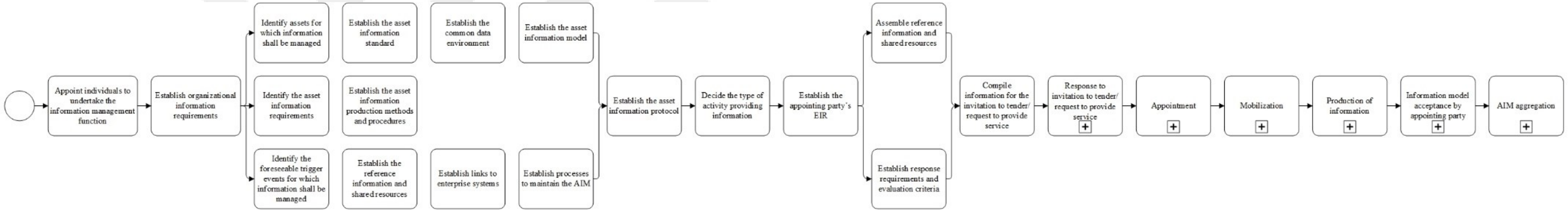


Figure 2.16: Information management activities by BS EN ISO 19650-3:2020.

The fourth part of the 19650 series, BS EN ISO 19650-4:2022 explains the information exchange process between the information provider and the information receiver. According to ISO 19650-4:2022, the information provider should produce the necessary information as “work in progress” containers, and then exchange the information with the information receiver as “shared” containers. Finally, the information receiver should control the shared information to ensure it fulfils the EIR standards and accepts it for “publication”. Figure 2.17 illustrates the overall process of information exchange. All the processes and actions are naturally expected to comply with the remaining ISO 19650 series which are ISO 19650 1-3 and 5.

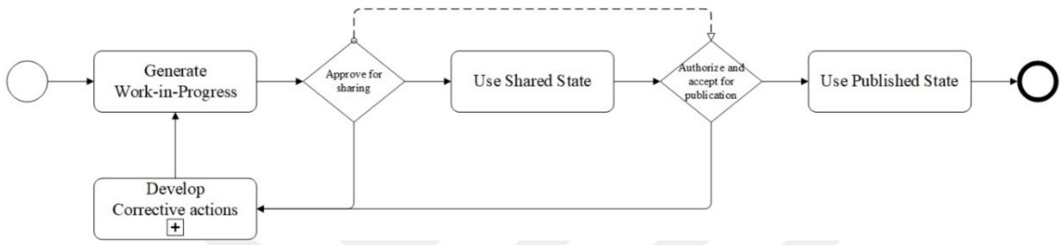


Figure 2.17: Information exchange process by BS EN ISO 19650-4:2022.

The final part of the 19650 series, BS EN ISO 19650-5:2020 is a specification that defines the principles of the management process of sensitive information with security in mind. The framework described in ISO 19650-5 guides organizations to understand the vulnerable nature of information, create and promote a security-minded culture, and reduce the risk of loss, misuse or modification of information. Figure 2.18 illustrates the process for implementing the security-minded approach by ISO.

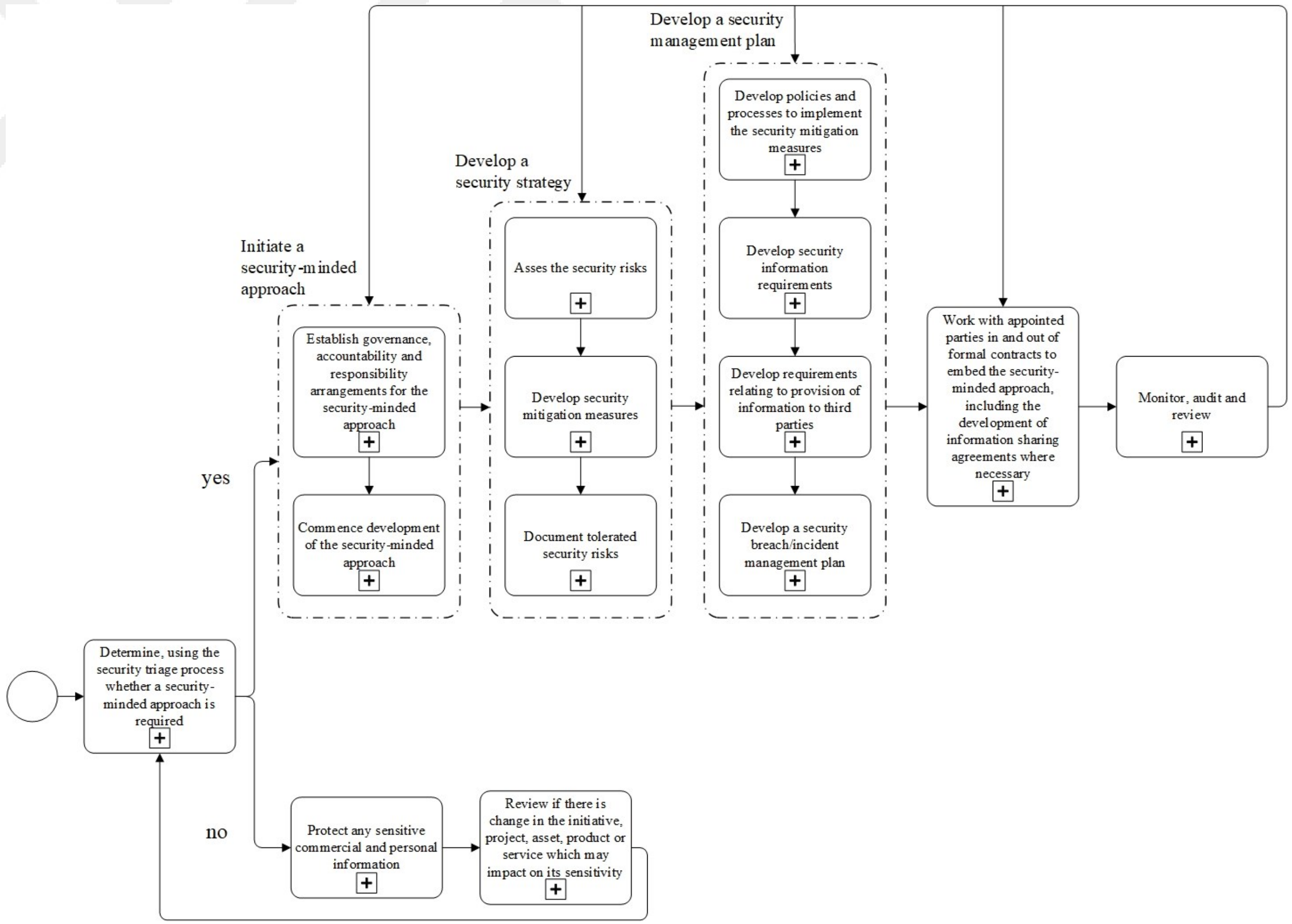


Figure 2.18: Implementation of security-minded information management approach by BS EN ISO 19650-5:2020.

3. A MIXED METHOD RESEARCH ON THE AWARENESS AND USE OF BIM FOR FM: CASE OF TURKEY

This chapter represents the results of a two-fold study on BIM-based FM practices within the Turkish FM industry. First, a quantitative research approach is employed to determine the current awareness and utilisation level of BIM by FM industry professionals, identify the information requirements for FM services, and understand the existing barriers to efficient and effective FM practices. Then, a qualitative research approach is employed to discuss the reasons for low BIM adoption among FM professionals and within the industry. Figure 3.1 illustrates the overall research process.

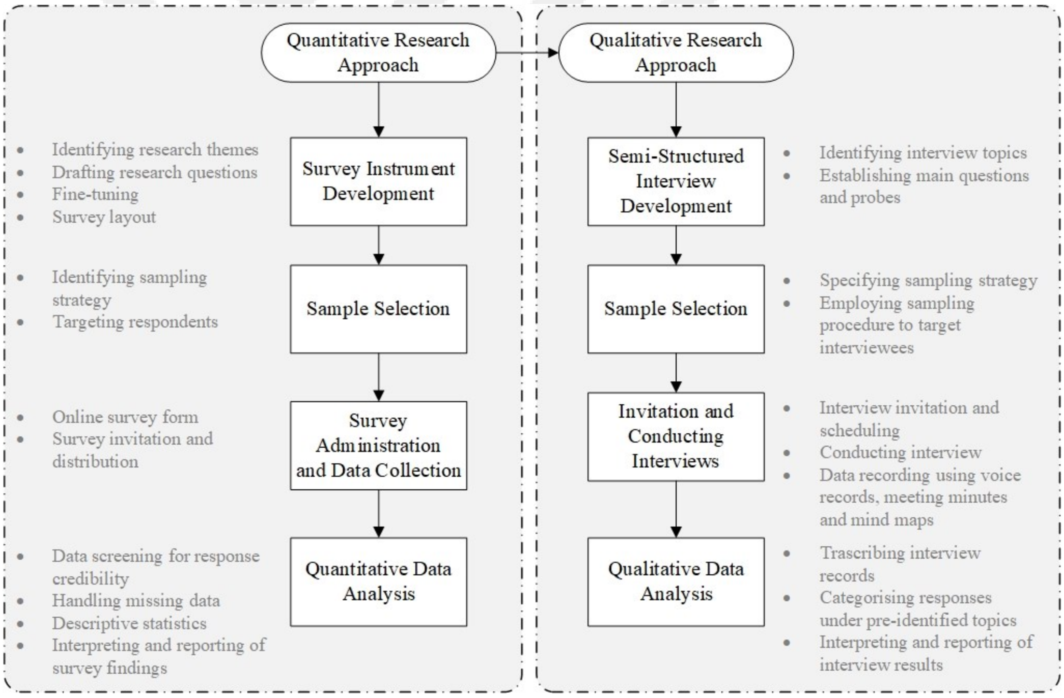


Figure 3.1: Overall research process on the awareness and use of BIM for FM in Turkey.

A questionnaire survey is a quantitative data collection tool that enables the researcher to measure how frequent a specific opinion, attitude, experience, process, behaviour, or prediction is in a particular phenomenon (Rowley, 2014). The structured set of questions in a questionnaire survey provides rapid and efficient data collection which later will be statistically analysed to explore further connections between questioned concepts. On the other hand, an interview is a qualitative data collection tool that has a planned list of questions yet is open for further dialogue and follow-up questions (Kendall, 2008). The combination of quantitative and qualitative methods by means of questionnaire surveys and semi-structured interviews is a prevailing research method (Bryman, 2006). Mixed methods, also known as the third research paradigm, has been defined as “a type of research design in which qualitative and quantitative approaches are used in type of questions, research methods, data collection and analysis procedures, and/or inferences” (Tashakkori and Teddlie, 2003). Incorporating mixed methods in an academic research allows for a more comprehensive and holistic understanding of a complex phenomenon. As a result, a mixed methods research has been employed to in this thesis study. The two-phase structure of the explanatory sequential mixed method applied in this study enables only one type of data collection at a time (Creswell, 2003; Subedi, 2016). Therefore, collecting and analysing quantitative data is followed by collecting and discussing qualitative data.

3.1 Survey on BIM Awareness and BIM Use within the FM Industry

Currently, BIM is not mandatory in Turkey’s AEC industry. Although many design and construction organisations have already been utilising BIM at Level-1 and Level-2 which allows them to create 2D and 3D models of projects and achieve multidisciplinary collaboration (Ozorhon and Karadag, 2017), there is a relatively slow market penetration compared to the other markets due to the internal dynamics (Ozener et al., 2020). A recent report by BIMgenius (2020) reveals that the use of BIM for FM purposes is around 10 per cent. In other words, current FM practices do not benefit from BIM as much as design and construction practices do. Nevertheless, BIM has started to change the FM industries in the same vein it did to the AEC. To carry out a smooth BIM implementation process, it is important to first understand the ongoing practices, issues and perspectives of professionals in the FM industry. Thus, a self-administrated questionnaire survey is employed as the quantitative research method in this study. The purpose of the questionnaire survey is to gather specific information on (1) the current level of BIM awareness and utilisation within the FM industry, (2) required information for FM services, and (3) existing barriers negatively influencing efficient and effective FM practices.

3.1.1 Survey development

The first section of the survey comprises a total of 5 questions to determine the current BIM awareness and utilisation levels within the FM industry. Respondents have multiple choices to indicate their familiarity with the BIM concept, understanding of BIM and BIM experience, and specify their perception of BIM utilization levels across the industry. The second section of the survey aims to identify the information requirements for FM services. Respondents are asked to indicate the level of importance of 15 items on a three-point scale from 0 to 2. Here, 0 denotes that specific data/information is not needed for the FM services, 1 denotes it is good to have that particular data/information, and 2 denotes that the FM team must have that particular data/information. The third section collects data on the problem areas that challenge the efficient and effective FM practices of industry professionals. Respondents are asked to indicate their agreement or disagreement on 11 problem items (0-disagree and 1-agree) retrieved from the literature. In addition to the listed items, two open-ended questions allow respondents to make further contributions to the FM information requirements and problem areas. The final section of the survey comprises 3 questions about the professional background of the respondents.

Table 3.1: Research themes, questions and question types.

Theme	Research Question	Question Type
BIM awareness	Familiarity with the BIM concept	Multiple-choice
	Meaning of BIM	Multiple-choice
BIM utilisation	BIM utilisation status	Multiple-choice
	BIM utilisation purpose	Checkboxes
Industry perception	Perception of BIM utilisation across the industry	Checkboxes
Information requirements	Required information/documents for FM services	Likert-scale, open-ended
Challenges	Problem areas in efficient and effective FM practices	Likert-scale, open-ended
Professional background	Position	Multiple-choice, open-ended
	Years of experience in the last organisation	
	Years of experience in the FM industry	

Table 3.1 shows the research themes, research questions, and question types involved in the survey.

3.1.2 Sampling strategy and respondent characteristics

A sample is required to investigate explanations for context-specific issues in the field of BIM-based FM practices. Therefore, this study targets participants from organizations that could potentially provide insight into the use of BIM for FM. Turkish Facility Management Association (TRFMA), Professional Facility Managers Association (PTYD), Urban Facility Management Association (TRKTYD), and Turkey branches of three well-known international FM-provider companies constitute the population for the study. The associations mentioned above house more than ninety member companies, among them are six international companies and two state-owned companies. Their responses are expected to be representative of the industry because these are the largest societies in Turkey, comprised of professional facility managers and leading FM companies. It is important to note that FM is a relatively young and scattered industry in Turkey. Several national and international FM service providers offer both soft and hard FM services to various types of buildings including healthcare, education, hospitality, and residences for years. However, there is a lack of consensus among the industry actors on the definition and the scope of FM services. The establishment of professional FM associations in Turkey is considerably new. In addition, national standards and guidelines are yet to be established.

The invitation for an online survey has been sent to these organizations via email and responses are collected within the first quarter of 2021. Overall, thirty-eight experts responded to the survey. However, one response is excluded during the data screening process because the missing information related to the respondent's professional background prevents the credibility of the answers. In the end, the study population consists of thirty-seven experts as given in Table 3.2.

As Table 3.2. indicates that the largest portion of the job titles of the respondents is Founder/General manager with a response rate of 43%. The second largest category of job titles is the Director/Leader/Manager category, which accounted for 24% of all job titles. Vice General Manager is the third largest group with a response rate of 16%. In addition, among the respondents are consultants, specialists and taking other roles within the FM industry. Given the results, it is fair to note that the survey drew a significant number of high-ranking respondents, including the company's founder, general manager, and vice general manager.

Respondents are asked to indicate their total industry experience and presence in their latest organisations among the following categories: (1) less than 5 years, (2) 6 to 10 years, (3) 11 to 15 years, (4) 16 to 20 years, (5) 21 to 25 years, and (6) 26 years and more.

Table 3.2: Characteristics of survey respondents.

Variable	Categories	Number of Responses	Ratio
Position	Founder/General Manager	16	0.43
	Vice General Manager	6	0.16
	Director/Leader/Manager	9	0.24
	Consultant	2	0.05
	Specialist	2	0.05
	Other	2	0.05
Years of experience in the FM profession	Less than 5 years	4	0.11
	6 to 10 years	11	0.30
	11 to 15 years	10	0.27
	16 to 20 years	5	0.14
	21 to 25 years	4	0.11
	26 years and more	3	0.08
Years of experience in the current organisation	Less than 5 years	14	0.38
	6 to 10 years	11	0.30
	11 to 15 years	5	0.14
	16 to 20 years	6	0.16
	21 to 25 years	1	0.03
	26 years and more	-	-

Almost one of each three respondents (30%) has 6 to 10 years of industry experience, followed by 11 to 15 years (27%), and 16 to 20 years (14%). Both less than 5 years experienced respondents and 21 to 25 years experienced respondents have an 11% of presence within the sample. The smallest group (8%) constitutes professionals who have been working within the industry for more than two and a half decades. Responses given to the question "How long have you been working in your latest organisation" shows that the largest group (38%) have been working in the same organisation for less than 5 years, followed by 6 to 10 years (30%), 16 to 20 (16%), and 11 to 15 years (14%) respectively. Among the respondents, only 1 professional has been working in the same organisation for more than 20 years (21 to 25) and none of the respondents has been in the same place for more than 26 years. Overall, the majority (60%) of the respondents have more than 10 years of experience in the facilities management profession and 62% have been working in the same company for more than five years. It can be concluded that the survey respondents are a highly experienced and representative group of professionals in the Turkish FM industry.

3.1.3 Survey results

Quantitative data collected through the survey is analysed in terms of frequency distribution, mean, rank, and comparison.

3.1.3.1 BIM awareness and utilisation

First of all, the BIM awareness of the respondents is measured by asking how familiar they are with the BIM concept. As seen in Figure 3.2, only 4 of 37 respondents are actively using BIM for FM and 1 individual is planning to use it. Apart from them, 5 respondents (14%) heard about BIM for the first time, 9 (24%) heard about BIM some time ago but they are not informed about its details, and 18 (49%) know what BIM is but did not use it so far.

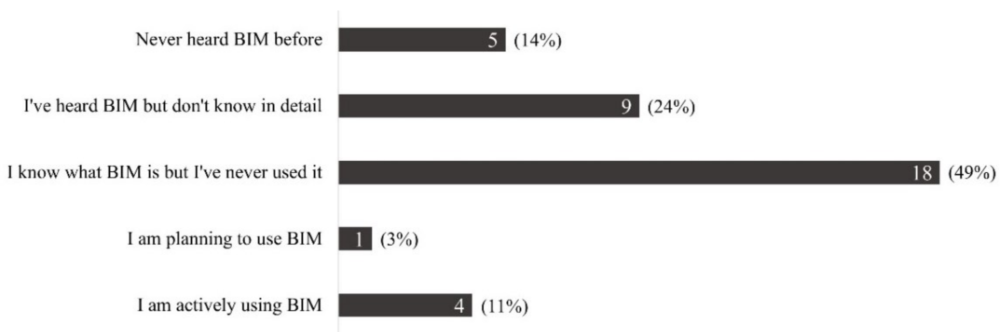


Figure 3.2: BIM awareness of the respondents.

Overall, 86% of the respondents indicated that they heard of BIM before taking the survey. Excluding the small minority (14%) who heard about BIM for the first time, it can be concluded that there is a high level of awareness of BIM within the industry. However, previous literature points out a low level of understanding regarding the potential of BIM in FM and people are highly expected to recall different aspects when hearing the BIM term. In fact, society treats BIM as a 3D modelling tool for architectural design or considers it as engineering software. To figure out what BIM means to the respondents, an additional question is included in the survey.

Concerning the question "What does the BIM concept mean to you?", Figure 3.4 presents the BIM understanding of the respondents. Around two-thirds of the respondents (65%) consider BIM as a platform that enables all disciplines to work throughout the design, construction and operation phases. The remaining treats BIM either as an architectural platform (3%), a platform for architects and construction engineers (8%) or a platform for architects and all engineering disciplines (16%). There are only a few respondents (8%) who do not have any idea at all.

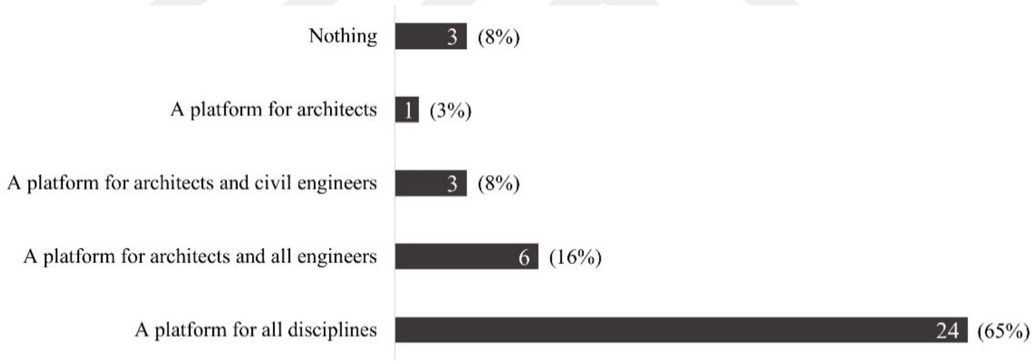


Figure 3.3: BIM understanding of the respondents.

The findings in Figures 3.2 and 3.3 indicate a high familiarity and awareness of FM professionals regarding BIM. To detect the BIM utilisation level within the FM industry, respondents are asked to specify if they have ever used BIM and if they have ever heard of other companies using BIM. The responses to both questions are displayed in Figures 3.4 and 3.5.

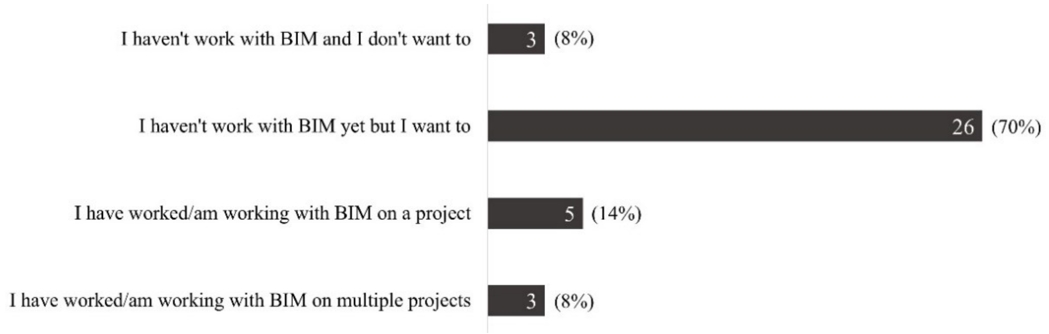


Figure 3.4: BIM utilisation of the respondents.

Figure 3.4 shows that the majority of the respondents (70%) are willing to work with BIM although they have not worked with it until now. Around 1 of every 5 facilities managers (22%) have used or are still using BIM in one or more of their projects. It is natural to observe resistance to BIM within the industry as well. Among the respondents are 3 professionals who strongly rejected the idea of BIM implementation. Yet, the findings provide great evidence of the growing tendency of BIM-based FM services in the country. On the other hand, Figure 3.5 shows the respondents' observations of other FM companies, where many of them (65%) have not heard of others using BIM. Among those who already heard about the use of BIM by other companies, 6 received positive feedback, 1 received negative feedback and 6 solely heard without any additional impression on its benefits or handicaps.

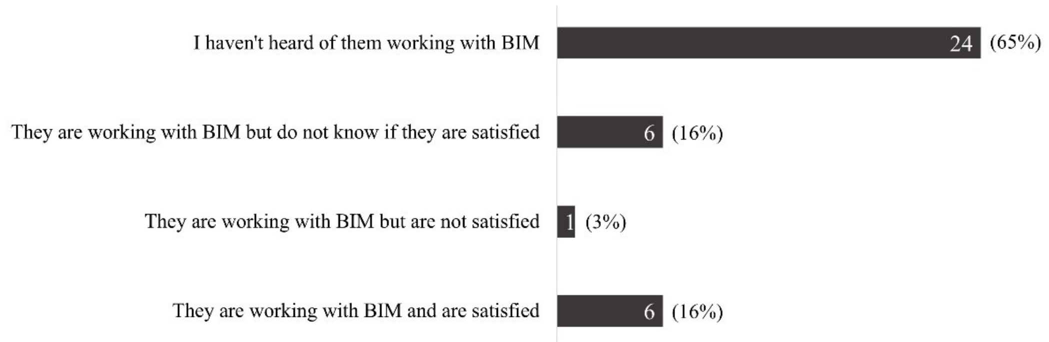


Figure 3.5: BIM use of other FM organisations.

The previous literature identifies and explains the application areas of BIM in FM. However, because each facility has its own needs and requirements, there is no one-size-fits-all solution in the operational phase. Respondents with prior BIM experience were asked to specify their reasons for employing BIM in facility operations, and the results are shown in Figure 3.6.

Figure 3.6 reveals the most frequent BIM application area in FM as tracking maintenance and repair works. 75% of the BIM-users issue maintenance and repair work orders for equipment or building components and track their progress using BIM. In connection with this, creating and updating digital assets and monitoring energy consumption are the second most frequent (63%) application areas of BIM in FM. In the conventional handover process, it is highly probable to observe discrepancies between the hard copy documents and the actual building. Moreover, during their life cycle buildings face numerous changes in the furniture, MEP system components, fire and other safety systems, façade elements and so on. Therefore, it is crucial not only to keep the data on an easy-access digital platform but also to keep them up-to-date (Korpela et al. 2015). At this point, BIM emerges as a promising platform because it can capture the data in a 3D environment, perform further analysis and simulations, and enable data transfer between different software systems. Although data updating requires extra time or the use of advanced technologies such as point cloud and laser scanning, a single and transferable data source contributes to the decision-making process of facilities managers and other FM personnel.

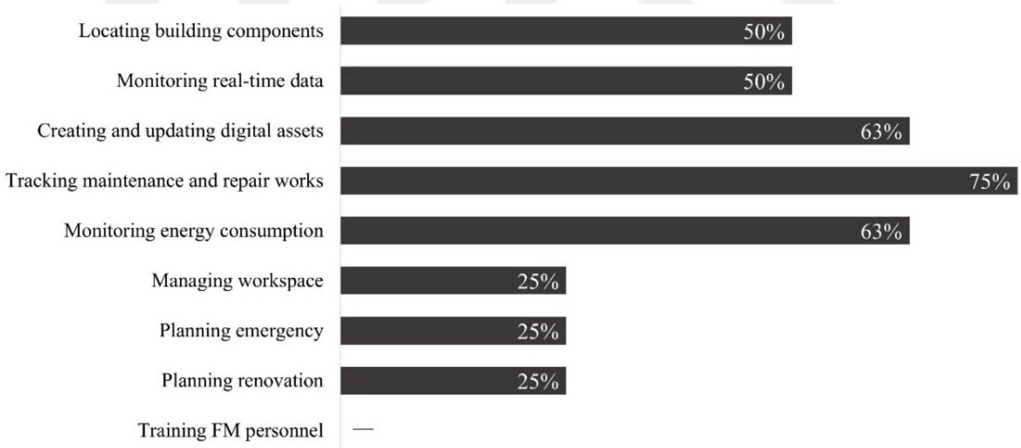


Figure 3.6: BIM use purposes of respondents.

FM professionals spend half of their time in building operations tasks including conducting equipment checks and daily rounds, maintaining facilities and systems, and conducting facilities repair activities (NIBS 2015). To efficiently perform these activities, they need to detect the exact location of building components and related information as soon and accurately as possible. Although BIM models are able to capture and visualize the necessary data and related documents (i.e., location, manufacturer information, attributes, manuals and warranties, etc.) of each component, only half of the users benefit from BIM for locating building components and monitoring real-time data of facilities. Furthermore, having the aforementioned data and real-time monitoring of the facility are critical to take immediate actions during emergencies. However, only 25% of the users are utilizing BIM to manage emergencies, plan renovation and manage workspace. Nevertheless, the most interesting finding is the missing use of BIM as a personnel training platform. BIM models are capable of realistically visualizing buildings and other assets so that FM personnel can get familiar with the facility in a virtual environment. Yet, none of the BIM-users benefits from BIM as a training platform. The last-minute involvement of FM teams might be the reason for the limited time for training, however fast personnel adaptation to the facility plays a crucial role, especially in emergencies.

Following the BIM awareness and utilisation measures, the survey collects industry insights about the future of BIM use in the FM sector in Turkey. Figure 3.7 highlights a clear difference among facilities managers' points of view regarding the future of BIM in the industry.

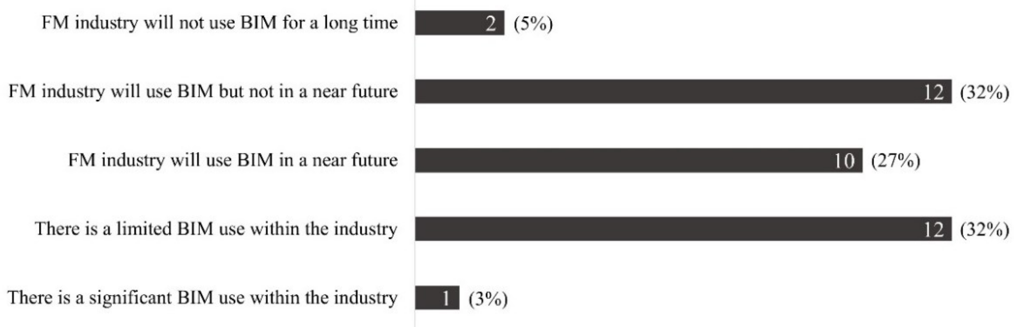


Figure 3.7: Future insights regarding the BIM use in the Turkish FM industry.

Around one-third of the respondents (35%) believe that BIM has already been used in the FM industry to some extent. 27% expect BIM-based practices will become popular in the near future (i.e., within 2 years) whereas 32% expect the same outcome to occur within 5 years. Overall, the majority (59%) of the respondents seem to agree that it will be implemented in the next two to five years. Even though 2 respondents do not believe BIM would be widely used for a long time, Figure 3.7 shows that a pioneering community is benefiting from BIM to some degree, while the rest are waiting for it to become more widely used.

3.1.3.2 FM information requirements

Table 3.3 shows the responses given to the question of how necessary it is to have the listed data and information for efficient and effective FM services. Contrary to common expectations, FM professionals prioritise an emergency plan, a document that describes the actions to take during emergency cases, and emergency scenarios at the top. Then, they look for equipment lists, manuals and warranties, equipment logs, maintenance and repair records, and the locations of emergency equipment (i.e., fire extinguisher, first-aid kit, etc.) within the building.

Table 3.3: Ranking of the FM data and information requirements.

Data/information requirements	**Responses**			**Mean**	**Rank**
	not needed (0)	**good to have (1)**	**must have (3)**		
Emergency plans	-	2	35	1.95	1
Emergency scenarios	-	3	34	1.92	2
Equipment lists and manuals	1	2	34	1.89	3
Equipment logs	1	2	34	1.89	3
Locations of emergency equipment	1	2	34	1.89	3
Regulations and standards	1	3	33	1.86	4
Specifications	-	5	32	1.86	4
Financial information	1	4	32	1.84	5
2D as-built drawings	-	7	30	1.81	6
Occupant information	2	3	32	1.81	6
Policies	2	7	28	1.70	7
Energy consumption logs	-	11	26	1.70	7
Personnel training documents	2	8	27	1.68	8
Certificates (energy, green building)	-	14	23	1.62	9
3D as-built models	-	17	20	1.54	10

It is interesting to note that, 2D as-built drawings such as floor plans and sections have relatively low priority compared to the above-mentioned documents. More interestingly, 3D as-built models that are supposed to be virtual copies of the buildings are the least requested ones. There may be two underlying reasons explaining this outcome. First, the data were collected during the first quarter of 2021, when all industries were still struggling with the COVID-19 pandemic yet they were continuing business under unstable economic conditions. Therefore, they may ask FM service providers to be prepared for emergencies. Secondly, facilities managers generally receive the major construction drawings, but the inaccurate or outdated floor plans or models do not help them to make further decisions regarding the building. Thus, they may not find these documents as useful as they were expected to be.

In addition to the listed items, Table 3.4 reveals other data and information requirements indicated by the respondents to the open-ended question “What is the other data and information required for efficient and effective FM services”.

Table 3.4: Other FM data and information requirements.

Other data/information requirements	Frequency
FM plan and clear definition of the FM service scope	7
Data for other asset and facilities management software systems (due time tracking, visitor/personnel tracking system, tenant/vehicle identification, etc.)	3
Information exchange and interoperability standards	2
Information on property owners	2
FM training documents, service-level agreements (SLAs) and KPIs	1
Repetitive maintenance work orders and instructions	1
Business continuity plan (BCP)	1

Respondents emphasise the importance of an adequate FM plan, a clear definition of the FM service scope, and interoperability standards for different FM technologies for better services. Based on the results, it can be concluded that the FM industry suffers from poorly defined contracts, unavailability of documents regarding critical assets, and technological discrepancies.

A further comparison is made to identify the difference between non-BIM-user and BIM-user facilities managers in terms of “must-have” information (see Figure 3.8). For all BIM users (100%), equipment lists and regulations and standards are the absolute must document when operating buildings, followed by 2D as-built drawings, equipment logs, emergency plans and scenarios, and financial data (88%). On the other hand, most of the non-BIM users require emergency plans first (97%), followed by equipment logs, emergency equipment locations, and emergency scenarios (93%).

It is interesting to note that none of the two groups looks for 3D digital models of the building, in contrast only half of the respondents in each group believe that 3D models are necessary and the remaining half do not need them at all. This finding may result from the limited BIM understanding of the respondents. Evidence shows that equipment checks, maintenance, and repair activities take half of the time of FM personnel every day (NIBS, 2015). Thus, an accurate 3D representation of each component with non-geometric details (i.e., manufacturer, install/replace date, manual, warranty, etc.) will be a time saver, especially in urgent cases. However, in most cases, BIM is accepted as a 3D visual without the associated “information”. Therefore, respondents may not find 3D models as necessary as other documents.

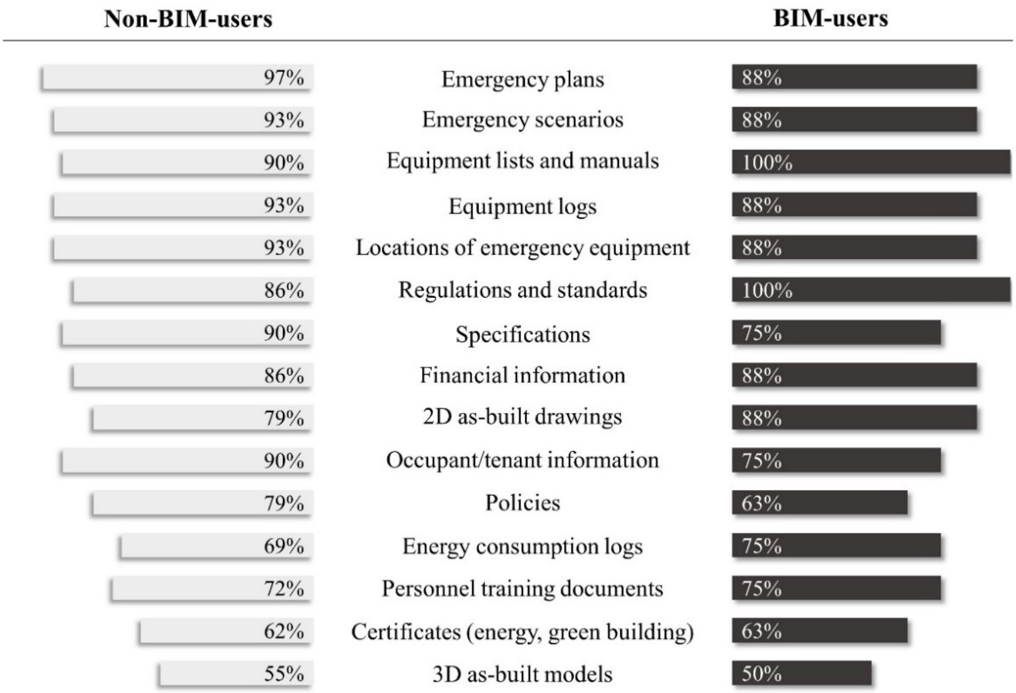


Figure 3.8: The “must have” information for non-BIM-users and BIM-users.

3.1.3.3 Existing problems of FM practices

A detailed review of both scientific literature and industry reports reveals several barriers to efficient and effective FM practices. Although most of these barriers have generic characteristics, they have different impacts on FM operations depending on the facility type and size, required services, applied technologies, and so on. Given the emerging BIM implementation within the FM industry, it is important to distinguish the problem areas for conventional and BIM-based approaches. Respondents were asked to indicate their agreement or disagreement with the given barriers to identifying the main issues influencing the efficient and effective operations of FM teams. The responses are represented in Table 3.5 to see the common problem areas and then divided into categories based on the respondents' BIM experiences to identify distinguishing factors (see Figure 3.9).

As seen in Table 3.5, the late involvement of the FM profession in projects and ignoring operational needs during the design phase are the top problem areas leading to further problems throughout the building life cycle.

Table 3.5: Ranking of the FM problem areas.

Problem areas	Responses		Mean	Rank
	disagree (0)	agree (1)		
Late involvement of FM	2	35	0.95	1
Neglecting FM in the design process	2	35	0.95	1
Lack of owner attention	6	31	0.84	2
Frequent changes in FM providers	7	30	0.81	3
Outdated drawings and documents	8	29	0.78	4
Limited resources for digitalisation	9	28	0.76	5
Incomplete as-built drawings	10	27	0.73	6
Diverse information requirements of FM	12	15	0.68	7
Interoperability between FM software	12	25	0.68	7
Technologically incompetent staff	13	24	0.65	8
Lack of BIM use in FM	13	24	0.65	8

The second problem is the lack of owner attention. More often than not, building owners or clients are concerned with the initial investment cost and do not pay attention to the importance of FM services on the economic life span of buildings. They prioritise lower operational costs over quality and frequently change FM service providers to obtain lower prices. The documents transferred to FM service providers are usually incomplete, insufficient or out-of-date. Digitisation and proper maintenance of these documents require an additional investment from building owners and clients. However, in opposition to the literature, the shortage of technologically competent FM personnel and lack of BIM utilisation by industry professionals are placed at the end. Although there is an expectation for widespread BIM implementation within the industry soon, it is not expected to solve the existing efficiency problems of the industry. Table 3.6 below shows additional problem areas perceived by FM professionals.

Table 3.6: Other problem areas perceived by the FM professionals.

Other problem areas	**Frequency**
Limited financial resources allocation for FM services	6
FM services provided by unprofessional agents	4
Short-term contracts and frequent changes in FM providers	3
Lack of understanding of the importance of FM services	2
Unnecessary involvement and service requests of clients	2
Design errors and unfinished construction works	2
Absence of regulations for the FM profession and services	1
Lack of integrated FM services	1

Figure 3.9 reveals that all the listed barriers are influencing FM operations to some extent regardless of the use of BIM. In other words, neither conventional nor BIM-based methods are a solution to the given problem areas. However, the most and the least frequent problems of both approaches are different. Among the non-BIM-users, late involvement of FM professionals in the projects and neglecting the FM requirements in the design phase are the most frequent problems with the highest rate of 97%. On the other hand, BIM-users fully agree on the outdated drawings and

documents of facilities as their most frequent problem. The most frequent problems of non-BIM-users settle among the second most frequent problems of BIM-users (88%) together with the delivery of incomplete as-built drawings, diverse information requirements of operational tasks, interoperability between FM software, allocating limited resources for digitalisation and insufficient use of BIM in FM.

The two groups also differ in terms of the least frequent problems as well. To the non-BIM-users, lack of BIM use in FM is the least frequent problem (59%) whereas to the BIM-users it is the technologically incompetent FM workforce (63%). Even though the scores seem close, the tiny difference between the two items embodies certain insights for FM professionals. First of all, although it is the least frequent problem for the BIM-users, technology-related incompatibilities of FM staff are still an important problem with 63% frequency. To fully benefit from BIM and other related technologies, FM personnel needs to use them actively and properly. On the other hand, the increasing use of machines and robots cause some people to fear losing their job. At this point, managers need to remind the importance of the personnel for building operations, emphasize the vitality of technology for fast and accurate decisions, and provide necessary training and support for the staff.

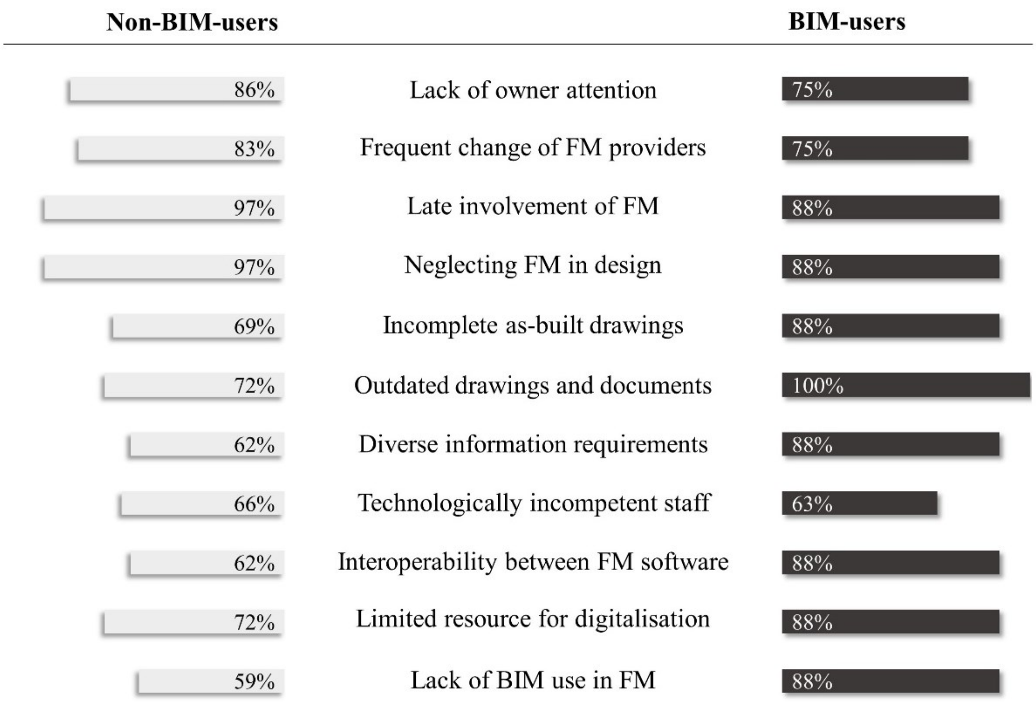


Figure 3.9: Barriers to efficient FM practices for non-BIM-users and BIM-users.

Another point is the thoughts of the non-BIM-users towards the current usage of BIM in FM. A non-negligible amount of them (59%) think that the lack of BIM use causes inefficiencies in operational tasks. Hence, the firms using BIM in FM are going to be the competitively advantageous ones.

3.2 Interview on BIM Implementation Challenges

In addition to the questionnaire survey seeking to understand the existing practices, issues and perspectives of professionals in the FM industry, a series of semi-structured interviews have been conducted to shed light on the reasons for the low BIM adoption levels within the industry. The qualitative data is collected through one-by-one interviews with industry experts who have prior BIM knowledge or demonstrable BIM experience.

3.2.1 Interview development

A set of semi-structured interview questions has been established to unveil the challenges of BIM implementation in FM practices through an in-depth examination of ongoing practices and perceptions of contemporary approaches. Table 3.7 shows the topic, main questions and follow-up questions (probes).

The interview questions are grouped into 4 main categories that are (1) FM business process, (2) FM team roles, (3) data/information collection, and (4) contemporary approaches to FM, respectively. The first question of the interview aims to understand the typical contracting process of FM services. The follow-up questions expand the understanding of FM contracts in terms of included services, contract duration, and the involvement of FM representatives in projects. The next question identifies which disciplines to be involved in a typical FM team. The probes of this question distinguish the absolute must people within the team together with their educational and professional backgrounds. The third question focuses on the data/information collection process. The follow-up questions in this section determine the critical data/information for FM services and the challenges to acquiring them. Moreover, this section discusses the early involvement of FM professionals in projects for better production, collection and management of building information. The final question measures the attitudes of interview participants towards contemporary FM approaches, namely BIM and Soft Landings phenomena. Further questions aim to clarify how familiar and experienced the participants are with these concepts, what are the expected/exercised benefits, and what are the anticipated/abided challenges of their implementation.

Table 3.7: Semi-structured interview questions.

Topic	Main Question	Follow-up Questions (Probes)
FM business process	Can you explain the steps of a typical FM contracting process?	- How do you contract FM services with a client? - What are the services that a typical FM contract covers? - At which phase of a project are FM representatives involved? - How long does a typical FM contract cover? - Is there a standard FM contract in Turkey? - What kind of contract do you use?
FM team roles	How do you form a typical FM team?	- Are there absolute must and desirable disciplines in an FM team? If so, what are they? - Why are some roles more important than others? - Are these roles differing according to the building type or contract type? How? - What kind of educational and professional background is desirable for each role?
Data/information collection	Can you tell us about the data/information collection process for FM services?	- What are the major problems with collecting information about the building? - Do you think that these problems are related to the attitude/awareness of other parties towards the FM phase? - What are the "must have", "good to have" and "not needed" data/information for FM services? - What data/information is the hardest to have? Why? - Do you think that the early involvement of the FM in the project (i.e., brief or schematic design) will solve these problems?

Table 3.7 (continued): Semi-structured interview questions.

Topic	Main Question	Follow-up Questions (Probes)
Contemporary approaches to FM	Have you heard of BIM or Soft Landings concepts?	- How familiar you are with these concepts? - What do they mean to you? - Do you use or intend to use any of them? - If you are using them, what kind of benefits do you have? - If you are planning to use them, what kind of benefits do you expect to have? - If you are using them, what kind of difficulties do you experience? - If you are planning to use them, what kind of difficulties do you foresee?

3.2.2 Sampling strategy and interviewee characteristics

The interview study employs an expert sampling (or judgment sampling) procedure to select the target respondents. Expert or judgment sampling is a strategy in which expert people are chosen to provide valuable options or assessments on the subject of the study (Taherdoost, 2016; Thietart, 2001). The interview respondents of this study are targeted from professionals with prior BIM knowledge or demonstrable experience in the BIM-based FM field. Prospective respondents were contacted via phone call and email, informed of the content of the interview, and invited to discuss the reasons for low BIM utilization within the industry, as well as the benefits and drawbacks of BIM for FM. In the end, a total of 9 semi-structured interviews with FM industry professionals have been conducted between 2019 and 2021. The primary reason for the unusually long study period of 2 years for an interview is the global outbreak of COVID-19. Due to the unexpected pandemic and associated restrictions, half of the interviews were held face-to-face and the other half were held using online meeting platforms. Each interview took between 30 to 60 minutes. Online interviews have been recorded with the consent of each respondent and later transcribed for content analysis. Meanwhile, face-to-face interviews were recorded as meeting minutes and mind maps. All records and transcripts were shared with the respondents during or after the meeting to ensure their responses were accurately reported and allow room for further comments. Table 3.8 shows detailed information about respondents as well as the interview process. In the table, each interviewee is represented with the letter P to ensure anonymity.

The first interviewee (I1) is the O&M chief of a national five-star hotel group. Department of I1 is responsible for the daily inspection of hotel grounds, maintenance and repair works of MEP systems, and monitoring of building energy consumption. I2 is the manager of one of the educational facilities of a well-respected national education group. The fundamental responsibility of I2 is to ensure a safe, healthy and quality educational environment for students. The school management doesn't have a permanent professional FM team but in-house personnel for the maintenance of the main building and other facilities within the campus. I3 is the operation manager of a shopping mall owned by the Turkish branch of an international real estate and investment organisation. The parent organisation has more than 55 years of experience in the professional operation and marketing of shopping centres, and the Turkey subsidiary has been in the retail market for more than 20 years. The responsibilities of the department of I3 include leasing, approval of interior designs and construction works, asset management and operations, budgeting, and centre finance. I4 is an academician with 20 years of experience in computer-aided design and BIM fields. I4 has an ongoing interest in the BIM-based FM domain and currently conducting a university-funded project. The purpose of the project is to generate BIM-based asset and space inventories of one of the university buildings to execute asset management, space management and periodic and preventive maintenance practices. I5 is a board member of a company that provides integrated facilities management services for more than 20 years. They follow a performance-based model in their services including property and asset management, energy management, sustainability management, performance management, and business continuity. I6 is the regional director and operations lead of a well-known international real estate and investment organisation that has more than 12 years of experience in managing various facilities. Department of I6 is responsible for real estate and lease management, space management, project management, and enterprise account operations including hard, soft and security services. I7 is an FM consultant, the former president of TRFMA and a board member of the European Facility Management Network (EuroFM). I7 is an experienced professional in ISO 41001 standards for FM services and has a particular interest in BIM-based FM research and practice. I8 is the technical service manager at the Turkey branch of a global organisation that provides integrated FM solutions. The parent organisation established its Turkey subsidiary in the 1990s and has been serving in more than 60 countries across the world. The final interviewee, I9 is the general manager at the Turkey branch of a global FM organisation. The parent organisation was established in the 1930s with the initial aim of providing security services to local customers. Today, they offer cleaning, catering, security, support, technical and workplace services in more than 30 countries.

3.2.3 Interview results

Qualitative data collected through the semi-structured interviews were initially transcribed and each individual response is grouped under pre-defined topics. Then, collected responses were scrutinized through an interpretive approach to spotlight the basis of the lack of BIM implementation and utilisation by the actors of the FM industry.

Table 3.8: Characteristics of interview respondents.

ID	Field of Organisation	Business Characteristics	Role in the Organisation	Experience	Interview	Date	Time
I1	Tourism	National	Operation & maintenance chief	15 years	face-to-face	2019	50 min
I2	Education	National	Manager	30 years	face-to-face	2019	40 min
I3	Real estate and investment	International	Operation manager	17 years	face-to-face	2019	30 min
I4	Education	National	Academician	20 years	online	2020	45 min
I5	Integrated FM services	National	Board Member	22 years	online	2020	65 min
I6	Integrated FM services	International	Director, Operations Lead	12 years	online	2020	60 min
I7	FM services and consultancy	National	Founder, FM consultant	37 years	online	2020	50 min
I8	Integrated FM services	International	Technical service manager	7 years	online	2021	45 min
I9	Integrated FM services	International	General manager	18 years	face-to-face	2021	60 min

3.2.3.1 FM business process

At the beginning of the interview, respondents are asked to explain a typical contracting procedure for FM services. Generally, clients or building owners are not very conscious of the scope and importance of the operational phase and FM services. The greatest concern is the construction cost of the building rather than its operational cost. The majority of the owners prioritise short-term gains and lower budgets over the life cycle performance of the facility. Moreover, there is a tendency to involve FM professionals at the end of the construction phase or even later. As I5 noted that "*Most of the time, an FM firm is invited shortly before the facility opens. However, FM needs to be involved during the conceptual design phase of the project. ... The facilities are opened before the construction works are completed. Therefore, we do not experience the commissioning and handover processes*". In addition, I6 indicated that "*Involvement of an FM team in the project, unfortunately, happens almost at the end of the construction. This puts us in a negative vicious circle. Because prepared designs are mostly not operational. ... When you are handed over a facility close to the end, the things you can do are limited*". This confirms the statement of I1 about the earliest possible involvement of FM. I1 noted that "*In the design meetings of our new hotel building, there was a projection showing an increasing trend of the number of potential guests. So, the owner was asking for a solution that allows future extensions and modifications without disrupting the daily operations of the hotel. Our team worked with the design office to reserve an additional cooking zone and related infrastructure in the kitchen to serve more people without delay in the future*". I7 emphasised that 80-85% of the building cost occurs during the operational phase and stated that "*Design decisions have a significant impact on most of the operational cost. Therefore FM experts should be members of the project team at the very beginning*".

In-house FM teams are not bounded by any contractual procedure, however, outsource FM service providers endure certain difficulties during the contracting process. The lack of awareness of owners and clients in the operational necessities of buildings results in ill-defined, short-term and unsuitable contracts for FM parties. The respondents agree that each FM contract has to be formed considering the organisational requirements and a 1 or 2-year contract period is not suitable for FM services. I6 stated that "*There is no standard contract in the field of FM because every client has different expectations and needs. Therefore, standardising the contract* *doesn't make much sense*". I2, I3, I4 and I8 confirm that by emphasising the diverse needs of different facilities such as pre and intermediate schools, higher education institutions, healthcare facilities and shopping centres. I5 added that "*For the employer to get the maximum benefit, a long-term contract in which the output of the services is charged, not the input, should be preferred*".

Based on discussions with interview respondents, following results have been revealed and several suggestions have been put forward regarding the ongoing practices of the FM industry. The first recommendation is for FM professionals to stress the importance of FM services in ensuring efficient building operations and to increase awareness among building owners about the value of FM. Additionally, owners are encouraged to involve FM consultants or representatives in projects as early as possible to ensure their contributions are included. With respect to this, FM services should also be contracted based on organisational needs and requirements identified in collaboration with FM consultants. Furthermore, owners should prioritise long-term facility performance over short-term financial gains and opt for output-based contracts rather than input-based ones. Lastly, each contract should cover an appropriate period of time to allow the FM service provider to understand the facility, provide suitable services, and analyse performance.

3.2.3.2 FM team roles

In the previous question, all respondents emphasised the relationship between the scope of FM services and the needs and expectations of clients as well as the market conditions, building type, service period, budget restrictions, and so on. This flexibility in the scope of contracts influences the number and diversity of specialists needed in the associated FM team. I6 explained that as follows "*This depends on the client's needs, the size of the facility, its physical conditions, and scope of the requested service. Of course, the facilities manager is indispensable though this title also changes depending on the project size*". I3 stated that "*It is the facilities manager's responsibility to decide on whom to involve in his team because he is the top responsible of the smooth operations of that facility*". I7 supported that by adding "*There are specific roles that are absolutely necessary for each team but it is not right to say anything definite because the teams are shaped according to the needs*". Moreover, I5 revealed the major problem of the team building process as follows

"*Most of the time the client requests bids on a fixed team of technical personnel, security guards and cleaning/housekeeping staff. This is the fundamental mistake*".

This concludes that the lack of understanding of owners about FM services, intense control over FM team structure and distrust towards FM provider capabilities result in inefficient business processes between parties. As noted by I7 noted, "*In our country, people do not know what FM is and what its importance is*". Owners should clearly identify their expectations and then rely on the FM provider's expertise in terms of specialities and the number of FM staff.

3.2.3.3 Data/information collection

The 2D as-built drawings and/or 3D models of the buildings, equipment lists, guarantee documents and policies, maintenance logs, and energy consumption records are some of the main documents that are essential for well-organized FM services. However, it is usually extremely difficult to get the necessary data/information with the required accuracy and at the required time. I6 claimed that "*I will tell you something interesting. If you ask most of the facilities managers in Istanbul, you may see that they don't even have the project for the building*". This is primarily due to the fact that a huge portion of the operated buildings is not young enough to have qualified digital drawings or models. Moreover, because most building owners prefer short-term FM contracts that generally cover only 1 year period, most FM service providers don't spend the effort to collect and record precise information regarding buildings. This creates an infinite loop that results in inefficient services and escalates distrust between parties. I1 further complained that "*Even we, an in-house team, don't have necessary documents in our hands. We usually receive a printed copy of floor plans, a poor list of equipment, warranties, and that's all*". In addition, I5 indicated that "*When the project is handed over to the FM party they don't know if it is the correct version or not. For example, they receive commercial catalogues instead of O&M manuals*".

Data/information is important, but having only the necessary information that is applicable for operational purposes is more important for facilities managers. The respondents indicate that they either receive very limited documentation that they have to rely on their experience and intuitions when making decisions or they receive every single piece of data that requires additional filtering and sorting out effort to find the necessary one. As I3 stated, "*On my first day here I was given a pouch full of CDs.*

Today I still don't know what is in there because I don't have time to go and check every single file one by one".

The case of BIM-based FM projects has particular differences. Most of the time BIM models are prepared for design and construction purposes. They usually represent a 3D virtual copy of the building in a digital medium in terms of building location, geometry and surface characteristics. More developed models contain element-specific data to plan the construction sequence, organise the procurement process and estimate construction cost. As noted by I8 "*A healthcare facility owner tried to use BIM models for FM. The project failed because design models do not possess sufficient data for FM and there weren't enough time and resource to create FM-ready BIMs*". There is no doubt that the AEC data is invaluable for FM services, but FM requires other data as well. As I4 noted "*We started by creating a 3D model of our building for BIM-based FM services. We utilised existing CAD drawings as the base, took on-site measurements and produced the model. The next step is to enhance 3D models by adding surface materials, room tags, equipment barcodes, O&M manuals and so on*". Furthermore, I1 added that "*People are not aware how valuable it is to keep systematical record about what is going on within the facility*".

In short, the late involvement of FM professionals in the projects together with inaccurate and outdated building documents are the major problems agreed upon by all respondents. They all believe that the early involvement of FM teams in projects is the only action to be taken. They emphasise that if FM joins the projects at the initial stages, they can follow the development of the project throughout the time, document the process and bring suggestions for more operable built environments.

3.2.3.4 Contemporary approaches to FM

Each respondent has a certain level of understanding of what BIM is and how it can improve FM practices. Among the respondents are three who have prior BIM experience and only one acknowledges the Soft Landings approach. The remaining either have a particular interest in BIM-based FM practices or has common knowledge in that field.

Although the respondents share akin perspective towards the previous question of data availability and collection, when it comes to BIM, there is a contradicting thought between respondents in terms of the usefulness and necessity of BIM for FM practices.

Half of them emphasise the potential benefits BIM can bring to FM and find BIM implementation inevitable for the FM industry. The other half are suspicious of BIM due to the lack of real-life evidence of its benefits in FM.

I1 highlighted the need for successful BIM implementation examples and noted that: "*We are of course following the latest developments in the design and construction side. Because hotel buildings require minor construction and refurbishment works within a couple of years. Though, we have serious suspicions of BIM. I believe we have a lot to overcome before BIM implementation*". Similarly, I2 considered BIM as software for architects and engineers and noted that "*Architecture and engineering disciplines may need to use this kind of new technologies but I can't agree that we need BIM for daily facility operations*". On the other hand, I7 indicated that "*Everything becomes digital, so do FM. And the FM companies have to prepare themselves for the future. What matters for the BIM implementation is for the client to believe and be ready to BIM*". I9 confirms that by adding "*We developed an in-house BIM-based system that provides a real-time illustration of various workspace management elements in a 3D environment. The software not only helps to control the indoor environment air conditions in terms of temperature, humidity and carbon dioxide levels but also visualize the user information in a particular workspace. Whenever we introduced our system to a client, they liked it but didn't want to implement it because of the additional effort and money*".

As emphasized earlier, only one respondent had a certain level of knowledge about Soft Landings methodology and two respondents were interested in it. The remaining haven't heard of it before and preferred not to make further comments on its applicability. I7 stated that "*We already have a similar methodology (Soft Landings) without naming it. Particular people from the construction stage transferred to the operational phase as building technical responsible or so. Since they know the building from the start they become the core team*". I5 noted that "*I don't know the Soft Landings concept but it sounds like a very good idea. Even if the design team does not live inside the facility, they should make regular visits. The architect needs to say 'We need a facilities manager here' at the very beginning of the project. Because the architect often does not work with an employer who knows his needs.*" I6 shared a similar point of view and indicated that "*My personal opinion is that involving the FM team in the project from the start is more acceptable and applicable in practice* *compared to these processes. It is debatable how accurate an approach like Soft Landings would be if your facilities manager or FM team is not involved in the project from the beginning*".

Overall, the study observes a consensus among industry experts in the ongoing procedures of FM business and their bottlenecks. When it comes to the data-driven approach to FM services, they again share similar problem areas. Today, the vast majority of the building stock is old and more often than not it is impossible to find the as-built drawings of them. They agree that recent technological developments can encounter problems related to information loss and enhance integration between different systems. However, in Turkey, most of the FM contracts cover short periods and prioritise the price rather than the continuity and value. When short-term advantages are a major concern, conceiving customer demand or reserving an additional budget for the technology investment is not an easy task. Therefore, half of the respondents have high expectations from BIM for FM while the other half are still sceptical towards BIM-based FM practices. According to the responses of those who support BIM implementation, we can conclude that BIM can be a great help for the predictive maintenance of mechanical systems, energy monitoring and management and workspace management of large-scale buildings. Still, BIM should not be considered as a single solution for all sorts of FM tasks. FM teams need to integrate BIM with other industry 4.0 technologies such as sensors, IoT infrastructure or AI to fully achieve these functions. This need for technology investment becomes the most explicit underlying reason for the low level of BIM adoption in FM. Another distinctive issue is finding an open-minded and technologically competitive human resource in the FM market. Excluding the professionals at managerial levels, most of the FM workforce is resisting the change due to the fear of losing their jobs. In summary, the FM market strives for more concrete evidence of real-life examples to demonstrate the benefits of BIM in FM.

4. A CONCEPTUAL FRAMEWORK FOR BIM-BASED PRACTICES IN FM ORGANISATIONS

It is evident that the BIM-based transition of the AEC practices influences the way of building operations. The field study with well-respected FM organisations and meetings with industry experts in Turkey disclosed the shortcomings of existing business procedures and revealed BIM expectations of the industry. FM experts show strong interest in BIM-based FM practices, however, they explicitly state the need for well-establish guidelines and standards to succeed in BIM implementation. ISO has recently started publishing the 19650 series of standards to lead the information management process for all actors in the entire building lifecycle. The generic nature of these standards establishes an essential template for BIM-based management of building information, yet they encourage local adaptations for better implementation. The FM industry in Turkey establishes a unique case for BIM implementation due to its traditional business processes, old building stock and emerging technological infrastructure. Therefore, this thesis study proposes a framework for BIM-based FM practices in FM organisations that carry out their business activities in the described environment.

4.1 Framework Overview

The framework proposed in the scope of this thesis study aims to guide FM organisations to implement a BIM-based approach in varying FM services in facilities of any size, form and function. The two major principles of the framework are to ensure the earliest possible involvement of FM in projects and enable collaborative implementation of the BIM-based FM process together with the building owner and/or client. The following sections explain the purpose of the proposed framework, reveal its originality, and highlight its limitations, respectively.

4.1.1 Purpose of the framework

ISO 19650 series forms a well-structured roadmap for BIM-based information management for all actors of the built environment. However, these standards become overwhelming for those who are not BIM-literate enough or do not have a dedicated mindset for a collaborative, structured and data-driven approach to building operations. Moreover, a few real-life examples of BIM-enabled FM practices are either unknown by the wider community or fail to prove tangible short and long-term benefits for both parties. Therefore, the framework proposed in this thesis study intends to be a preparatory model for the major parties of building operations.

4.1.2 Originality of the framework

FM is a young and developing industry in Turkey with an anticipated business volume of $12-15 billion per year (TRFMC, 2021). The absence of regulations and standardisation in FM services drives FM organisations to develop custom-made measures, yet most of the time these measures end up in an unstructured format and with a limited scope. The 19650 series published by ISO provide well-structured procedures to ensure the collaborative production of information and its management throughout the entire building lifecycle using BIM. However, these procedures require a high level of BIM literacy, stakeholder commitment, and technical infrastructure.

This thesis study bridges the gap between well-established information management standards and unsystematic business processes of the developing FM industries. In this essence, the framework is trusted to be a timely effort to guide developing FM industries in the BIM implementation process and is attributed to be the first attempt to catalyze BIM adoption for FM in Turkey. The framework proposed in this thesis study responds to the call for local adaptations of ISO by suggesting a collaboration-oriented approach to implement BIM for FM. The framework aims to provide guidance for FM organisations to adapt BIM-based building operations with a data-driven approach. The field study results discussed in the previous chapter disclosed a high BIM expectation of FM professionals. This framework proposes an introductory medium to BIM-based practices and an implementation pathway for BIM-enabled building operations. To achieve its goals, the framework revisits the procedures of ISO 19650 to promote an alliance between the owner/client and FM organisations at the very beginning of the process. This alliance of two major parties serves as a ground for the transparent information exchange process throughout the agreed time frame for FM services and boosts trust between parties for prospective collaboration. BIM-based information management requires the investment and utilisation of ICT and other technologies, which arises one of the most common reasons for the low BIM implementation rate in the industry. The aforementioned alliance between parties in the early stages enables a share of the burden in terms of describing data/information requirements for both parties, identifying available and missing data/information sources, and determining supplementary resources for the production, exchange and maintenance of building information.

In addition to the capital investment, new technologies necessitate further training for respective personnel to adjust. More often than not, the implementation of a new technology or business model slows down routine practices at the beginning. Therefore, people insist on using what they are already familiar with and show resistance to change. The proposed framework prioritizes the management of data/information throughout the entire building lifecycle, encourages the utilisation of existing technology infrastructure as much as possible, and advocates a step-by-step improvement path to achieve higher levels of BIM adoption for building operations. The entire framework is shown in Figure 4.1 on the next page.

4.1.3 Limitations of the framework

The framework proposed in this thesis study does not intend to identify the complete set of information requirements for a specific FM task or favour a particular BIM-based software system for a particular FM case. In addition, the framework does not directly apply the ISO procedures in a specific industry case. This study approaches FM as an information management problem, advocates the utilisation of data-driven methodologies to increase efficiency in FM services, and employs BIM-based principles to complement existing business procedures without imposing high technology investments.

Turkey sets an example for a young and emerging industry of FM. Currently, there isn’t an established FM education and service standardization in this country. Most FM professionals are individuals who either have a background in diverse fields of architecture, engineering and management or are self-trained experts. In addition, most building owners or tenants prefer to operate their facilities prioritizing ephemeral cost-driven decisions without prior AEC-FM experience.

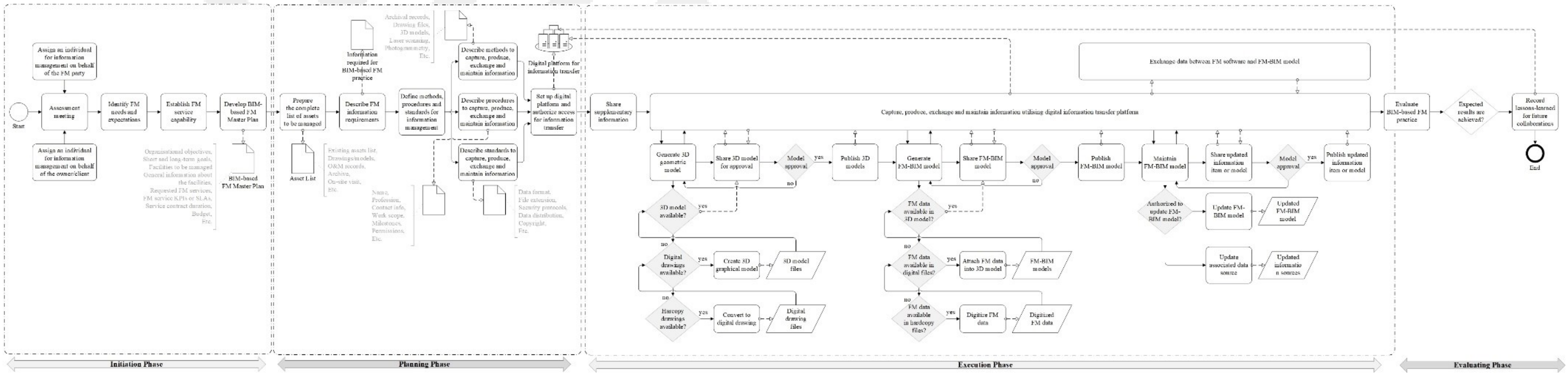


Figure 4.1: The overall framework proposed to implement BIM for FM practices.

On the other hand, many constructed facilities are old and suffer from the lack of accurate as-built drawings and systematic digital documentation. Therefore, the proposed framework is addressing several fundamental problems rather than suggesting sophisticated data exchange procedures among numerous technologies. However, the existing conditions of the Turkish FM industry do not inhibit industry actors from implementing an inclusive approach for BIM-based management of information in the entire building lifecycle. Instead, the framework accelerates collaborative production, exchange and maintenance of building information. The model forms a stepping stone for improving FM industries through their transition from BIM Level 1 to BIM Level 2, and eventually, BIM Level 3.

4.2 Development of the BIM-based FM Practices Framework

This section starts with describing the functions of symbols and elements used in the framework to provide a common understanding to individuals who are interested in implementing BIM for FM purposes. Then, each phase of the framework is explained in detail to guide professionals to adopt a BIM-based approach in the operational phase of built assets even though they are not designed or constructed using BIM.

4.2.1 Framework elements and symbols

The framework proposed in this thesis study includes various symbols and elements to visualise all processes, actors, data/information sources and relationships between them. Following is the list and explanation of each symbol and element used in the model:

- Light circle represents the starting point of a process or an event.
- Dark circle represents the finishing point of a process or an event.
- Rounded rectangle indicates there is a process, task or activity.
- Rounded rectangle with a + sign indicates that the activity has additional details that are not visible in the diagram. This symbol is also knowns as a collapsed sub-process.
- Diamond refers to a decision gate that channels the actors to make a decision in a particular situation. Each decision requires an associated arrow to be followed.
- Parallelogram symbolises any digital source of information that could be either an output of a former event or an input for a later event.

- Single page or multiple pages symbolise any printed or document-based source of information that could be either an output of a former event or an input for a later event.
- Data centre or database represents a central digital platform for information inflow and outflow among all actors. This platform constitutes a data repository for the entire life cycle information of the buildings and their associated assets. It has significant importance to ensure security and access authorisation when establishing a data centre.
- Continued line arrow connects processes and decision gates and indicates the direction of the flow.
- Dashed line arrow indicates there is an information input into or an output from a process or process group.
- Dashed line draws invisible boundaries for process groups to eliminate complexity and simplify the model for all actors.
- Square bracket explains or exemplifies the content of its associated process or information source.

A complete set of elements and symbols are shown in Table 4.1.

Table 4.1: The complete set of elements and symbols used in the proposed framework.

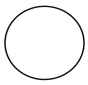
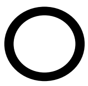
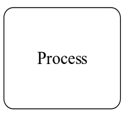
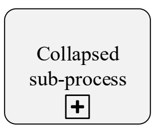
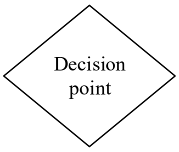
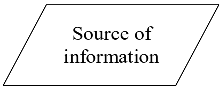
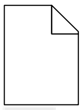
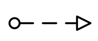
Symbol	Name	Function
 Start	Start	Beginning of a process or an event
 End	End	Ending of a process or an event
 Process	Process	A process, task or activity
 Collapsed sub-process	Collapsed sub-process	A process, task or activity that has details not visible in the diagram

Table 4.1 (continued): The complete set of elements and symbols used in the proposed framework.

Symbol	Name	Function
 Decision point	Decision	Decision point between processes or actions
 Source of information	Data	Digital source of information
 Source of information	Page	Printed or document-based source of information
 Data centre	Data centre	A central platform for information flow among associated actors
	Continued line arrow	The connection between processes and decision points
	Dashed line arrow	Information input or output
	Dashed line	Boundaries of each process group
Content Explanation Example	Text annotation	Content of the associated process or information source

4.2.2 Phases and processes

This section focuses on explaining four major phases of the BIM-based FM model and the complementary processes of each phase. The model phases follow a path similar to traditional project management, namely, initiation, planning, execution, and close-out. All phases require cooperation between the building owner/client and the FM service provider organisation, thus naturally involving a control mechanism themselves.

4.2.2.1 Initiating the BIM-based FM practice

Initiation is the first phase of the proposed model. This phase starts with an assessment meeting between the building owner/client and the FM organisation to identify the FM service needs and expectations of the owner/client, establish the capability requirements of the FM service provider, and develop the BIM-based FM Master Plan. Initially, both parties should authorize an information manager who is responsible for the management of the building life cycle information. The information manager of the owner/client could be the owner or client themselves or a third-party expert. On the other hand, the information manager of the FM party is encouraged to be the facilities manager with prior BIM experience or an information management team involving the facilities manager and a BIM coordinator.

The assessment meeting should take place at the earliest possible time of a project to include an operational perspective in the project. For facilities that are due for design, the earliest possible time could be the brief or initial design meetings. The early involvement of the FM representatives in the projects that are in the design phase provides a medium for parties to start with the end results in mind and achieve operable built environments. The earliest possible time for the existing facilities could be when the owner/client is delivered to the building by the construction team or by the previous tenant. The assessment meeting facilitates collaborative decision-making of the parties on the following aspects:

- Owner/client's organisational objectives, priorities, short and long-term goals,
- Facility or facilities that are subject to the assessment meeting,
- Function, geographic location, size, and condition of the associated facilities,
- Required FM services within the associated facilities that complement organisational objectives, priorities, short and long-term goals,
- Scope of each FM service required in the associated facilities,
- Expected performance outcomes of each FM service in terms of key performance indicators (KPIs) or service level agreements (SLAs), and
- Duration of the FM services contract with specific milestones to measure performance.

- Anticipated budget for the requested services.

The assessment meeting also enables FM organisations to evaluate themselves in terms of service capability and decide on:

- Disciplines to be involved in the FM team for the particular services,
- Required number of personnel from each discipline,
- Technologies to be utilised and/or implemented,
- Consultancy requirement for any service, process or technology.

The assessment meeting accumulates both parties to agree on the scope, expected outcomes, duration, and budget for the required FM services. The outcome of the assessment meeting is the BIM-based FM Master Plan. Figure 4.2 represents the flow and the relationship between the processes of initiating BIM-based FM practices explained above.

4.2.2.2 Planning the BIM-based FM practice

The following phase is the planning phase where both parties work together to form the information management process of the BIM-based FM methodology. This phase starts with the preparation of the complete list of assets to be managed within the facilities indicated by the BIM-based FM Master Plan. Then, parties should describe the information requirements for BIM-based FM services so that the FM organisation will be able to perform requested FM services and the owner/client will be able to evaluate the performance of the FM service provider.

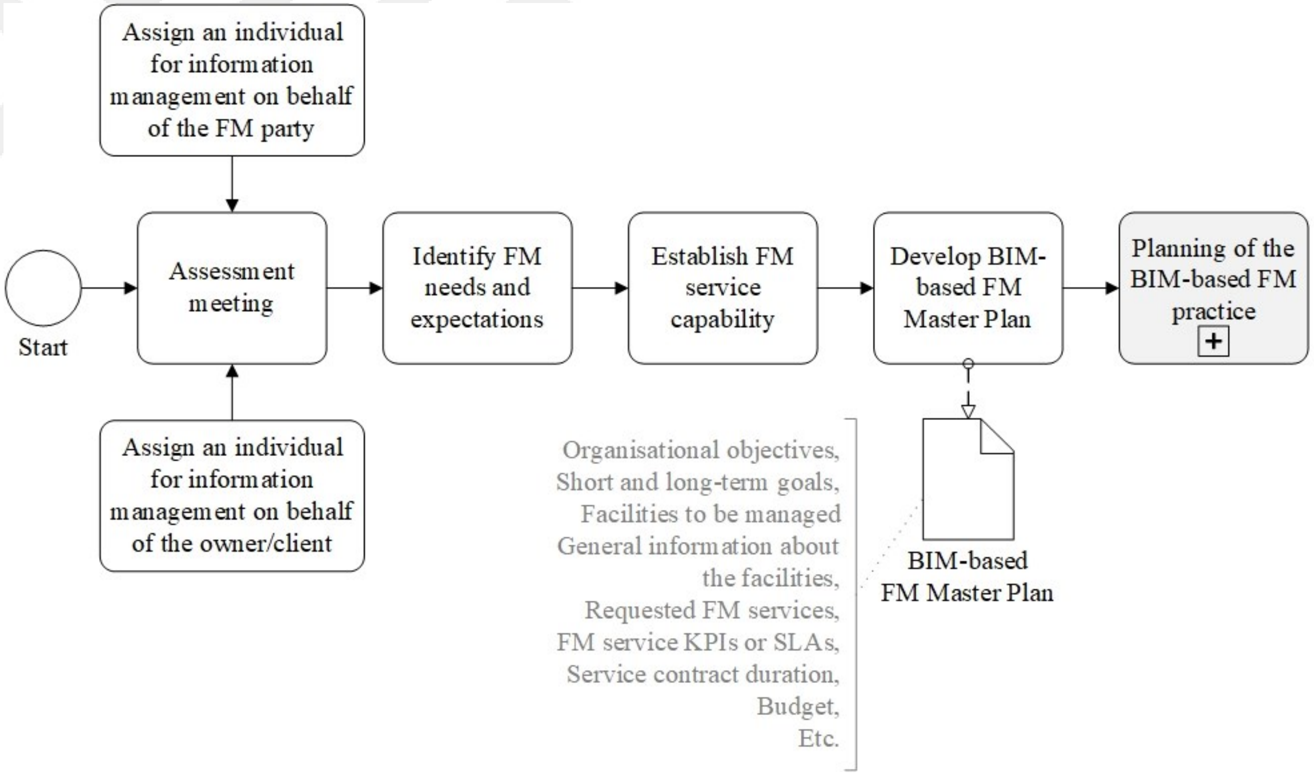


Figure 4.2: Phase one – initiating the BIM-based FM practices.

The following is the information needs to be specified for each asset within the facility:

- Unique identifier,
- Asset name,
- Asset description,
- Asset category (architectural, structural, MEP, etc.),
- Spatial information (location, height, length, width, altitude, etc.),
- Content-related information (colour, material, hazardous content, etc.),
- Manufacturer or vendor information (name, address, contact details, etc.),
- Installation, commissioning and/or replacement date,
- Operations, maintenance and repair manuals,
- Emergency instructions,
- KPIs, technical and/or performance specifications,
- Warranty and guarantee conditions and economic life span,
- Historical records of failure, proactive and reactive maintenance (if known),
- Operating requirements (energy consumption, carbon dioxide emission, etc.), and
- Responsible personnel (department, name, contact details, etc.).

The requirements listed above demonstrate a basis for useful asset information for building operations and are open for further alterations depending on the owner, facility, or asset necessities.

The next step after the identification of required information is the development of methods, procedures and standards for the acquisition, production, exchange, and maintenance of information. A method refers to the mechanism to capture, generate, transfer and maintain BIM-based FM information. A procedure refers to the steps showing who is the responsible party for capturing, producing, exchanging and updating the information, when they should perform their designated role in the management of information, and how they should capture, generate, transfer and update information. A standard refers to the specification of data format (i.e., IFC, COBie, etc.), file naming and versioning, file extensions for geometric, alphanumeric and documented information, copyright, data distribution and data security protocols, and so on. The methods, procedures and standards defined at this stage indicate how BIM-based FM practice will take place in that particular project. It is more than likely for each project to have unique characteristics in terms of FM requirements, asset criticality, information availability, and level of digitisation. Therefore, methods and procedures vary depending on the specific conditions of each project. It is important to adopt and implement the BIM-based methodology that corresponds to the project requirements the most. The proposed model is open to implementing more than one method or procedure on the same project.

Finally, the owner/client is responsible for the establishment of a digital platform for collecting and transferring all sorts of data and documents. In BIM terminology this platform is also known as the common data environment (CDE) that enhances collaboration between authorized parties and management of building life cycle information through a secure interface. The data transfer platform describes the mechanisms to access, review and approve transferred data.

The proposed model suggests utmost collaboration among major actors of the building life cycle and advocates a BIM-based methodology to support an inclusive environment. Therefore, an intelligent 3D model of the facility and its critical assets grows into the backbone of this aforementioned collaborative medium. However, given the conditions of the current building stock, it would be unrealistic to expect the owners to provide accurate BIM models of their buildings. Moreover, developing a fully comprehensive BIM model for operational purposes requires a tremendous workforce, time and investment which ultimately dissuades building owners to embrace BIM-based approaches. The model promotes digitisation and data-driven practice in the operational phase of built assets without forcing a huge technology investment burden onto the shoulders of involved parties. Identifying all assets and their criticality for contracted FM services is therefore essential when planning the BIM-based FM practice. The methods, procedures and standards to create intelligent models of these assets should be derived from their criticality in the operational phase. Figure 4.3 represents the flow and the relationship between the processes of planning the BIM-based FM practices explained above.

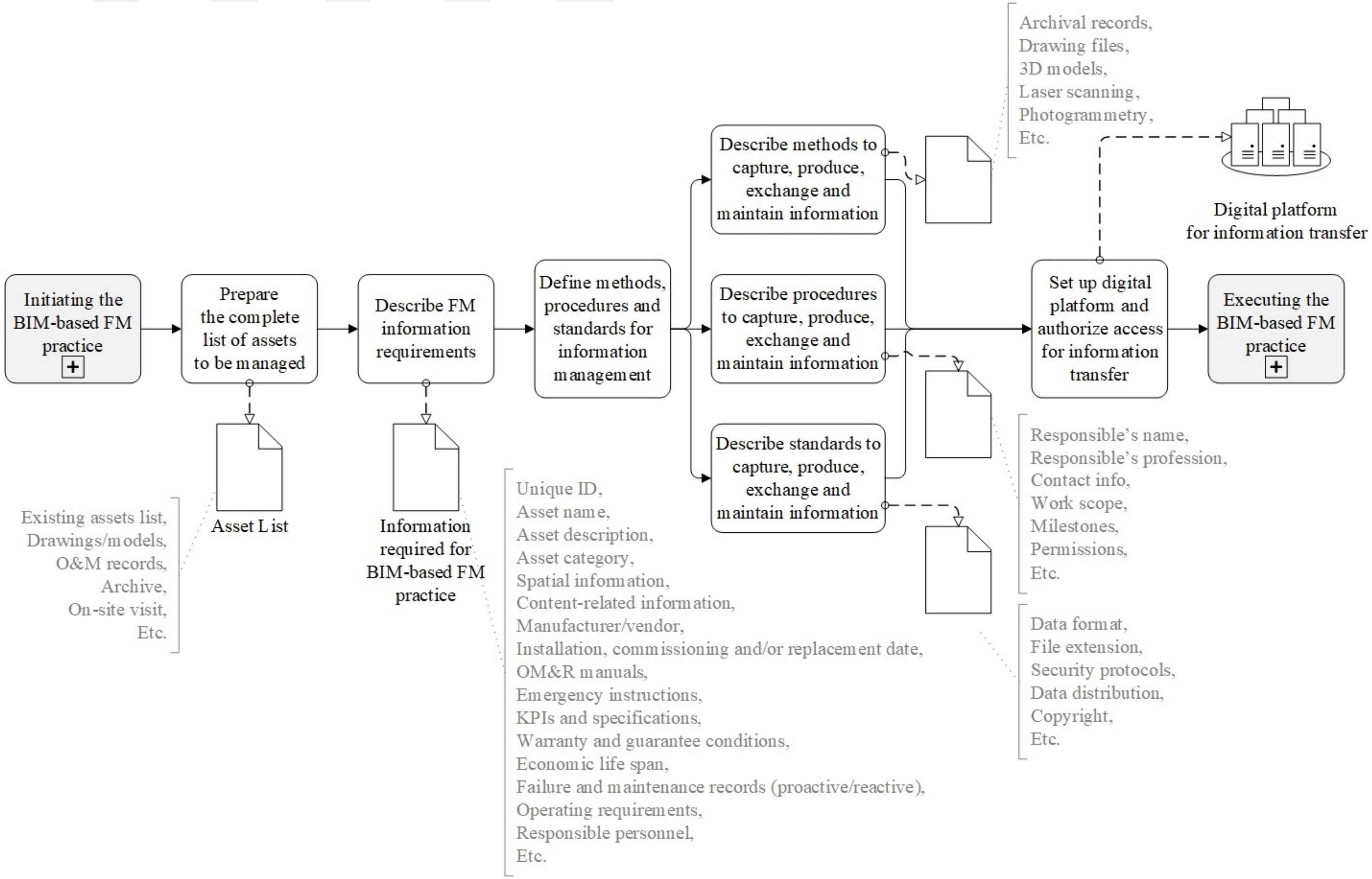


Figure 4.3: Phase two – planning the BIM-based FM practices.

4.2.2.3 Executing the BIM-based FM practice

The third phase of the proposed model involves the real-life execution of BIM-based FM methodology for data-driven management of building life cycle information. This phase starts with the delivery of any supplementary information by the owner/client to initiate the information management of assets employing the information transfer platform. The supplementary information involves:

- Complete list of assets to be managed,
- As-built drawings of the associated facilities,
- Installation, commissioning and/or replacement records for each asset,
- Operations, maintenance and repair manuals,
- Warranty and guarantee conditions,
- Archival documents,
- Occupancy schedules,
- Reference documents for information production, and
- Information model templates.

The availability of supplementary information initiates the process of generating the intelligent 3D model or BIM-based FM model. The proposed model represents this process as three consecutive steps to thoroughly explain the implementation of BIM-based practices. The first step is the generation of the 3D geometric model of the facilities and associated assets. This step involves the generation of a basic geometric representation of facilities and critical assets in a digital 3D environment. It is important to note that a 3D model is not a BIM model but a critical milestone to achieve a complete BIM model. A 3D model comprises geometric data regarding each asset and visually represents the actual facility with its all subsystems. Although visualisation is one of the greatest benefits BIM offers for the operational phase, only a minor portion of building projects have 3D graphical models. However, there are various technologies available in the market (i.e., laser scanning, photogrammetry, 3D models from 2D drawings, etc.) to create a 3D model either from scratch or employing existing documentation. Depending on the asset criticality, contract duration, or budget limitations, the owner/client and FM service provider could decide on one or more methods to generate a virtual duplicate of the actual facility and associated assets. The owner/client has the responsibility to have the 3D model done either utilising their internal resources or third-party suppliers. Yet, the FM party should be the consultant in the modelling phase to ensure the geometric model involves all necessary assets in their actual dimensions and locations. As-built drawings are of significant importance for the model to reflect the real situation as much as possible. However, both literature and survey study results reveal that obtaining accurate and complete as-builts on time is one of the greatest challenges for FM professionals. The proactive involvement of facility owners in the building handover process enables the correct and thorough delivery of actual building and digital information.

The second step is upgrading the 3D model into a BIM model. Geometric models are useful because they support numerous FM decisions with their visualisation capabilities. Yet, not every decision can rely only on visual senses. Facilities managers govern diverse sources of information to maintain required performance within the facility. BIM models support the decision-making process of facilities managers because they become a repository for building life cycle data. BIM-based software allows for improving 3D objects by attaching non-geometric or alphanumeric information to each asset. Examples of non-geometric data include unique asset ID, colour, material, location, and so on. This type of information is not suitable to visualise but is crucial when making a maintenance or replacement decision. Additionally, these software systems enable to attachment of documents onto the model objects, so that the responsible actor could check the operations manual or performance specifications of each asset within the same interface.

BIM models are intelligent models that enable continuous data updates to maintain the virtual duplicate of the exact situation of a building. Thus, the third step involves the maintenance of BIM models through constant data flow between FM software systems and BIM software systems. This step aims to guarantee a living virtual duplicate of the actual building and associated assets. Creating a living BIM model is an essential yet highly overlooked measure to make any operational decision based on the real-life condition of the assets. The real benefit of BIM for building owners derives from its ability to keep accurate information available and maintainable throughout the entire life cycle of the building. Therefore, the BIM-based FM model proposed in this thesis study engages principles to ensure the continuity of information.

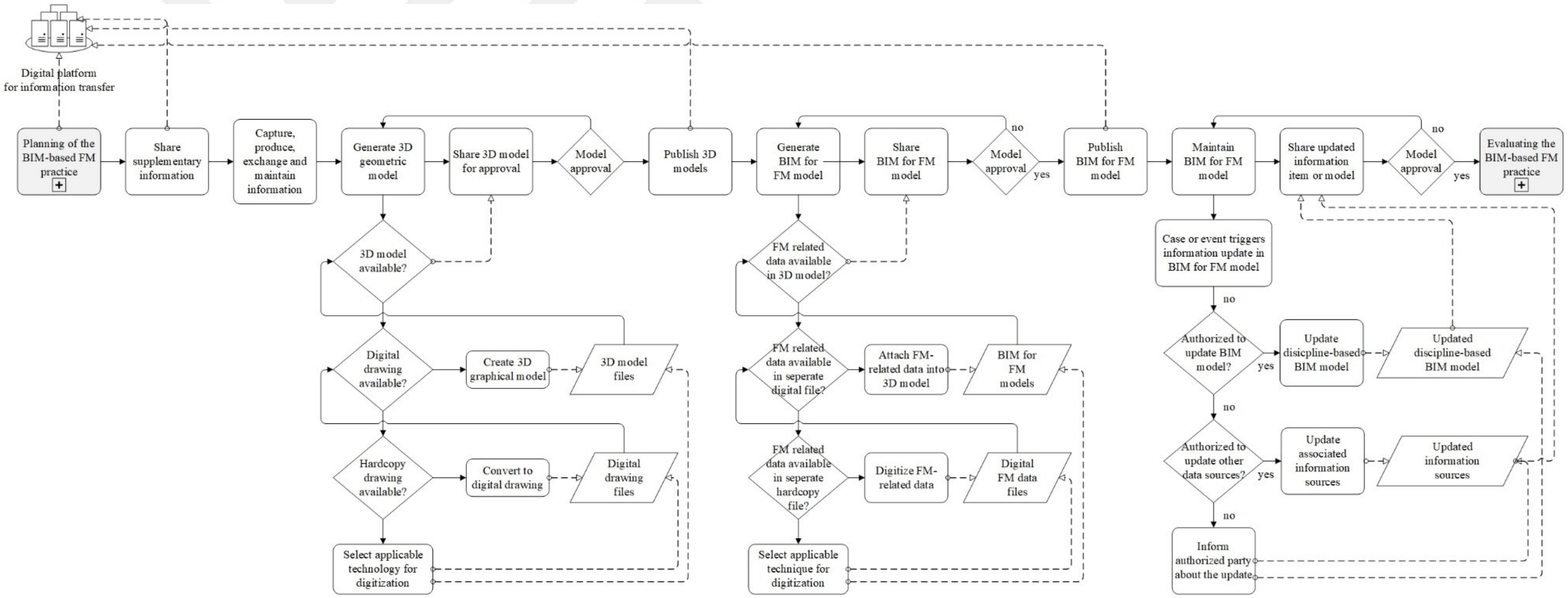


Figure 4.4: Phase three – executing the BIM-based FM practices.

Each of the three steps activates internal control and approval processes before proceeding to the next step. Once an asset is modelled in the 3D environment as indicated in the planning phase, the party who produced the model share the associated model file with the owner/client through the data transfer platform. The model should be controlled by the owner/client or their assigned information manager for compatibility with the agreed methods, procedures and standards. If the model is confirmed by the owner/client party, then it should be visible to other parties for reference or further use. If the model does not conform with the predetermined conditions, then the owner/client requests necessary revisions.

Figure 4.4 represents the flow and the relationship between the processes of executing the BIM-based FM practices explained above.

4.2.2.4 Evaluating the BIM-based FM practice

The final phase of the proposed model encourages a thorough evaluation of the performance of BIM-based FM practice in numerous aspects. The two major parties of the BIM-based FM model should cooperate in an objective assessment of the process from start to finish. An evaluation meeting involving the representatives from occupied and consulting parties facilitates a panel to discuss the need for, challenges to, and benefits of implementing BIM for FM purposes. The evaluation meeting engages different perspectives to analyse:

- The scope of the BIM-based FM Master Plan,
- Primary and secondary asset information required for BIM-based FM practice,
- Methods, procedures and standards to capture, generate, exchange and maintain building life cycle information,
- Access to the information transfer platform,
- Information availability,
- Processes and technologies to generate discipline-based 3D geometric models to maintain the collective BIM model,
- Expected and actual outcomes of BIM implementation, and
- Future collaborations.

The proposed model suggests at least one evaluation meeting upon the completion of the contracted period, yet the number of meetings could be increased corresponding to project milestones. Finally, the recording of the lessons learned throughout the implementation process of BIM-based methodology highlights the shortcomings and opportunities of the model proposed to guide further applications. Figure 4.5 represents the flow and the relationship between the processes of evaluating the BIM-based FM practices.

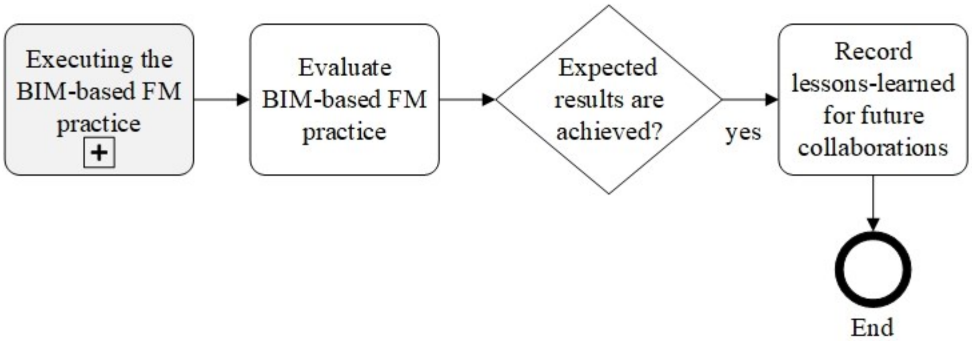


Figure 4.5: Phase four – evaluating the BIM-based FM practices.

5. APPLICABILITY OF THE PROPOSED FRAMEWORK IN THE TURKISH FM INDUSTRY

This section introduces the validation process employed to question the applicability of the conceptual framework proposed to streamline the BIM implementation process of the FM industry and support FM professionals throughout their transition to BIM-based practices. The validation process adopts a focus group discussion of FM industry experts and employs a two-fold phase involving the content analysis and the thematic analysis to report the findings.

5.1 A Brief Overview of Focus Group Studies

A focus group study (FGS) is a method of research used to gather people's opinions or understand their feelings on an issue, idea, product, or service (Krueger and Casey, 2014). Focus groups have been the primary data source of behavioural science studies since the mids of the 20th century, and have recently been adopted by many other fields including education, political science, marketing, policy and management research (Stewart and Shamdasani, 2015). A typical focus group involves 5 to 10 participants who share certain characteristics and a moderator who asks open-ended questions to direct the discussion. The number of participants in focus groups is determinant to accommodate diversity while ensuring participation. As noted by Krueger and Casey (2014), a focus group is small enough to let every participant share their insights and big enough to include diverse perspectives. It is important to conduct multiple focus groups to solicit qualitative data on the topic of interest. Literature shows that two to three focus groups are capable enough to discover more than 80% of all themes and this ratio increases up to 90% within three to six groups (Guest et al., 2016).

5.2 Framework Validation Using Focus Group Study

Focus groups bring experts together to discuss a particular topic. That makes FGSs suitable to be employed as a technique to measure the validity of theoretical and conceptual models, frameworks or proposals. Focus groups can be used to pilot-test proposed programs, policies, or services and calibrate associated concepts or procedures prior to their implementation (Krueger and Mayer, 2014). However, the use of focus groups as a model validation method is rather new, particularly in information technology and information system studies (Subiyakto et al., 2015; Irfan and Putra, 2019). This thesis study adopts an FGS technique to discuss the proposed framework's applicability and practicality for the following reasons. First, this study proposes a conceptual framework to streamline the BIM implementation process of the FM industry. Even though the framework reflects on international standards with an industry-specific focus, it could require fine-tuning to increase its applicability to local conditions. Second, the proposed framework approaches BIM adoption in FM as a managerial issue and implements project management methodology which divides the implementation process into four phases, namely, initiation, planning, execution, and evaluation. Therefore, it is only natural to discuss it with the facilities managers rather than designers, contractors or any other stakeholders. Figure 5.1 below represents the details of the focus group study.

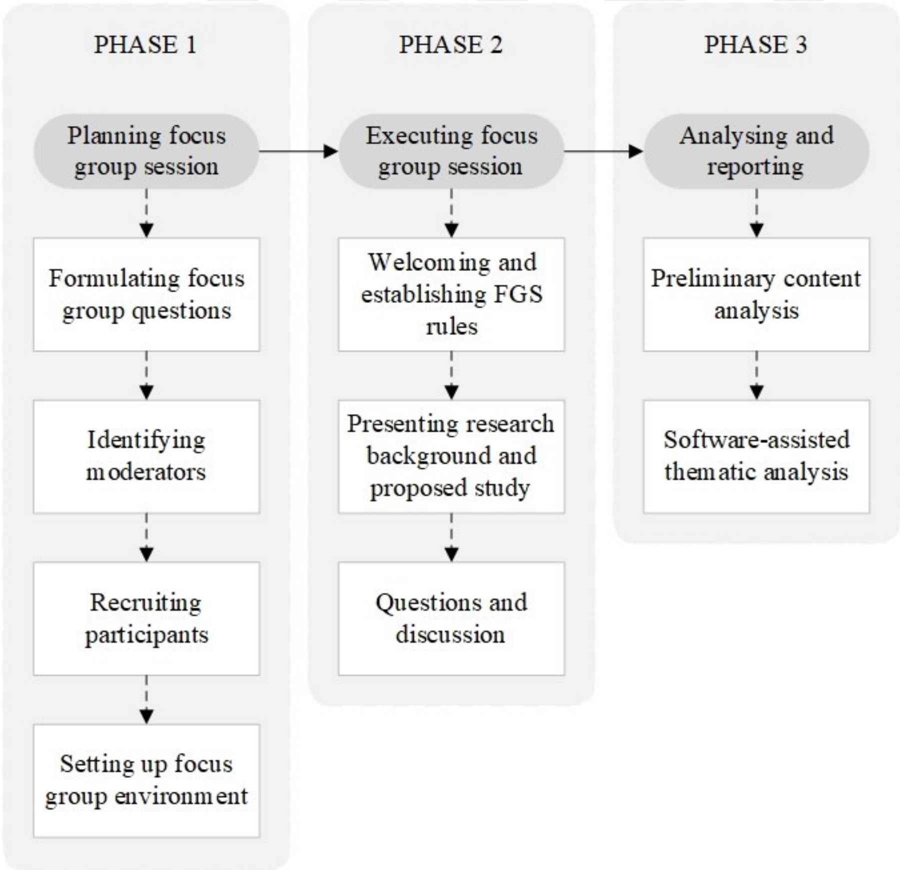


Figure 5.1: Focus group study procedure.

The meeting revolves around two major concerns regarding the thesis research: the applicability of the proposed framework and the success criteria for BIM-based FM practices. The discussion starts with the question "do you expect to experience a digitisation and BIM-based transformation within the Turkish FM industry in the near future?". This aims to figure out how respondents observe the industry tendencies and establish a relationship between their observations and questionnaire survey results. Then, the discussion focuses on the proposed framework and continues with the question "could the proposed framework become a preliminary roadmap to guide this transformation process?". This question directs attention to the proposed study and facilitates a thorough evaluation in terms of its strengths as well as weaknesses. It does not oblige the respondents to give feedback about every framework item or step, howbeit, motivates them to reflect on the overall process, stakeholder involvement, and the collaborative management of substantial information throughout the operational phase. Finally, the last question asks "what would be the criteria that make you say, 'I am glad we implemented BIM, I am glad we practised BIM-based FM'?". This final question encourages the respondents to anticipate further outcomes of BIM-based FM practices. Answers to this question incorporate potential research directions for future studies.

5.2.1 Planning the focus group study

The focus group study was organised in the form of an online meeting due to three reasons. First of all, the focus group members were targeted among the FM industry professionals based on their experience and familiarity with the BIM subject. These professionals were located in different cities, therefore it was not applicable to gather all of them in person. Secondly, each professional was serving different types of facilities which differentiates their office hours and work environment. An online meeting enables each member to join the discussion from their preferred location where they feel more comfortable and participatory (Daneva and Ahituv, 2010). Finally, most online meeting platforms have a built-in video recording feature that expedites the note-taking and transcription process.

The focus group members were individually invited to the online meeting using an e-mail invitation and direct messaging via a popular professional networking platform. The online meeting was held via the Zoom platform licenced by the İstanbul Technical

University Information Technology Department. Participants were informed about the purpose, scope and progress of the meeting. The meeting was recorded based on the respondents' consent, and responses were guaranteed to be reported anonymously solely for scientific purposes. The coding scheme and participant details are given in Table 5.1 below.

Table 5.1: Characteristics of focus group members.

Respondent ID	Experience	Area of Expertise
R1	18 years	Housing management, digitisation
R2	40 years	FM services, digital transformation
R3	32 years	Digitisation, data analysis
R4	21 years	Facilities and portfolio management
R5	20 years	Academic, digitisation in CM and FM

The first respondent (R1) is the president of an international facilities managers association and has worked as an FM expert for more than 18 years. R1 has profound expertise in housing management and was awarded a PhD degree in the same field. The second respondent (R2) is a highly experienced FM consultant who actively involves in the digital transformation of the Turkish FM industry. R2 collaborates with academicians to promote standardisation, digitisation and BIM implementation. The third respondent (R3) is the general manager of a technology company that provides personnel, energy, equipment, production efficiency and measurement, and analysis services to industrial facilities using a cloud-based IoT platform. R3 has a bachelor's degree in architecture and a master's degree in computer-aided building design. The fourth respondent (R4) is the general manager of an integrated FM company that serves public-private partnership (PPP) projects in Turkey. R4 is experienced in the FM services of city hospital projects since 2016. The fifth respondent (R5) is a faculty member at a university in the United States. R5 has a bachelor's degree in architecture with an established research background in FM, maintenance decisions, and implementation of digital technologies.

5.2.2 Executing the focus group study

Prior to asking questions and discussions, the thesis researcher provided a brief background of the research studies and presented the conceptual framework developed within the scope of the thesis research. This introductory presentation provided a common understanding of the basic concepts, research motivation, and study scope. Following the presentation, focus group members were asked to evaluate the applicability of the proposed framework based on the two research questions explained in the previous section. The initial discussion focused on the digitization and BIM implementation tendencies of the FM industry and the evaluation of the guiding potential of the proposed model for the BIM implementation process. The second discussion topic explored future expectations from BIM-based practices by industry experts. The researcher and the advisor were the co-moderators of the discussion; the first moderator asked the main questions and the second moderator reviewed the responses and added follow-up questions to reach a deeper understanding of the subject. The collected responses were immediately transcribed for primary analysis and then imported to the Nvivo software to uncover hidden patterns between the lines.

5.2.3 Analysing the focus group study

The analysis of the qualitative data gathered during the focus group sessions went through a two-fold phase. The first phase employs content analysis which entails organising the data per principal research subjects and drawing reasonable conclusions from it. The next phase applies thematic analysis which involves organising, analysing and reporting concealed patterns within the data. Findings of the content analysis were reported as narratives supported by illustrative quotes of the respondents, whereas findings of the thematic analysis were graphically represented using Nvivo software.

5.2.3.1 Preliminary content analysis

The preliminary analysis of the qualitative data revealed four underlying concerns with respect to the applicability of the proposed framework in the Turkish FM industry practices and two major success criteria to promote BIM implementation in FM. The concerns include the limited examples of BIM-suitable projects and services, lack of BIM knowledge and experience, resistance to the digitisation and adopting digital technologies, and contractual relationships, whereas the success criteria include cost and time benefits.

BIM-suitable projects and services

The first concern highlights the limited number of projects and services suitable to BIM-based practices. The moderators noted that there is a fair degree of doubt among FM professionals regarding the applicability of BIM in the majority of facilities. Turkey recently mandated BIM for public infrastructure and transportation projects only (Url-6). Thus the number of BIM projects does not exceed the fingers of a hand, and additionally, these are extremely exclusive facilities. As stated by R1:

"*Except for the senior managers, we employ people with a relatively lower educational background in residential projects. And oftentimes, it is challenging for us even to get the daily reports from them. It may be easier to track performance before and after BIM in non-residential projects.*"

R2 confirmed the statements of the first respondent in terms of the suitability of housing projects for BIM-based practices and pointed out the similarities between Turkey and different regions of the world in terms of BIM utilisation for FM purposes:

"*Of course, BIM is something that will be used later in housing projects, it may be a bit of luxury for them at this point. There are many owners there and they are not knowledgeable enough about these issues But if there are very special projects, such as luxury housing projects developed by large investment groups, then BIM can be used there. Apart from that, it can be used in offices, shopping malls, mixed-use buildings, and speciality buildings like airports.*"

R3 agreed with previous comments and added:

"*Housing has multiple owners by its nature and thus it is farther away from using BIM. Other real estates such as commercial real estate, hospitals, sports centres or offices have single owners. Therefore, it is more accurate to contemplate BIM for commercial real estate. … So, BIM can be a bit of a luxury in some situations. But if you ask that should we use BIM, of course, we should.*"

They also added:

"*BIM is more important in maintenance and repair works and space management tasks, but it does not have much to offer in other tasks of FM such as reception, catering or mail services.*"

In addition to these statements, R5 acknowledged the generic structure of the proposed framework ad suggested typological modifications based on facility type. They added:

"*This is not a complex framework; I am sure industry practitioners would understand how it works. Still, to me, your proposal needs alterations to serve different types of buildings. For example, we might know which FM firm will operate a hospital building. However, if we have a multi-storey office building and we are planning to rent out different storeys to different organisations, then we need to consider property management rather than FM.*"

The initial comments indicate that the proposed framework promising for BIM implementation as it involves fundamental parties and a clear flow. Still, the generic characteristic of the framework requires project-based modifications to serve the distinguishing needs of different buildings. Respondents earnestly noted the distinctive characteristics of residential projects and acknowledged BIM-based FM practices as more suitable for commercial real estate, hospitals, and offices. They appreciate the theoretical explanations and academic effort to promote BIM in FM, yet they require best practice cases to fully understand and become convinced about its applicability.

Below are the concluding remarks of R4:

"*I think your proposal is quite successful, there could be such a start. ... Digitisation will surely come, there is no escape from it. But it (BIM) should influence the European region first, then Turkey will follow it five years behind. Even the US is not mature enough in digitisation yet.*"

BIM knowledge and experience

The second concern regarding the applicability of BIM in FM highlights the limited BIM knowledge of the main stakeholders and the lack of BIM-experienced FM personnel. Here, it is important to note that each respondent has a distinguishing BIM expectation. As such, for example, R4 indicated:

"*As a manager, it is very advantageous to see what is going wrong and where, from a single source that contains all the inventory, without going down to the field or being overwhelmed with field reports.*"

As opposed to them, R3 shared a list of FM software specific to different FM tasks and emphasized the supportive potentials of BIM-based software for them:

"*FM already has many software systems specific to its own business. That's why we have to take BIM as an agent that will work in integration with them. It won't be possible for us to do all our work with BIM. The important thing here is that BIM can exchange data with other FM systems.*"

R5 supported R3 with the following examples:

"*We should integrate BIM models with the inventory. Then, this BIM model should also be integrated with other FM systems, such as CMMS. Thus, we can see both the model data from BIM and the malfunctioning period of certain equipment from CMMS. Using the data, we can make a future projection and add an extra budget for a foreseeable problem. ... Also, BIM can be integrated with BAS and occupant behaviour data. This will help, for example, to control energy expenses in the long run.*"

Similar to them, R2 briefly mentioned a group of software used for BIM-based FM and stressed the need for informative events to increase BIM awareness among the major stakeholders:

"*There are various ready-made tools and software used in other countries. But I am not sure which firms are using them and how effective they are using them here in Turkey. Our survey on this topic showed that there is very limited BIM utilisation in FM. ... The important point is, we need to inform building owners and investors about what we can achieve with BIM.*"

The competing ideas towards and expectations from BIM for FM practices disclose different digitisation levels between projects. Yet, respondents arrived at a consensus about the lack of a data-driven approach in building operations. They all agreed that BIM won't be beneficial unless accurate, complete, and up-to-date data is available. Here, R5 exemplified a typical visual inspection procedure as the first-day action of an FM company and highlighted that:

"*When an FM firm takes over a building, no matter if it is new or old, they inspect the building and create an inventory from scratch. If your BIM model does not include this inventory, then what will that BIM model do?*"

They continued:

"*From the AEC point of view, we know that subcontractors are better in BIM compared to the main contractors. Because they are the ones who are responsible for the preparation of these models. But, at the end of the day, how do we know that the models are correct? How will the building owner control the accuracy or approve the submitted models?*"

R3 pointed out another important matter related to data collection and capturing practices. According to them, the biggest issue is information jealousy. R3 complained about:

"*In Turkey, let alone BIM models, the architect or the contractor is looking for a way to avoid submitting as-built drawings when the project is finished.*"

There is a clear need for information days and practice-based activities for the industry stakeholders to increase BIM awareness, understanding, and knowledge. Without a clear understanding and its applicability within the FM industry, it is unlikely for them to implement BIM. These events should explain which BIM-based technologies improve existing FM practices and how while emphasizing the value of data in essence.

Resistance to digital technologies

The previous discussion about inaccurate and missing data reveals arguably the most important hindrance to BIM-based FM practices or digitisation in FM: resistance to change. The two fundamental factors that lead the resistance are the culture and fear of losing jobs.

R3 explained this: "*People do not believe in the virtue of entering data. They are worried that they might lose their job after a detailed data analysis. Sharing information is essential in European countries, whereas hiding it is essential in our country.*"

They also added:

R3: "*Educational profile of some of our employees is not very suitable to utilise such technologies. In digital transition, culture is a more critical component than cost. I suggest you evaluate the cultural aspect in your studies.*"

R1 also highlighted the need for change in mindset and said:

"*I think it is time to go digital. A manager who is both younger and better educated is now coming. ... We, too, need to be open to innovation, even if it is a bit challenging.*"

R5 compared the BIM-based FM applications in the United States and stated:

"*Many of the difficulties experienced in incorporating BIM and other advanced technologies into FM are encountered in existing buildings. If the owner is not the user of the building, then they do not really care whether they have the drawings or not. In such cases, usually, a third-party organisation generates a 3D model of the building using laser scanning and point cloud technologies. Of course, these models have shortcomings, but it's better than nothing.*"

Finally, R4 noted that:

"*It is important to how much you are off from your initial plan. Therefore, it is crucial to have available and measurable data.*"

Early involvement of FM

The final discussion regarding the applicability of the proposed framework within the FM industry focuses on the early involvement models for FM organisations and their contractual relationships with other project stakeholders. The moderators observed a complete consensus among focus group respondents in terms of problems occurring due to their late involvement in projects.

As represented by R4:

R4: "*We have been saying for years that we need to get together with FM companies and professionals at the architectural design stage and get their opinions. Failure to do so creates problems with enormous costs for the operational period. But Turkey has not yet reached that maturity.*"

A further discussion by R5 pointed out a critical question of how to involve FM representatives in a project organisation. R5 asked:

"*Who will pay them, and to whom will they be responsible for?*"

A connected discussion by R2 highlights the need for BIM-experienced personnel in professional FM services. R2 noted that:

“*BIM itself, together with its software is a matter of expertise. Many projects could not employ BIM-experienced personnel. Depending on the project needs, the investor may employ BIM experts in some projects and may obtain BIM services through outsourcing.*”

Although the respondents acknowledge the earliest possible involvement to ensure the operable design and construction of buildings, the question of how remains unsolved.

Criteria for successful BIM implementation

After disclosing the four major concerns that impact the applicability of the proposed framework in the Turkish FM industry practices, the respondents were guided to a discussion to identify success criteria that contribute to wider acceptance and adoption of BIM in FM. The discussion discloses two fundamental criteria, namely, cost benefits and time benefits from the industry perspective. R5 highlighted an important point and added:

“*If we take a closer to the backgrounds of FM professionals, not all of them are architects or engineers; most of them have expertise in finance or management fields. So, how do we explain the benefits of BIM in FM to those people?*”

R5 later added:

“*If we implement BIM, what will be its return on investment (ROI), and how long will it take to get the invested money back? These people are curious about it.*”

In the words of R4:

“*You have to convince the management board by saying I will make this much money within this much time.*”

R2 further explained the monetary gains and highlighted its connection with time:

“*Operational expenses are really high. The same goes for energy bills, same goes for maintenance bills. It is important to stress the cost benefits BIM offers to us. Second, it is important to stress the time benefits. Because we, unfortunately, lose a huge amount of time when we are looking for a piece of information. Where is the information, is it correct or not, is it up-to-date, too much time to be lost.*”

R1 also supported the previous comments and added:

"*To me, the cost of time is the biggest. This is also true for our daily lives. ... It is important to save our time and make our decisions based on objective data with BIM.*"

The final remarks of R4 considered the ongoing political and economical conditions of Turkey:

"*I personally believe that the FM industry will experience digitisation and implement BIM in the medium-run, let's say within 3 to 5 years. But the post-pandemic conditions, economical instabilities, and political issues will hinder these steps for a certain while.*"

Apart from the proposed framework, any future research in the BIM-FM field must provide evidence of time and cost savings.

In the end, all respondents agreed to the necessity for digitisation and BIM-based transformation in the FM industry and acknowledged the proposed framework as a square one. In this respect, R2 indicated that:

"*BIM will be used in FM, this is inevitable. But how soon we will use it is a question mark. In 5 years, in 10 years? But in my opinion, you need to be the flag bearer of this issue and raise awareness on this issue, both in the FM sector, in the architectural field, and the field of other investors.*"

They once again noted:

"*We need best practice examples. I regret to say this but investors do not take the initiative to spend money and implement BIM without witnessing a tangible benefit.*"

5.2.3.2 Software-assisted thematic analysis

In the later stage, the qualitative data gathered from focus group sessions were analysed using a thematic analysis method. Thematic analysis refers to a method for exploring and reporting patterns hidden in qualitative research data (Braun and Clarke, 2006). Although there are overlapping applications of content analysis and thematic analysis in the qualitative research field, these two methods differ from each other in terms of how they quantify the data (Vaismoradi et al., 2013). The process of content analysis involves organising research data into categories according to the main research topics, whereas the process of thematic analysis requires a more focused review of research data to identify codes and themes (Bowen, 2009). This thesis study follows the step-by-step guide for conducting a thematic analysis explained in Braun and Clarke (2006) and employs Nvivo 14.23.0 software to visualise the findings. Table 5.2 outlines the thematic analysis steps applied.

Table 5.2: Process of thematic analysis (adapted from Braun and Clarke, 2006).

No	Phase Name	Procedures
1	Familiarising with data	Transcribing data (if verbal) Reading and re-reading data Taking notes or marking ideas for coding
2	Generating initial codes	Coding interesting aspects in the data in a systematic manner Collating data relevant to each code
3	Searching for themes	Sorting different codes into potential themes Gathering all data relevant to each identified theme Visualising codes and themes using tables or mind maps
4	Reviewing themes	Checking, reviewing and refining themes Generating a thematic map
5	Defining and naming themes	Identifying the essence of themes and sub-themes (if applicable) Determining the aspects of data to be captured in each theme Giving concise and compelling names to themes
6	Producing report	Final analysis Producing a concise, coherent, logical and non-repetitive report

Prior to analysis, it is important to read through the documents and get familiar with the transcribed data. This first phase recommends taking notes or marking ideas throughout the reading process. Then, in the second phase, interesting aspects of data are systematically identified and initial codes are generated. In qualitative data analysis, a code refers to a word or phrase to label and organise the data, and coding refers to the process of assigning descriptive labels to the data for categorising and exploring patterns (Saldanã, 2009; Joffe, 2011). It would be wise to generate as many potential codes as possible so that in the next phase, the researcher can collate and sort different codes into prospective themes. At this stage, visualising codes and themes using coloured papers, tables or mind maps assist the process. The fourth phase involves checking, reviewing, and refining themes and generating a thematic map to represent the overall findings. As "coding is an ongoing organic process" (Braun and Clarke, 2006, p.21), it is not unusual to add, modify or exclude codes at this stage. The fifth phase aims to define and refine the themes drafted in the thematic map. This phase involves naming the themes with brief, compelling, and coherent names. The final phase refers to the preparation of the report. The purpose of this report is to establish the credibility of arguments derived from the research questions by providing substantial evidence from the data.

Nvivo is a computer software, initially released in 1999 by QSR International and today developed by Lumivero, used for qualitative analysis of unstructured or semi-structured data. Various software programs can help with qualitative data analysis however, this study employs Nvivo because of several reasons. Being a widely-used tool, Nvivo supports different types of documents, involving text, spreadsheet, audio, video, and image. Moreover, Nvivo provides a structured and user-friendly interface for organising and analysing data. Another important feature of Nvivo that helps researchers to visualise a large amount of data is its graphics such as concept maps, mind maps, and project maps. This study visualises thematic analysis findings in the form of a project map to represent themes (codes) and the links between them.

Themes related to the challenges

The thematic analysis reveals six main themes related to the factors challenging the application of the proposed framework by the industry. These six themes include challenges related to (1) BIM-FM awareness and knowledge, (2) buildings and FM services, (3) delivery methods, (4) employees, (5) building handover process, and (6) investment cost. Each theme either involves one or more sub-themes or particular challenge items. A total of 39 individual items under 24 sub-categories were identified and visualised by Nvivo. Figure 5.2 below represents the themes, sub-themes, particular challenge items, and their relationships referred by the focus group participants.

As seen in Figure 5.2, challenges concerning BIM awareness and knowledge correspond to a shortage of knowledge of investors and FM experts about BIM, available BIM software systems, local and global BIM-FM examples as well as concerns regarding data exchange between existing FM software and BIM. The investors and FM experts are not well-informed about BIM and associated software. Therefore, they call for best practice examples of BIM-FM to understand the application and lift their doubts. However, most FM tasks rely on the labour force and manual operations. Thus, the current digital maturity level of FM firms and employees establishes a great challenge to BIM implementation in FM.

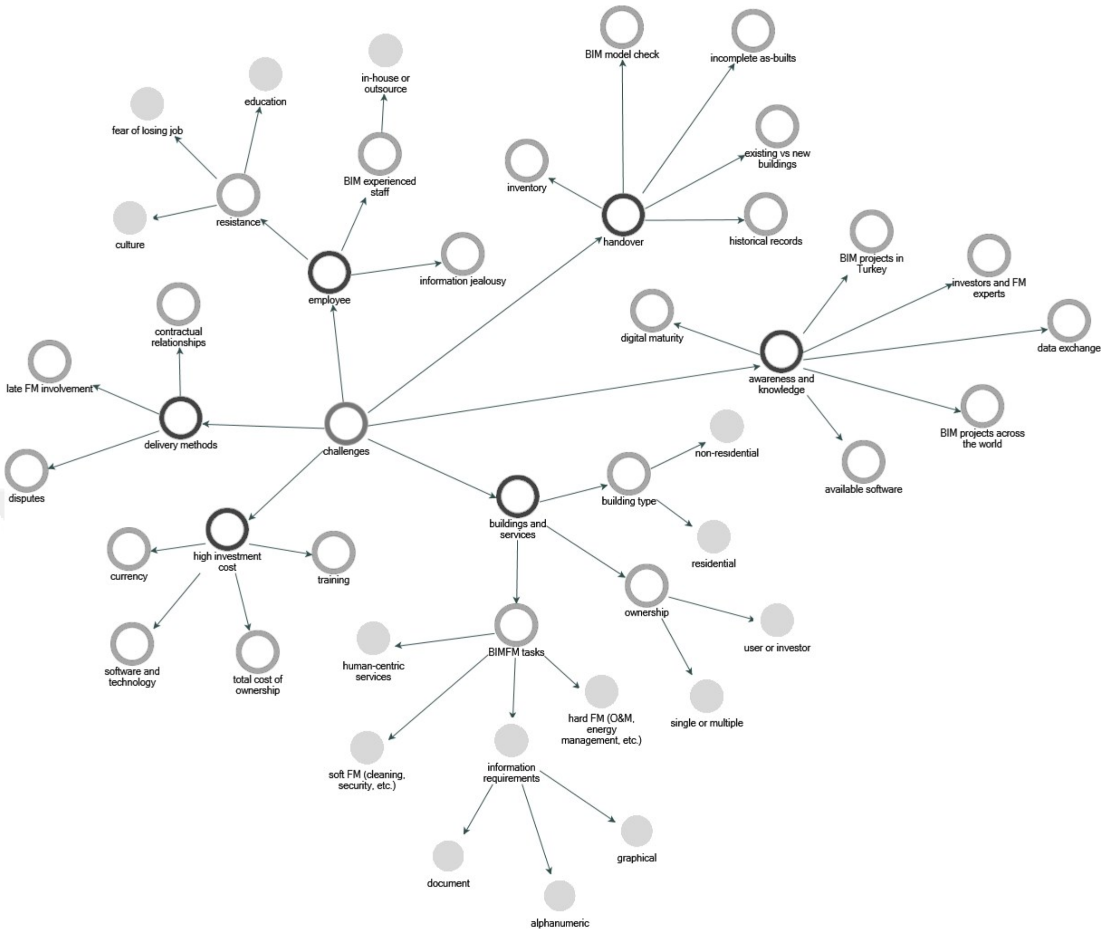


Figure 5.2: Themes related to the challenges.

The second theme refers to the lack of BIM-suitable buildings and FM services and involves three sub-themes, namely, BIM-FM tasks, building type, and ownership. Responses point out the high density of residential projects within the FM market and claim that the characteristics of residential projects do not perfectly support BIM implementation. Likewise, non-residential buildings implicate different types of ownership that result in repelling BIM investments. All these aside, FM refers to an umbrella term covering various soft and hard FM tasks of multiple disciplines underneath. Among these numerous tasks, only a portion suits BIM-based applications, yet identifying BIM information requirements for those tasks remains problematic.

The third theme criticises the existing project delivery methods in terms of the inclusivity of FM. Although the proposed study prioritises an assessment meeting between the owner and/or client and the FM representative at the very beginning, conventional business models push FM involvement to the last minute. The late involvement of FM restricts the ability to achieve better project results in terms of fewer design flaws or cost-effective solutions. In short, the lack of early FM insight into projects and appropriate contractual arrangements between parties become another hindrance to the smooth BIM implementation process.

The next theme does not particularly blame the current labour force but emphasises the importance of employee commitment to achieve digitisation and BIM implementation within the FM industry. This theme acknowledges the educational and cultural background of employees as the major source of resistance towards innovation. In addition, the lack of BIM-literate personnel results in lower motivation for BIM implementation.

The fifth theme accuses the problems occurring in the building handover process as an obstacle to the applicability of the proposed framework. Respondents specify handover problems of existing buildings and new projects in terms of BIM models, as-built drawings, inventory lists, records of previous maintenance and repair works, and so on. In the end, a successful BIM transition relies on the availability of complete, correct and up-to-date data.

The final theme, investment cost, forms the heart of any digitisation movement. Advanced technology and novel software are definitely appreciated by every actor in the building life cycle, yet they require a significant amount of investment to install and a separate budget for employee training. Moreover, the exponential development pace of technology entails frequent updates of both hardware and software and training programs. These circumstances lead every stakeholder to set a budget -usually in foreign currencies- for new technology and enhancement. However, setting a technology budget is easier said than done. There is an accompanying reason that constitutes an obstacle to this budget; cost of ownership. As previously explained, each building project has special ownership models, which create unique authorship issues in return. As an example, when the owner and the occupant are the same entity, then, they might be more likely to welcome BIM and other advanced technologies compared to the temporary tenants. In short, to increase the applicability of the proposed framework and wider BIM acceptance within the industry, alternative solutions tailored to different ownership models should be developed.

Themes related to the criteria for successful BIM implementation

Figure 5.3 below represents the four themes regarding the success criteria for smooth BIM implementation of the FM industry.

The first theme represented in Figure 5.3 refers to the data management potential of BIM. Providing a shared database for all actors is one of the most powerful characteristics of BIM. Becoming a central repository for different types of information including geometric, alphanumeric and document, BIM enables easy access to building information from a single source. Yet, keeping BIM models alive is the key to maximising BIM benefits in the entire life cycle of buildings. It is unrealistic to expect BIM to replace all other FM software, however, BIM models can become the central point of accurate data for other software systems. Developing and applying standards, protocols and procedures to generate, exchange and maintain building information would accelerate the BIM implementation process.

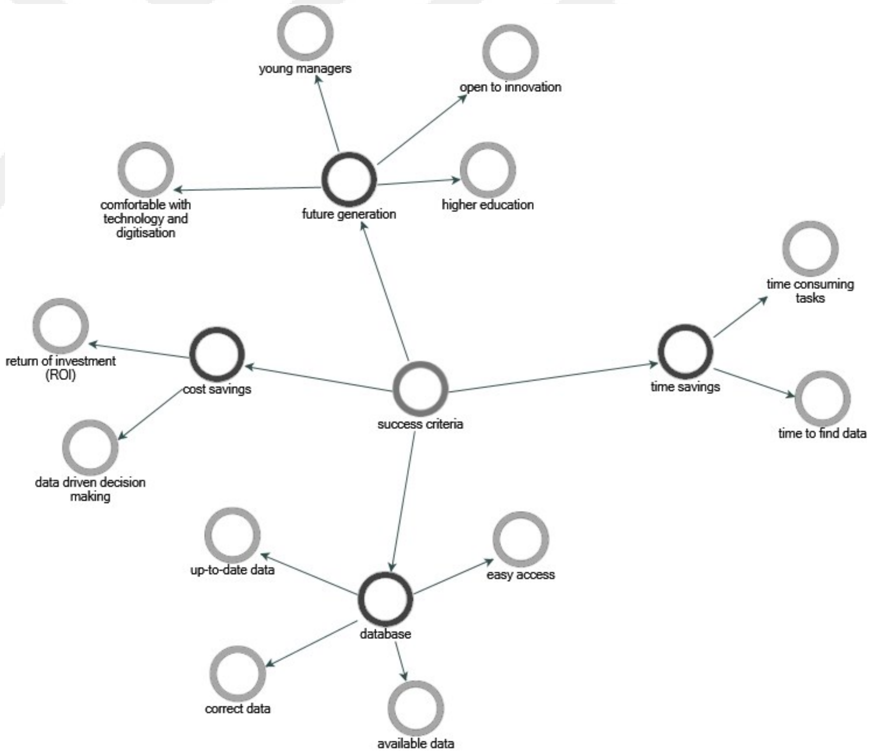


Figure 5.3: Themes related to the criteria for successful BIM implementation.

The second theme, cost savings, derives from the data management capabilities of BIM. BIM supports various FM decisions by providing a reliable source of building data throughout the entire building life cycle. However, most decisions in traditional FM models rely on the personal judgments of individuals or outdated documents regarding building elements. Even though BIM investment leads to additional costs for owners in the initial phase, it has the potential to reduce O&M costs in the long term due to data-supported decisions. Unfortunately, studies confirming FM cost savings after BIM implementation is scarce. However, respondents indicate that it is crucial to provide solid evidence to demonstrate the cost savings achieved by BIM implementation to increase the applicability of the proposed framework.

The next theme refers to time savings achieved after implementing BIM and has a strong connection with the previous two themes. Employing BIM models as the central source of building data and engaging with BIM-based procedures enable quick access to information regarding building elements and up-to-date versions of associated records or documents. This leads to less time consumed to find specific information related to zone within buildings, historical records of specific equipment, repair and maintenance manuals of mechanical system elements, and so on. The data archived in BIM models is used for various purposes, such as analysing the performance of particular equipment, room, or part of the building, predicting future maintenance, repair or replacement expenses, and providing insight reports for future investments.

Finally, the applicability of the proposed framework highly depends on the principal actors, namely the facilities managers themselves. Until recently, FM did not have a place in the professional career development of young generations. As a result, a significant proportion of facilities managers were old and experienced experts in various disciplines. However, participants indicate that FM has been recognised as a profession day by day. The upcoming generations of FM professionals are not only young but have higher education degrees, are more comfortable with technology and digitisation and more open to innovations. These attributes of the new FM generations would have a positive impact on the transition to BIM-based practices within the FM sector.

In conclusion, thematic analysis enabled a more in-depth analysis of the results gathered from the focus group sessions and uncovered implicit themes and relationships that were not revealed in the content analysis. The graphical representations of themes and their relationships facilitated a better understanding of intense qualitative data. The results of this study would serve two purposes. First, it guides FM firms that are aiming to implement BIM to assess the compatibility of the proposed framework with their organisational constraints and business characteristics.

Second, it introduces new opportunities for BIM-FM researchers to focus on by providing an overall evaluation of the proposed framework involving its strengths and weaknesses.

5.3 Development Areas and Future Research

The scope of this thesis study was to propose a framework for the Turkish FM industry to refer to in implementing BIM. To this extent, the study reflected on the international ISO 19650 standard series from a local point of view and suggested a road map compatible with the characteristics of the FM industry in Turkey. Having a generic characteristic, the proposed framework is open for project-specific adjustments.

The overall results of focus group discussions conducted with FM industry experts support the proposed framework, yet introduce further research directions. The future research and development directions are categorised into three major topics.

The first suggestion stresses the need for a holistic BIM training program designed specifically for the major actors in the industry. The principal reason is that each industry actor has a different BIM understanding. For example, building owners are not fully aware of the BIM use cases in the operational phase and take BIM as an additional cost to their budget. On the other hand, most facilities managers come from an administrative background and focus on the payback period or ROI of such technology-intense investment. In addition, FM task teams consider BIM as another fancy 3D model with no practical outcome. Hence, the program should be designed for different groups to introduce BIM and other contemporary technology, methods and procedures and highlight the importance of continuous data throughout the entire building life cycle. Although that requires an intense emphasis on the theoretical background of BIM and BIM-based FM, respondents insisted on supporting the theory with best-use examples.

The lack of real-life BIM-FM cases is the second principal reason for resistance towards BIM. There is a growing interest in BIM-FM studies in the international literature. Many scholars publish a variety of theoretical papers and case studies to promote wider BIM implementation for FM purposes. Scholars of respected universities in Turkey are also shifting their focus from BIM-based design and construction to BIM-based building operations and management. However, the limited number of BIM projects causes disadvantages for FM firms on a local scale. In addition, a significant majority of these studies promise intuitive time and cost gains of BIM, however, they lack solid evidence. More research could be carried out to prove BIM gains in the operational phase. Researchers could focus on demonstrating BIM advantages in terms of a list of FM work items. That is to say, BIM-FM researchers collaborate with FM taskforces to prepare a detailed work breakdown structure for each FM task, and then they demonstrate how BIM-based methods and technology could contribute to better management and operations of buildings. Moreover, international examples of best cases could be translated and shared with FM professionals in commercial magazines or during industry-wide events. These knowledge-sharing mediums could gradually contribute to the overall BIM awareness and acceptance of the industry.

Finally, there is a need to review conventional project delivery setups of owner, designer and contractor, and discuss the ways of involving FM feedback at the possible earliest phase. Both literature and focus group results underline the influence of early FM involvement in projects. No doubt inviting FM representatives at the beginning of a project could accommodate operational perspective during early design stages. That ensures an inclusive start to projects with the end in mind. However, the contractual relationships of this involvement are not fully covered within the widely-used project delivery methods of AEC. Although contracts for the operational phase clearly identify the operational needs and expectations, the roles and responsibilities of the FM representative at the beginning of a project remain unclear. Therefore, it is essential to distinguish the service scope of FM in the early and later stages. The roles and responsibilities should clarify the relationships among all the actors within a project delivery team. To do is, the ambiguities regarding how to involve FM within the project delivery team, to whom would the FM be responsible, would FM become an advisor of the owner or designer, how to implement FM feedback into the design and/or construction projects, how to solve any possible conflict between FM and design and construction teams should be addressed. Future studies could respond to the discussion of how to position FM within the project delivery and contracting methods of AEC.

6. CONCLUSION

Referring to the longest period in the building life cycle, the operational phase requires various FM services to ensure a building's functionality, comfort, safety, and efficiency. Decisions made by the AEC professionals during the pre-construction and construction phases have a significant impact on the post-construction phase, where 60 to 85 per cent of the total life cycle cost occurs. Services given within the operational period such as repair and maintenance, space management, renovation and refurbishment, or emergency planning require tons of information regarding buildings including as-built drawings, equipment inventory, operation and maintenance manuals, repair records, and many others. Typically, FM teams have to rely on documents and blueprints archived in boxes or stored in separate digital files for the detection, diagnosis, and response to an issue occurring within buildings. This traditional workflow of operational tasks is apparently time-consuming and error-prone. It is crucial to deliver accurate, complete and easily accessible information to the operations team for efficient FM planning and execution.

BIM responds to this dire need for information and facilitates rapid access to necessary information from a single digital data source. Contemporary practices of the AEC industry embrace BIM to assist collaboration among stakeholders and achieve integrated design and construction of projects. Since the 2000s, global BIM research and practice are mainly concentrated on building delivery rather than building operations. Day after day, the BIM-based delivery of buildings is evolving into the BIM-based operations of buildings. As a result, many scholars are rechannelling their efforts to achieve wider BIM implementation in FM for more than a decade. The results of the science mapping method applied in this study revealed the increasing scholarly interest in BIM-FM integration and highlighted BIM-based FM as a trending research topic across the world. Although several scientific publications have been published on different aspects of BIM for FM, the BIM subject still challenges organisations involved in the operational phase because there is a lack of guidance for identifying BIM information requirements and implementing BIM processes. The

19650 standard series of ISO focuses on BIM implementation and defines the processes of BIM-based management and exchange of building information throughout the entire building life cycle. These series propose a comprehensive guideline for BIM-based information management while encouraging the establishment of national procedures to ensure wider BIM implementation in distinguishing industry conditions.

These guidelines represent a synthesis of knowledge, experience and insights of industries with a high level of BIM maturity and are of great importance for developing industries to ensure smooth and successful transition to BIM. Being a young and developing industry, the FM industry in Turkey exhibits a suitable case for transforming its ad hoc approaches into more profound methods. Thus, as a response to the ISO call, this thesis study examined the 19650 series from the perspective of FM professionals in Turkey and proposed a conceptual framework to promote BIM implementation within the FM industry. The quantitative and qualitative studies carried out within the scope of this thesis study investigated the BIM awareness, knowledge and utilisation level of FM professionals, and identified hindrances to adopting BIM by the FM industry. Results uncovered the need for a BIM implementation roadmap tailored to local business practices. The purpose was to introduce a path for FM companies to switch to a BIM mindset and successfully implement BIM-based practices. The two major principles, namely, early FM involvement and collaboration with the building owner and/or tenant were promoted in the proposed study. Collaboration is the key to success in BIM, thus, the absence of one of the parties causes failure. The focus group discussion conducted with the industry experts evaluated and confirmed the proposed framework as a promising approach within the Turkish FM sector context and suggested further development areas to focus on. The main lessons learned from the validation of the framework are the following:

- There is a need for a holistic BIM training program tailored to increase BIM awareness and understanding of the major actors involved in building operations.
- The actors should be trained about the value of data in the entire life cycle of buildings and reminded of their roles in the continuous data stream.

- BIM use cases and international examples of real-life BIM-FM projects should be introduced in various mediums, such as trade magazines or industry symposiums to escalate BIM familiarity and promote BIM recognition among industry actors.
- BIM-FM researchers and FM industry experts should establish collaborations to experiment and demonstrate the capabilities of BIM to overcome the shortcomings of traditional practices of the operational phase.
- Numerous FM tasks could be examined in terms of the time spent to find relevant information, response time, the accuracy of response, and the cost spent before and after implementing BIM.
- Solid evidence in terms of gains in time and cost could be represented to owners and/or tenants and the executive board to ensure managerial support for digitisation and BIM adoption.
- Existing business models and contractual relationships among the key stakeholders of building delivery and operations should be reviewed to involve FM representatives at the beginning of projects.

Although this thesis study does prioritise a generic approach for the acceptance and implementation of BIM by the FM industry, the proposed framework can be refined and exploited for any specific FM task. The increasing number of projects delivered with BIM necessitates FM organisations to promptly adopt and utilise BIM-based technology and procedures. Well-structured implementation guidelines facilitate the quick adaptation of the FM industry to the upcoming developments in BIM. However, local authorities and regulatory bodies should support and promote BIM for the delivery and operations of speciality projects, such as healthcare facilities, office buildings, and shopping malls to catalyse BIM implementation in both the AEC and FM industries.

It is worth noting the limitations of this thesis study. First of all, this study approaches FM as an information management problem and utilises BIM as a tool for the efficient management of information. The framework proposed within the scope of this study intends to provide a roadmap for FM organisations to implement BIM without favouring a particular software or technology. Although the absence of tool and technology recommendations dissatisfies industry experts, there are numerous vendors available in the market. Second, the limited number of BIM-delivered projects in Turkey inhibits a real-life experiment of the proposed framework. Still, the framework was thoroughly evaluated and validated by highly experienced FM industry professionals. Increasing BIM adoption in the design and construction phases would definitely encourage BIM adoption for building operations. Finally, it is known that a smooth and successful BIM transition requires a collaborative mindset of all parties. Therefore, it is important to take a step back, review the existing building delivery and operations models, eliminate disconnectedness among major actors, and establish an inclusive environment to allow early FM input into projects.

As a whole, this thesis study can be attributed to remarkable research focusing on the BIM transition tendencies of the FM industry in Turkey and a timely response to the call for national adjustments of international information management standards. Acknowledging high technology investment as one of the primary obstacles to BIM-FM integration, this study analyses local circumstances and syntheses research outcomes to promote scalable yet robust steps for prospering BIM-FM transition in a developing industry. The proposed study could initiate a data-driven approach to building operations and lead to a BIM-based shift in the FM work culture. The more firms embrace digitisation and BIM for FM, the more efficient and competitive they become.

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APPENDICES

APPENDIX A: Steps of information management by BS EN ISO 19650-2:2018

APPENDIX B: Steps of information management by BS EN ISO 19650-3:2020

Appendix A

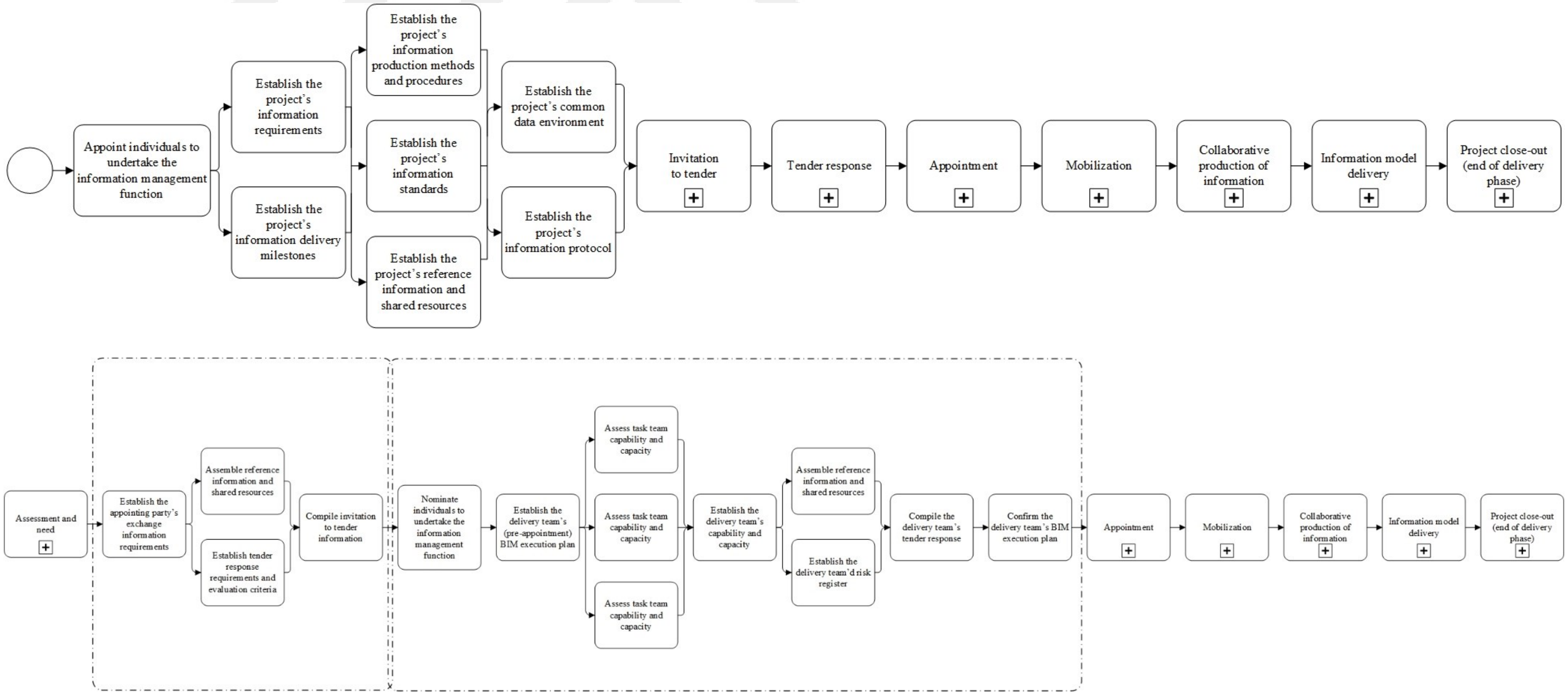

Figure A.1: BS EN ISO 19650-2:2018 information management steps.

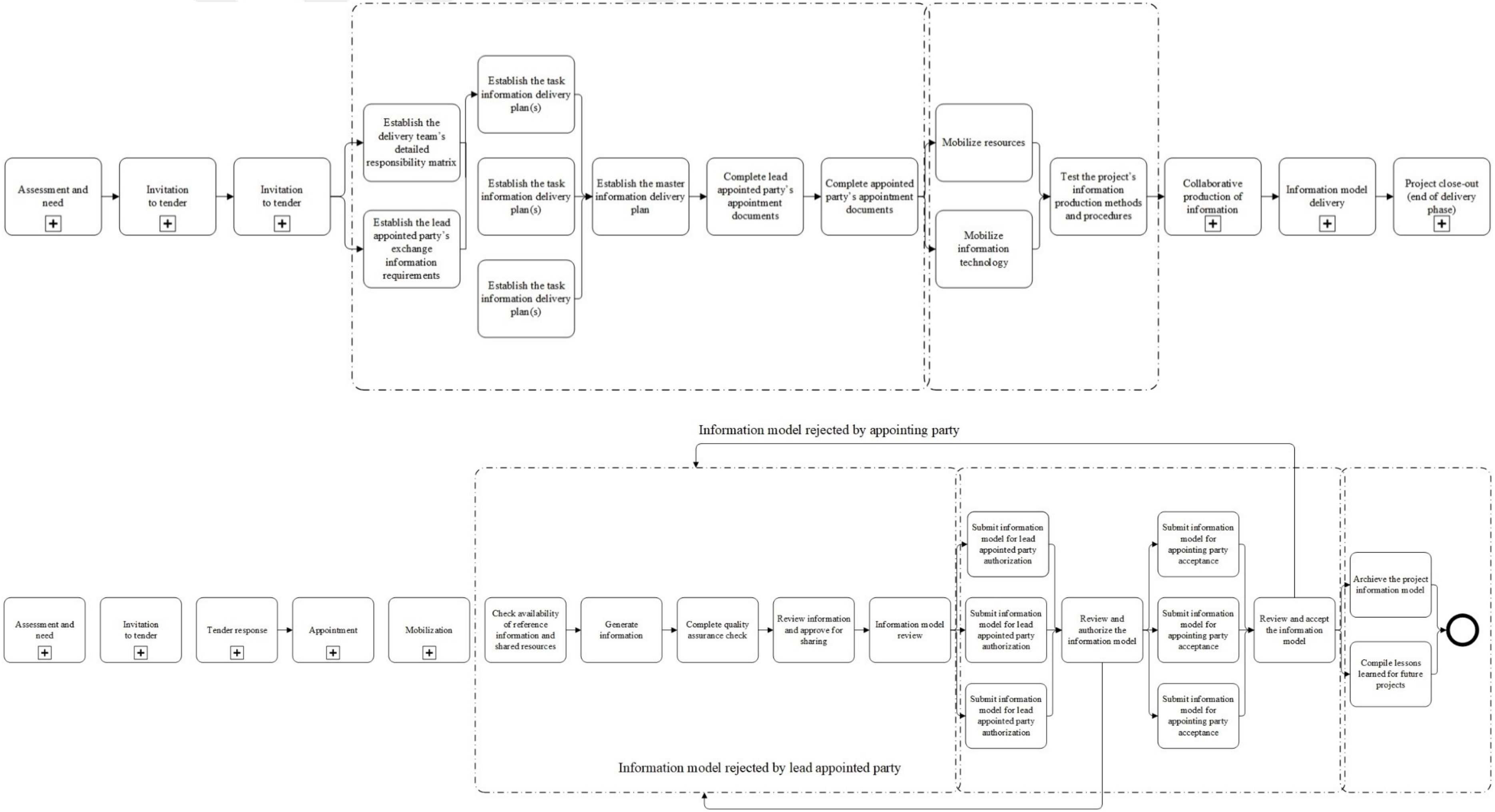

Figure A.1 (continued): BS EN ISO 19650-2:2018 information management steps.

Appendix B

Figure B.1: BS EN ISO 19650-3:2020 information management activities.

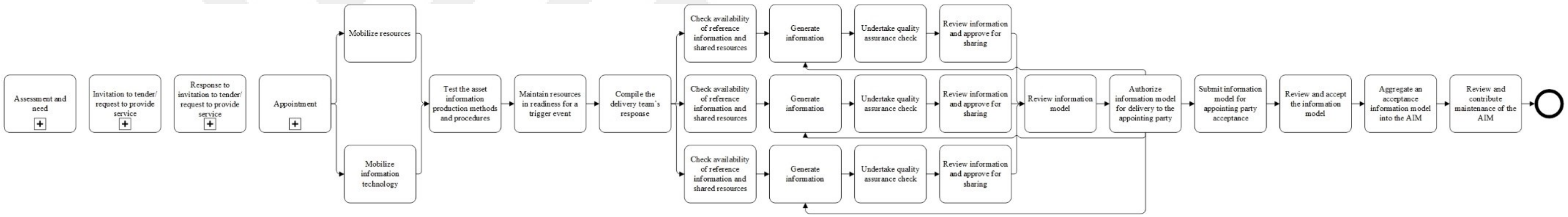

Figure B.1 (continued): BS EN ISO 19650-3:2020 information management activities.

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