出國報告（出國類別：其他-視訊會議）

參加「2022 世界建築大會 (CIB World Building Congress)」視訊會議報告

服務機關：內政部建築研究所
姓名職稱：呂文弘　簡任研究員
游伯堅　助理研究員
派赴國家：視訊會議
出國期間：111 年 6 月 27 日至 6 月 30 日
報告日期：111 年 9 月 20 日

摘要

關鍵字：聯合國永續發展目標、建築物理、節能減碳、室內環境

全球暖化問題日益嚴重，為減緩氣候變化，地球環境保護之相關政策已成為全球重要的議題。為使國人有更優質、舒適及健康之居住環境，內政部建築研究所長期推動「生態」、「節能」、「減廢」、「健康」之綠建築，並與內政部「建構永續宜居環境」之施政目標整合，辦理「創新循環綠建築環境科技計畫(108-111)」，發展符合臺灣亞熱帶及熱帶高溫高濕氣候條件與生態環境之綠建築科技與技術，已成功帶動我國綠建築、綠建材相關產業的蓬勃發展與良性競爭，然而面對全球能源結構與經濟情勢的快速變動，永續建築及永續基礎建設的發展策略仍須不斷滾動調整。

另一方面，全球自 2019 年受到嚴重特殊傳染性肺炎(Coronavirus disease 2019, COVID-19)肆虐，各國經濟與生活都受到顯著的衝擊影響，直至 3 年後的今年，全球仍受到其威脅，且目前從全球國際政策與策略顯示，未來將與疾病共存，因此為因應疫情衝擊與後疫情環境改變，建築物、社區或整體都市發展都將因應健康與防疫需要而有所改變。為瞭解國際間相關發展現況及未來趨勢，並考量國內外疫情發展與防疫規定，爰以視訊方式參加 111 年 6 月 26 日至 30 日由國際建築與營建研究創新聯盟 (International Council for Research and Innovation in Building and Construction, CIB)主辦，於澳洲墨爾本召開之 2022 世界建築大會(CIB World Building Congress 2022, WBC2022)。

本報告係彙整發表於 WBC2022 國際研討會，且與本所業務相關之研究主題，包括：都市與建築環境減碳策略、建築廢棄物管理之循環經濟、零碳建築、木結構生命週期評估研究等，提出國際間相關研究趨勢之說明，期能作為本所規劃未來淨零建築路徑策略與下一期科技計畫(112-115)研究課題發展方向之參考，以確保我國永續健康綠建築等政策之發展符合國際發展趨勢。最後，本文亦提出本次會議之心得及建議。

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壹、出國目的

為因應氣候與社會環境變遷、減緩地球暖化，本所「創新循環綠建築環境科技計畫(108-111)」整合內政部「建構永續宜居環境」之施政目標，本於「生態、節能、減廢、健康」的綠建築基本概念，積極研發適用於臺灣亞熱帶及熱帶氣候條件與生態環境之綠建築科技與技術，以科技創新打造永續宜居環境，提升生活環境與居住品質。

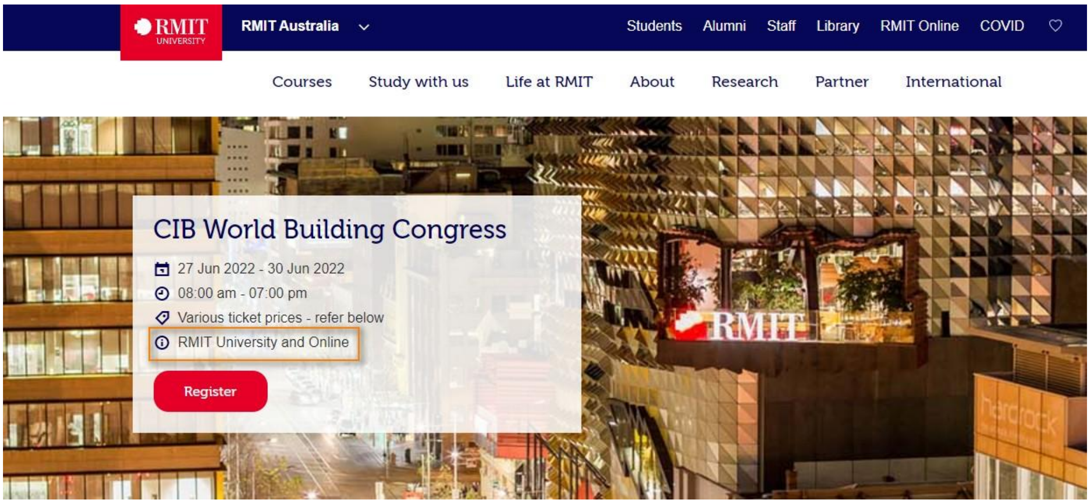
而在國際間，全球暖化與氣候變遷的議題持續受到全球關注，聯合國氣候變化綱要公約（United Nations Framework Convention on Climate Change, UNFCCC）的歷次會議均確認全球必須努力把溫度上升控制在 1.5~2℃的範圍以內，各國也透過相關協議與自願性的減碳承諾，共同推動溫室氣體減量，在此背景下，各國對於永續與智慧建築所能發揮的減碳效益，均予高度重視，催化了永續與智慧建築的快速發展。

本次以線上會議方式參加 2022 世界建築大會(CIB World Building Congress 2022)之目的，即是希望藉由國際研討會平臺的交流，廣泛蒐集國際最新永續環境與氣候變遷、數位建築、健康建築環境對嚴重特殊傳染性肺炎 COVID-19 的因應措施等相關技術及研究成果，作為本所推動淨零建築及健康建築計畫擬議之參考。

貳、視訊會議議程

一、 國際研討會改以視訊方式參加

2022世界建築大會(CIB World Building Congress 2022)於111年6月27日至30日，在澳洲維多利亞州首府-墨爾本市辦理，鑒於嚴重特殊傳染性肺炎(COVID-19)疫情肆虐全球，該會議主辦單位於網站上公告，改採以線上與實體會議併行的方式辦理(圖1)，本所評估線上參與研討會議之方式，仍可達成蒐集資料之目的，尚無於防疫期間派員出國之必要，因此依據「行政院及所屬各級機關因公派員出國案件編審要點」第4點及「內政部及所屬各級機關因公派員出國案件處理要點」第4點相關規定，報陳上級機關同意變更計畫，改以派員2人於國內參加線上會議之方式執行。



CIB World Building Congress

27 Jun 2022 - 30 Jun 2022

08:00 am - 07:00 pm

Various ticket prices - refer below

RMIT University and Online

圖 1　2022世界建築大會(CIB World Building Congress 2022)線上與實體會議併行方式辦理

(資料來源：https://www.rmit.edu.au/events/2022/june/cib-world-building-congress)

二、 會議及主辦單位簡介

2022世界建築大會(CIB World Building Congress 2022) (圖2) 召集國際間建築行業的研究人員、從業人員、教育工作者和學生，共同交流創新的研究和技術，並討論建築學領域當前問題與未來挑戰，並提出永續解決方案。本次會議由國際建築與營建研究創新聯盟 (International Council for Research and Innovation in Building and Construction, CIB)主辦，該會成立於 1953 年，旨在

促進和促進建築和建築領域政府研究機構之間的國際合作和信息交流，重點是這些機構從事技術領域的研究，其中每 3 年舉辦 1 次世界建築大會(World Building Congress)，為建築環境與營建產業相關的重要國際研究交流活動。

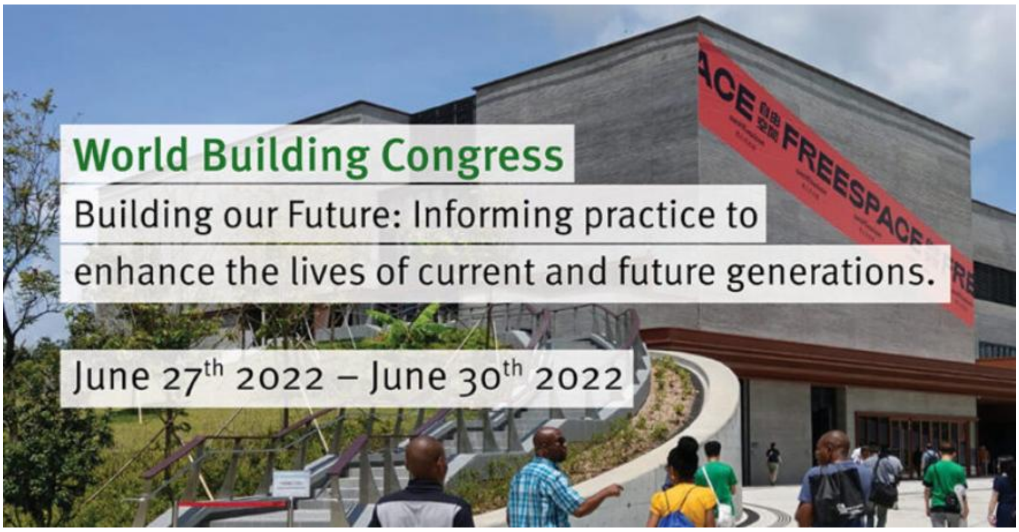


圖 2　2022 世界建築大會(CIB World Building Congress 2022)

(資料來源：https://cibworld.org/world-building-congress/)

本次 2022 世界建築大會由墨爾本皇家理工大學承辦(圖 1)，並有墨爾本市政府及多家產業共同贊助(圖 3)，會議活動包括主題演講、研討會、技術會議、工作媒合和交流活動。

圖 3　2022 世界建築大會(CIB World Building Congress 2022)共同贊助單位

(資料來源：WBC2022 E-Booklet)

三、 線上會議時間與議程

本次會議於澳洲墨爾本市當地時間111年6月27日至6月30日召開，奉派與會人員配合2地時差於國內以視訊方式參與。會議主題針對永續環境與氣候變遷、數位建築、健康建築環境對COVID-19的因應措施等相關技術及研究成果，並從設計手法、施工構造、設施設備等回應永續循環之執行策略，共約發表了500篇研討會論文，研討會議程與各分項主題彙整如下表1至表4所示：

表 1　2022世界建築大會會議程表(111年6月27日星期一)

時間 (111年6月27日)	議程	
09:00-10:30	開場致詞	
11:00-12:00	發表簡介 ● 永續智慧城市與建築 ● 運用數據資料的機會與挑戰	● 改善教育和工作環境
13:00-14:00	發表簡介 ● 永續智慧城市與建築 ● 創新工程和製造 ● 運用數據資料的機會與挑戰	● 改善教育和工作環境 ● 建造的管理和組織:新的機會與挑戰
14:00-15:00	會議講座:石墨烯與建築技術的創新發展	
15:30-17:00	發表簡介 ● 韌性城市的發展 ● 永續智慧城市與建築 ● 創新工程和製造 ● 運用數據資料的機會與挑戰	● 改善教育和工作環境 ● 建造的管理和組織:新的機會與挑戰
 (資料來源：https://virtual.oxfordabstracts.com/#/p/wbc2022/program)		

表 2　2022 世界建築大會會議程表(111 年 6 月 28 日星期二)

<table>
<tr><th>時間
(111 年 6 月 28 日)</th><th colspan="2">議程</th></tr>
<tr><td>09:00-10:30</td><td colspan="2">會議講座 1:永續混凝土工程的發展
會議講座 2:創新的科學對都市革新的影響</td></tr>
<tr><td>11:00-12:30</td><td>發表簡介
● 加速創新的建設
● 韌性城市的發展
● 循環建築的環境
● 創新工程和製造
● 專業知識的利用與自動化的進步</td><td>● 建築空間和基礎設施的規劃
● 耐久性及氣候變遷
● 異地施工</td></tr>
<tr><td>13:30-15:00</td><td>發表簡介
● 加速創新的建設
● 韌性城市的發展
● 循環建築的環境
● 創新工程和製造
● 專業知識的利用與自動化的進步</td><td>● 建築空間和基礎設施的規劃
● 耐久性及氣候變遷
● 異地施工</td></tr>
<tr><td>15:30-18:00</td><td>發表簡介
● 加速創新的建設
● 耐久性及氣候變遷
● 循環建築的環境
● 創新工程和製造</td><td>● 專業知識的利用與自動化的進步
● 異地施工</td></tr>
<tr><td>18:00-19:00</td><td colspan="2">建築空間和基礎設施的規劃</td></tr>
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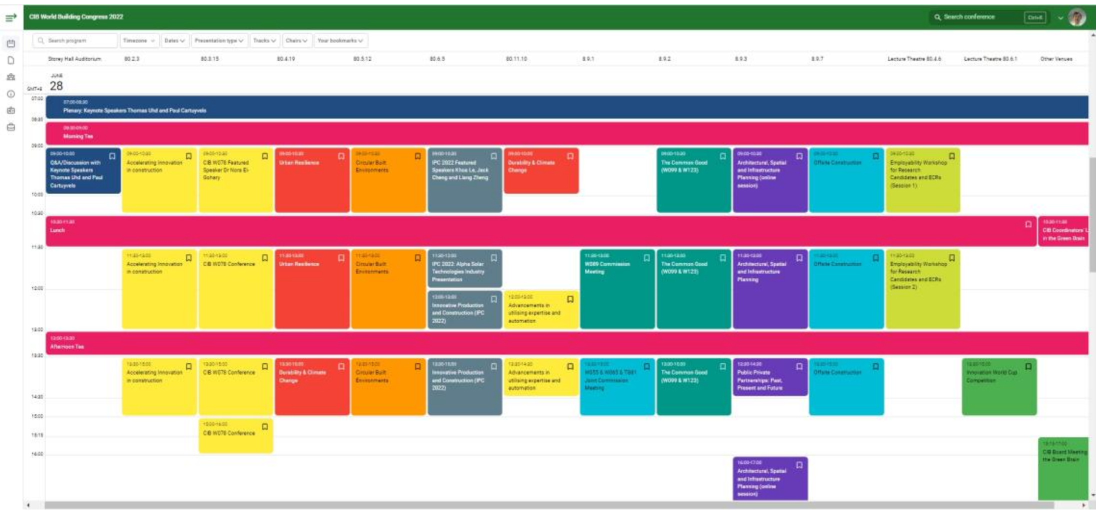


Plenary: Keynote Speakers Thomas Uhd and Paul Cartuyvels

Morning Tea

Q&A/Discussion with Keynote Speakers Thomas Uhd and Paul Cartuyvels

Accelerating Innovation in construction

CIB W078 Featured Speaker Dr Nora El-Gohary

Urban Resilience

Circular Built Environments

IPC 2022 Featured Speakers Khoa Le, Jack Cheng and Liang Zheng

Durability & Climate Change

The Common Good (W099 & W123)

Architectural, Spatial and Infrastructure Planning (online session)

Offsite Construction

Employability Workshop for Research Candidates and ECRs (Session 1)

Lunch

CIB Coordinators' L… in the Green Brain

Accelerating Innovation in construction

CIB W078 Conference

Urban Resilience

Circular Built Environments

IPC 2022: Alpha Solar Technologies Industry Presentation

Innovative Production and Construction (IPC 2022)

Advancements in utilising expertise and automation

W089 Commission Meeting

The Common Good (W099 & W123)

Architectural, Spatial and Infrastructure Planning

Offsite Construction

Employability Workshop for Research Candidates and ECRs (Session 2)

Afternoon Tea

Accelerating Innovation in construction

CIB W078 Conference

Durability & Climate Change

Circular Built Environments

Innovative Production and Construction (IPC 2022)

Advancements in utilising expertise and automation

W055 & W065 & TG81 Joint Commission Meeting

The Common Good (W099 & W123)

Public Private Partnerships: Past, Present and Future

Offsite Construction

Innovation World Cup Competition

CIB W078 Conference

CIB Board Meeting the Green Brain

Architectural, Spatial and Infrastructure Planning (online session)

(資料來源：https://virtual.oxfordabstracts.com/#/p/wbc2022/program)

表 3　2022 世界建築大會會議程表(111 年 6 月 29 日星期三)

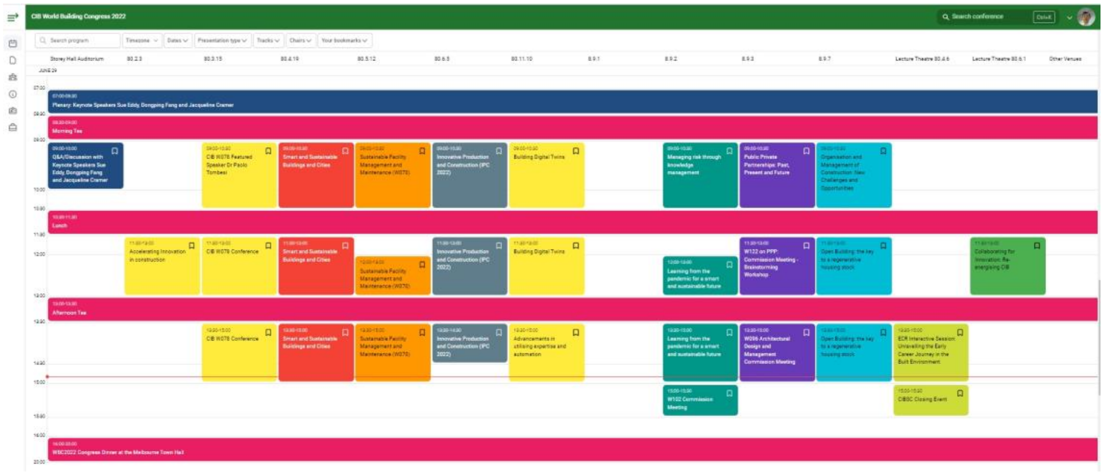
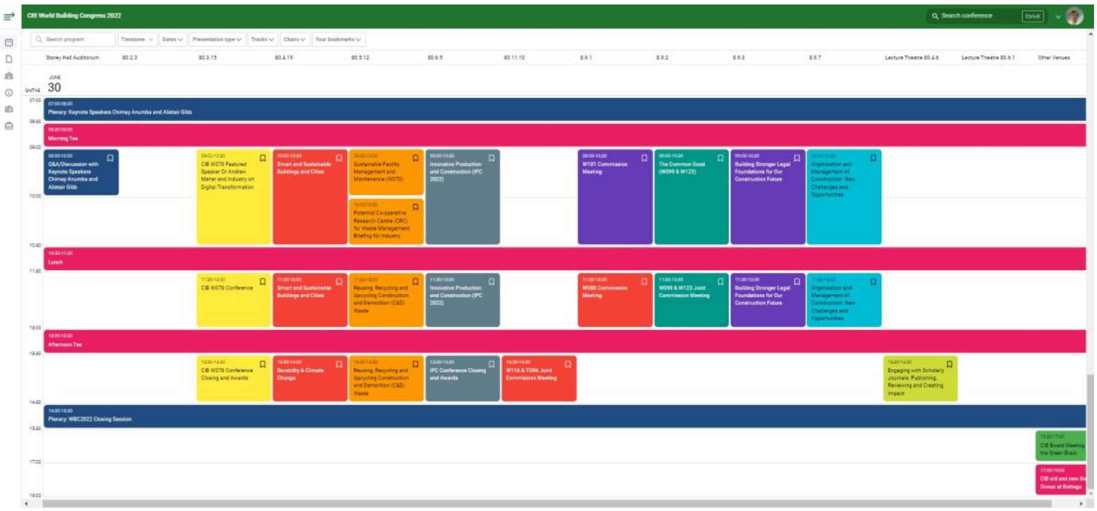
時間 (111 年 6 月 29 日)	議程
09:00-10:30	會議講座:永續建築的環境研究
11:00-12:30	發表簡介 ● 永續智慧城市與建築 ● 公司永續發展的管理與維持 ● 創新工程和製造 ● 經由知識管理的風險管理 ● 建造的管理和組織:新的機會與挑戰
13:30-15:00	發表簡介 ● 加速創新的建設 ● 永續智慧城市與建築 ● 公司永續發展的管理與維持 ● 創新工程和製造 ● 從疾病的大流行中學習未來如何智慧及永續的發展
15:30-17:30	發表簡介 ● 永續智慧城市與建築 ● 公司永續發展的管理與維持 ● 創新工程和製造 ● 專業知識的利用與自動化的進步 ● 從疾病的大流行中學習未來如何智慧及永續的發展 ● 建築設計及管理
 (資料來源：https://virtual.oxfordabstracts.com/#/p/wbc2022/program)	

表 4　2022 世界建築大會會議程表(111 年 6 月 30 日星期四)

時間 (111 年 6 月 30 日)	議程
09:00-10:30	會議講座:建築的未來發展和環境
11:00-12:30	發表簡介 ● 永續智慧城市與建築 ● 公司永續發展的管理與維持 ● 創新工程和製造 ● 為建築產業建立更強大的法律基石 ● 建造的管理和組織:新的機會與挑戰
13:30-15:00	發表簡介 ● 加速創新的建設 ● 公司永續發展的管理與維持 ● 建築工程的再使用、再回收、升級回收建材及拆除廢棄物 ● 創新工程和製造 ● 為建築產業建立更強大的法律基石 ● 建造的管理和組織:新的機會與挑戰
15:30-16:30	發表簡介 ● 耐久性及氣候變遷 ● 建築工程的再使用、再回收、升級回收建材及拆除廢棄物
16:30-17:30	閉幕式

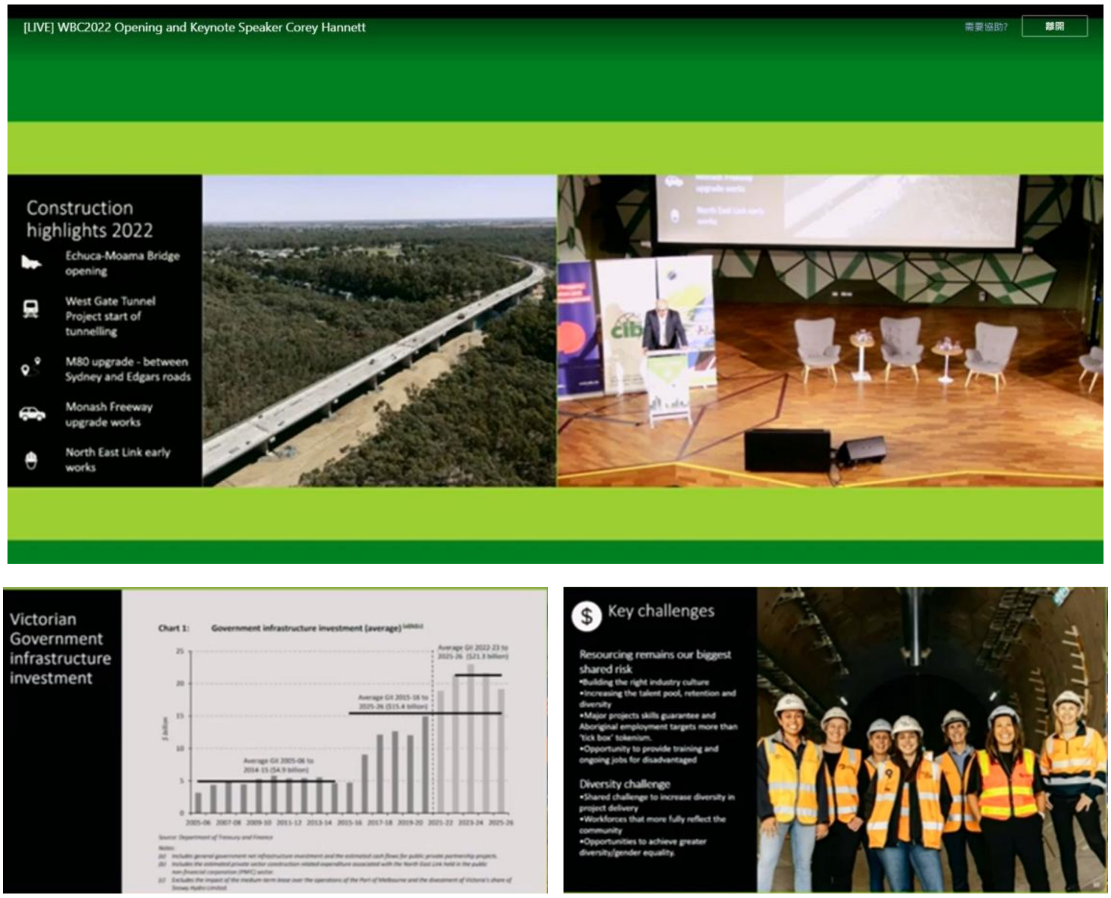


(資料來源：https://virtual.oxfordabstracts.com/#/p/wbc2022/program)

參、會議參與過程

一、 會議開幕致詞

會議開幕式由墨爾本皇家理工大學 Ron Wakefield 主持，並邀請到澳洲交通設施部門主管(Major Transport Infrastructure Authority) 局長(Director-General) Corey Hannett 擔任主講嘉賓，就其負責該國全國大型交通工程超過 25 年的實務經驗（其中包括 16 年的公共部門經驗），分享澳大利亞維多利亞州如何規劃和執行基礎設施，以及這些基礎設施將對該州的未來發展的具體貢獻。Corey Hannett 局長主講重點包括澳洲在面對氣候變遷帶來因高溫乾旱產生的野火侵襲，以及高強度的暴雨致生的水患，在都市與國土規劃思維產生轉變與相關作為(圖 4)。主辦單位邀請本項主題演講，即是希望藉由 WBC2022 國際建築大會的舉辦，期勉全球有志者，透過學術交流與資訊學習，創造更好的建築環境，共同維護人類生存環境永續發展。



Construction highlights 2022

- Echuca-Moama Bridge opening
- West Gate Tunnel Project start of tunnelling
- M80 upgrade - between Sydney and Edgars roads
- Monash Freeway upgrade works
- North East Link early works

Victorian Government infrastructure investment

Key challenges

Resourcing remains our biggest shared risk
- Building the right industry culture
- Increasing the talent pool, retention and diversity
- Major projects skills guarantee and Aboriginal employment targets more than 'tick box' tokenism.
- Opportunity to provide training and ongoing jobs for disadvantaged

Diversity challenge
- Shared challenge to increase diversity in project delivery
- Workforces that more fully reflect the community
- Opportunities to achieve greater diversity/gender equality.

圖 4　Corey Hannett 局長分享澳洲交通設施部門今(2022)年主要工程內容與特色

(資料來源：視訊會議錄影截圖)

二、 會議重要內容概述

本次研討會研究論文主題廣泛，且發表論文多達500篇，為因應國際間永續發展、循環經濟以及COVID-19健康防疫等發展趨勢，本報告摘錄其中與本所業務相關之研究發表項目，內容說明如下：

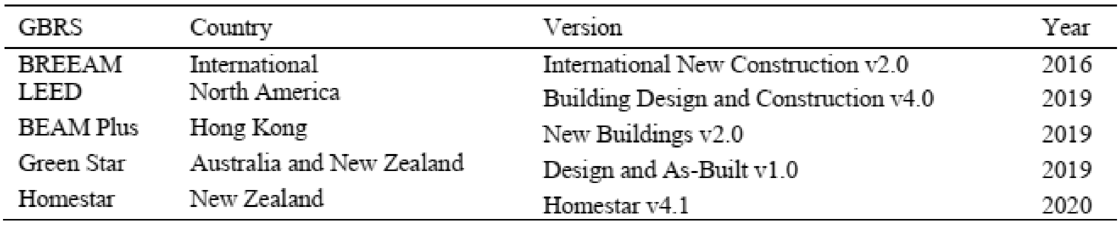
(一) 建築碳足跡與淨零排放

Fatma Abdelaal 等人於「Comparison of Green Building Rating Systems from LCA Perspective」研究指出，自2010年以來，全球建築物碳排放量大約以每年近 1% 的速度增長。因此世界各國均致力於推動綠建築評估系統 (Green Building Rating System, GBRS)，以評估建築環境績效並減輕其對氣候變化的影響。該研究及從全生命週期的角度比較國際 Leadership in Energy and Environmental Design (LEED)、Building Research Establishment Environmental Assessment Method (BREEAM)、Building Environmental Assessment Method (BEAM) Plus、Green Star 和 Homestar 等5個綠建築評估系統(表5)，於(1)整體建築全生命週期、(2)實體碳排放(embodied carbon emissions)和(3) 運(使用)碳排放(operational carbon emissions)評估和計算建築總碳排放之效率、有效性和可靠性。

該研究結論指出，實體碳排放通常可在綠建築評估系統中的材料和廢棄物類別中得到認可，然而這些系統缺乏對實體碳排放的評估和計算。儘管各種綠建築評估系統均鼓勵選擇永續建築材料，但多以建築材料的定性方法為評估準則，因為在全生命週期中定量分析需要龐大的數據庫，故建築運營階段的營運(使用)碳排放評估構成了各種綠建築評估系統的主要部分，其中於「能源」和「水」類別中進行評估。(圖5)

該研究最後建議，依據2017 年聯合國環境全球狀況報告說明，從現在到2050 年前，實體碳排放將占新建築總排放量的近一半，然國際現有的綠建築評估系統多以能源為導向，仍集中於計算營運階段碳排放，並忽視建築實體碳排放，因此呼籲各界需要將重點從營運階段碳轉向全生命週期(圖6、7)的視角，以實現減排目標，從而實現建築環境的減碳。

表 5 FatmaAbdelaal 等人探討的綠建築評估系統種類與版本



GBRS	Country	Version	Year
BREEAM	International	International New Construction v2.0	2016
LEED	North America	Building Design and Construction v4.0	2019
BEAM Plus	Hong Kong	New Buildings v2.0	2019
Green Star	Australia and New Zealand	Design and As-Built v1.0	2019
Homestar	New Zealand	Homestar v4.1	2020

(資料來源：Fatma Abdelaal et al, Comparison of Green Building Rating Systems from LCA Perspective)

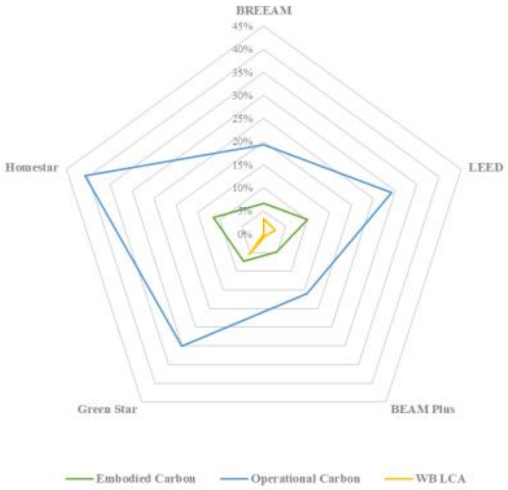
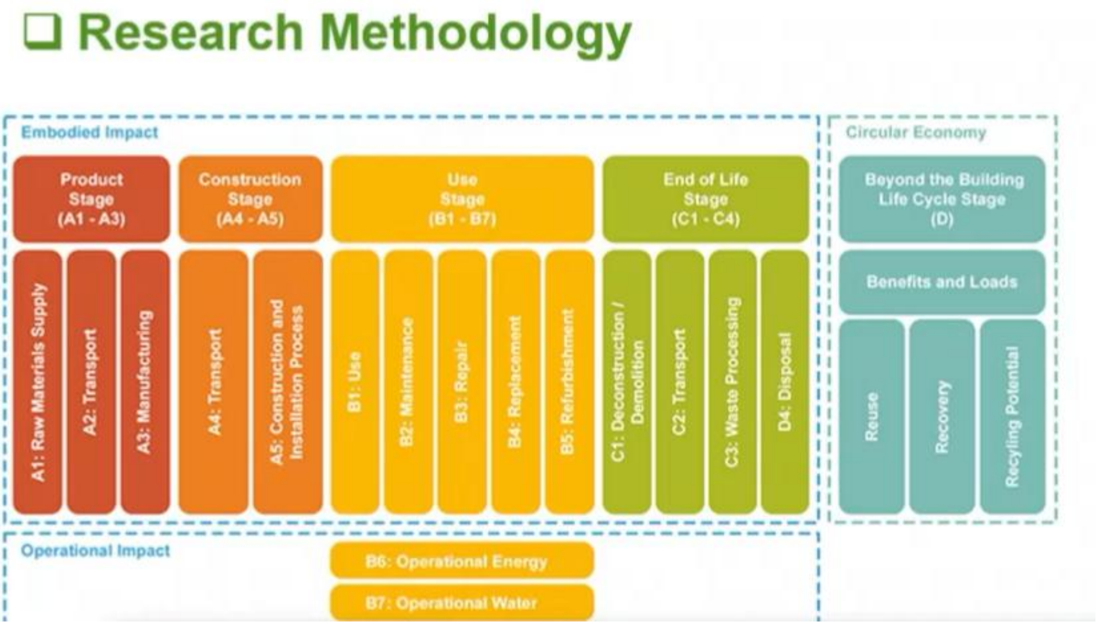


圖 5　Fatma Abdelaal 等人對 5 種綠建築評估系統版本分析其碳排評估之結果

(資料來源：Fatma Abdelaal et al, Comparison of Green Building Rating Systems from LCA Perspective)



❑ Research Methodology

Embodied Impact

Product Stage (A1 - A3)
- A1: Raw Materials Supply
- A2: Transport
- A3: Manufacturing

Construction Stage (A4 - A5)
- A4: Transport
- A5: Construction and Installation Process

Use Stage (B1 - B7)
- B1: Use
- B2: Maintenance
- B3: Repair
- B4: Replacement
- B5: Refurbishment

End of Life Stage (C1 - C4)
- C1: Deconstruction / Demolition
- C2: Transport
- C3: Waste Processing
- D4: Disposal

Circular Economy

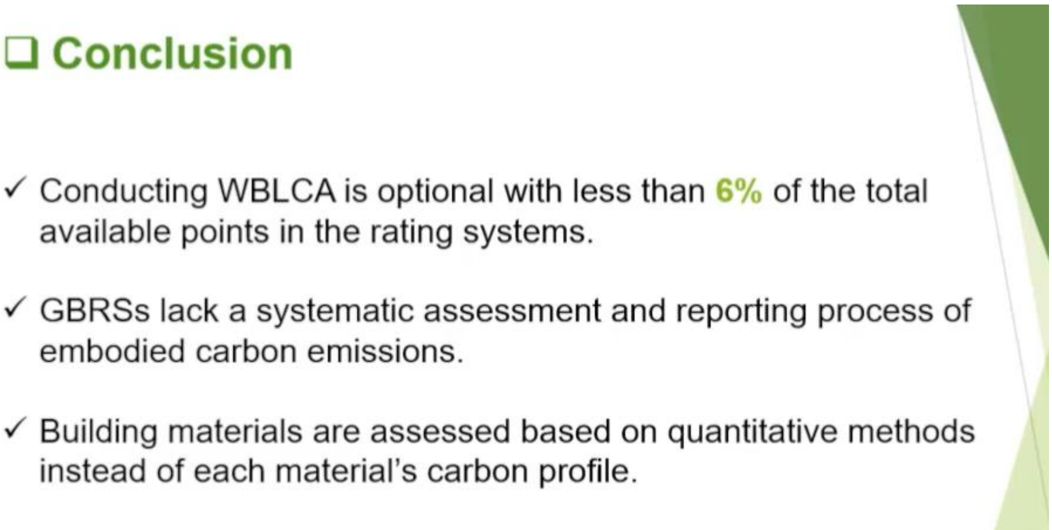
Beyond the Building Life Cycle Stage (D)

Benefits and Loads
- Reuse
- Recovery
- Recyling Potential

Operational Impact
- B6: Operational Energy
- B7: Operational Water

圖 6　Fatma Abdelaal 等人於簡報中說明建築碳排放之種類

(資料來源：視訊會議錄影截圖)



❑ Conclusion

- ✓ Conducting WBLCA is optional with less than 6% of the total available points in the rating systems.
- ✓ GBRSs lack a systematic assessment and reporting process of embodied carbon emissions.
- ✓ Building materials are assessed based on quantitative methods instead of each material's carbon profile.

圖 7　FatmaAbdelaal 等人研究結論簡報

(資料來源：視訊會議錄影截圖)

另 Thais Sartori 等人於「Challenges in developing a holistic Whole Building Life Cycle Assessment (WBLCA) soft tool: developers' goals」研究指出，全球 40%溫室氣體排放來自建築部門，必須從全生命週期點思考有效降低建築環境衝擊的影響，因此該研究發展全建築生命週期評估軟體工具，從軟體開發、教育訓練、資料庫建置及評估成果共享，分階段推動應用。

該研究結論指出，透過增加全建築生命週期評估需求，將可解決建築部門面臨的溫室氣體排放減量其他的挑戰。其次，營造業也會逐步順應全建築生命週期評估的推動，尋得適應新現狀的方法；第 3 階段則會促使設計者在評估作業時更有成本效益和可行性，以克服其他執行建築溫室氣體減量上的挑戰。(圖 5)

International Council
for Research and Innovation
in Building and Construction

Challenges in developing a holistic Whole Building Life Cycle Assessment (WBLCA) software tool: developers' goals

Thais Sartori, Robin Drogemuller, Sara Omrani, Fiona Lamari

Queensland University of Technology (QUT)

June 30, 2022

CIBworld.org

Contextualization

40% of the global greenhouse gas (GHG) emissions derive from the building sector

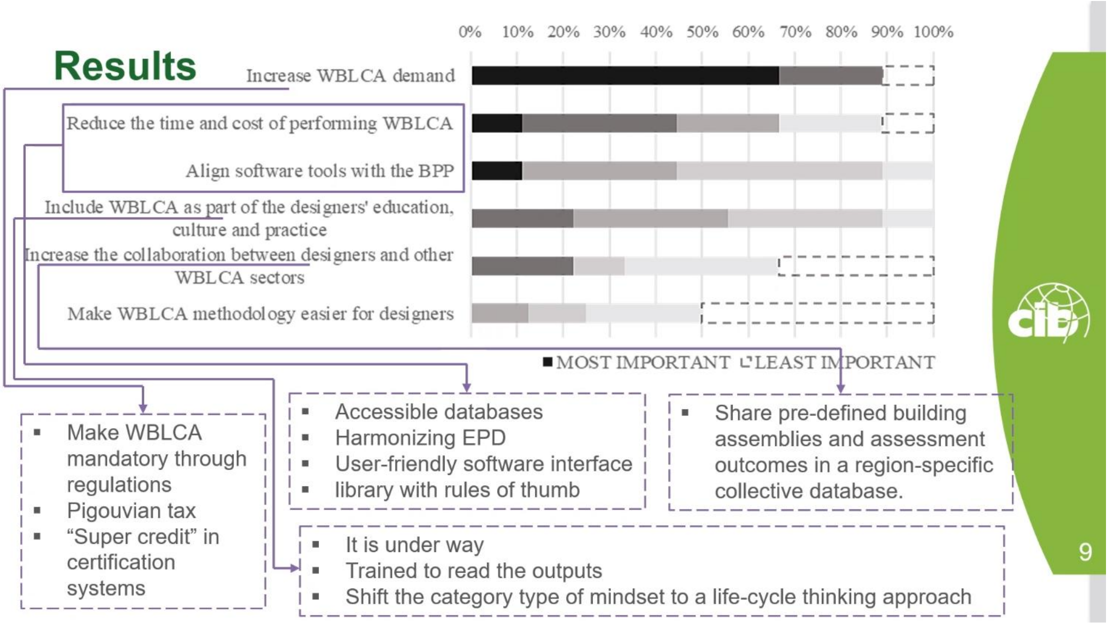
A **whole life-cycle approach** should be considered to effectively reduce building's environmental impact.

Whole building Life Cycle Assessment

WBLCA

圖 8　Thais Sartori 等人研究發表簡報

(資料來源：視訊會議錄影截圖)



Results

- Increase WBLCA demand
- Reduce the time and cost of performing WBLCA
- Align software tools with the BPP
- Include WBLCA as part of the designers' education, culture and practice
- Increase the collaboration between designers and other WBLCA sectors
- Make WBLCA methodology easier for designers

- Make WBLCA mandatory through regulations
- Pigouvian tax
- "Super credit" in certification systems

- Accessible databases
- Harmonizing EPD
- User-friendly software interface
- library with rules of thumb

- Share pre-defined building assemblies and assessment outcomes in a region-specific collective database.

- It is under way
- Trained to read the outputs
- Shift the category type of mindset to a life-cycle thinking approach

圖 9　Thais Sartori 等人研究發表結果

(資料來源：視訊會議錄影截圖)

(二) 循環經濟與再生建築材料

由於建築營造產業佔全球 40-60% 的原材料開採，隨之亦產生大量營建廢棄物，導入循環經濟與再生建築材料技術，將有助於減少自然資源與能源消耗以及環境溫室氣體排放。S Schützenhofer 等人於「Improvement of environmental sustainability and Circular Economy through construction waste management for material reuse」研究指出，以實證研究與案例分析的方式(圖 8)，分析數種建材拆解、回收和再循環過程，並透過相關參數評估，比較不同再生建材技術之作業成本與對環境影響，所得之數據可用於推廣既有建築之拆除規劃、營建廢棄物處理，且有助於政府稅收機制。

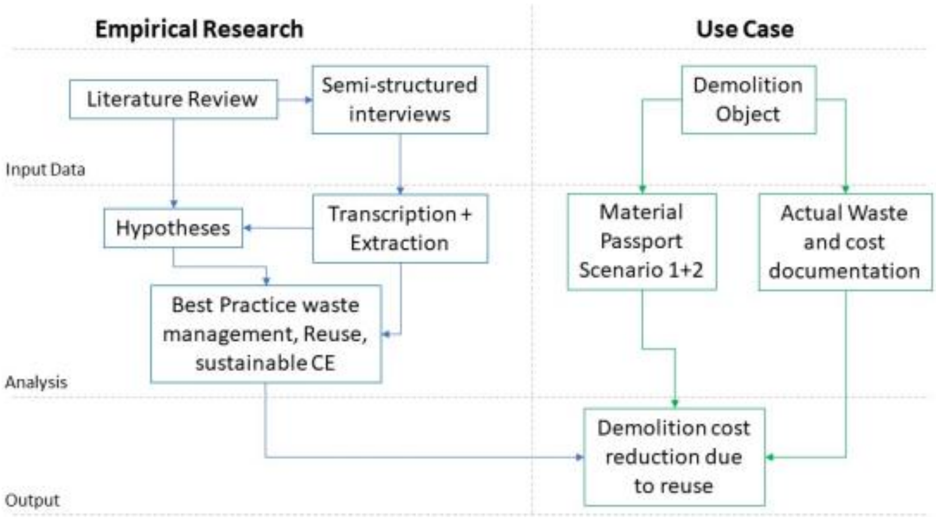
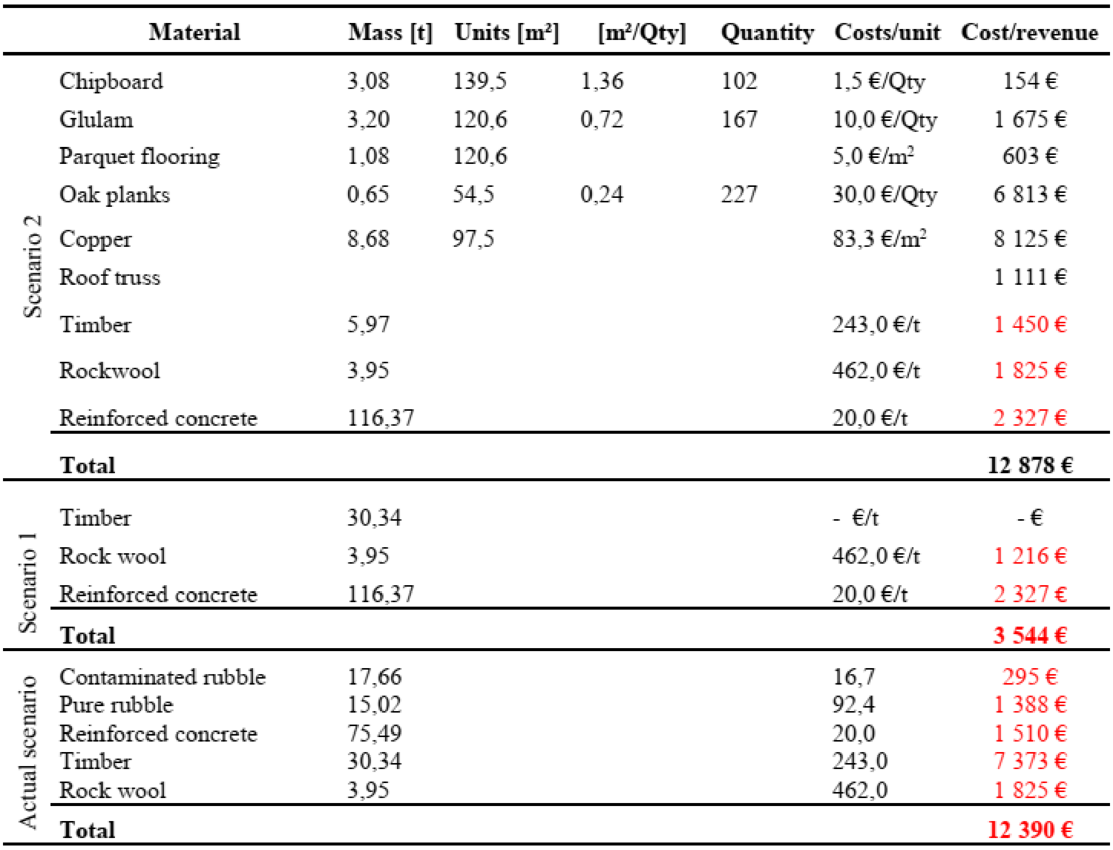


圖 10　S Schützenhofer 等人之實證研究與案例分析方法

(資料來源：S Schützenhofer et al, Improvement of environmental sustainability and Circular Economy through construction waste management for material reuse)

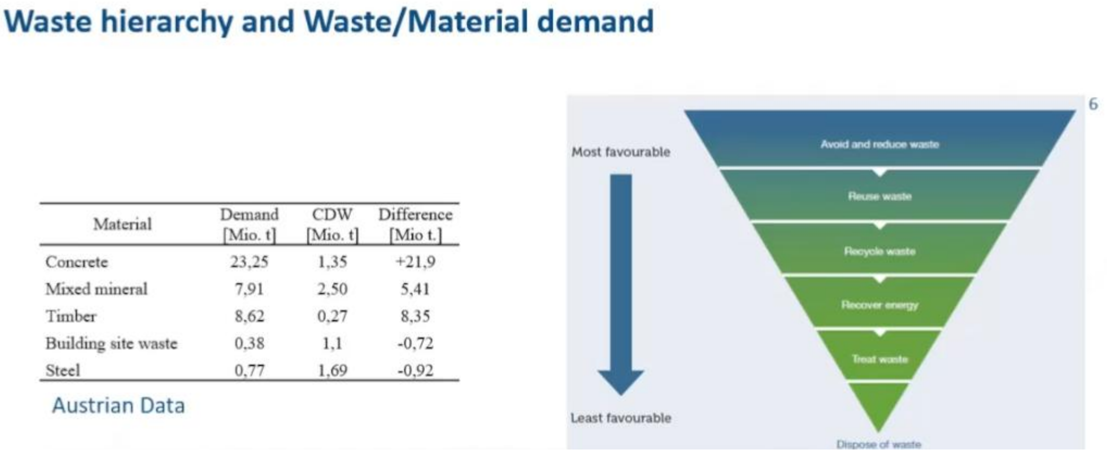
表 6　S Schützenhofer 等人於案例分析結果指出循環建材具有商業效益



	Material	Mass [t]	Units [m^2]	[m^2/Qty]	Quantity	Costs/unit	Cost/revenue
Scenario 2	Chipboard	3,08	139,5	1,36	102	1,5 €/Qty	154 €
	Glulam	3,20	120,6	0,72	167	10,0 €/Qty	1 675 €
	Parquet flooring	1,08	120,6			5,0 €/m^2	603 €
	Oak planks	0,65	54,5	0,24	227	30,0 €/Qty	6 813 €
	Copper	8,68	97,5			83,3 €/m^2	8 125 €
	Roof truss						1 111 €
	Timber	5,97				243,0 €/t	1 450 €
	Rockwool	3,95				462,0 €/t	1 825 €
	Reinforced concrete	116,37				20,0 €/t	2 327 €
	Total						**12 878 €**
Scenario 1	Timber	30,34				- €/t	- €
	Rock wool	3,95				462,0 €/t	1 216 €
	Reinforced concrete	116,37				20,0 €/t	2 327 €
	Total						**3 544 €**
Actual scenario	Contaminated rubble	17,66				16,7	295 €
	Pure rubble	15,02				92,4	1 388 €
	Reinforced concrete	75,49				20,0	1 510 €
	Timber	30,34				243,0	7 373 €
	Rock wool	3,95				462,0	1 825 €
	Total						**12 390 €**

(資料來源：S Schützenhofer et al, Improvement of environmental sustainability and Circular Economy through construction waste management for material reuse)

該研究透過案例分析發現，積極且高密度地使用再生建材，除可節約材料資源外，且於一定的條件下(須明確定義材料循環次數、每次循環之使用期間與每個案件應用的循環建材比例)，可具有一定之經濟效益(表 6)。因此本研究建議應將建築生命周期結束後之廢棄物處理納入建築規劃設計，以依據個別案件之特性(圖 9)，提前評估選用之材料種類與工法、優化廢棄物處理對區域的經濟影響(圖 10)。同時建議政府單位可建立相關資料庫，其中涵蓋拆除項目的成本結構與參數，如此有助於創造新的商業模式和就業機會(再利用、再加工和拆除回收產業。此外建議可以無線射頻辨識(Radio Frequency Identification, RFID)和建築資訊模型(Building Information Modeling, BIM)等技術適合連接到中介平台，進行區塊鏈技術於循環建材之數位管理。



Waste hierarchy and Waste/Material demand

Material	Demand [Mio. t]	CDW [Mio. t]	Difference [Mio t.]
Concrete	23,25	1,35	+21,9
Mixed mineral	7,91	2,50	5,41
Timber	8,62	0,27	8,35
Building site waste	0,38	1,1	-0,72
Steel	0,77	1,69	-0,92

Austrian Data

圖 11 S Schützenhofer 等人說明澳洲對不同種類建材之需求

(資料來源：視訊會議錄影截圖)

Comparison recycling/waste mass

圖 12 S Schützenhofer 等人說明不同循環建材應用模式的成果

(資料來源：視訊會議錄影截圖)

(三) 預鑄建築之實體碳排放物聯網評估與監測

隨著建築能源效率的提高，**實體**碳排放在新建築的生命週期碳排放中所佔比例提升。由於傳統的來自不同碳源的數據收集和通信方法(例如手動記錄）易導致估算效率低且出錯。考量物聯網技術已應用於製造業生產線的碳排放監測，由於預製構件的製造過程與工業產品的製造過程相似，因此 Jiayi Xu 等人於「Internet of Things (IoT)-Integrated Embodied Carbon Assessment and Monitoring of Prefabricated Buildings」研究中，提出一種用於預鑄建築的物聯網（Internet of Things, IoT）**實體**碳排放之評估和監測系統（Embodied Carbon Assessment and Monitoring System, ECAMS），該研究所提出之系統包括三個層次，即數據收集、數據通信和數據分析。

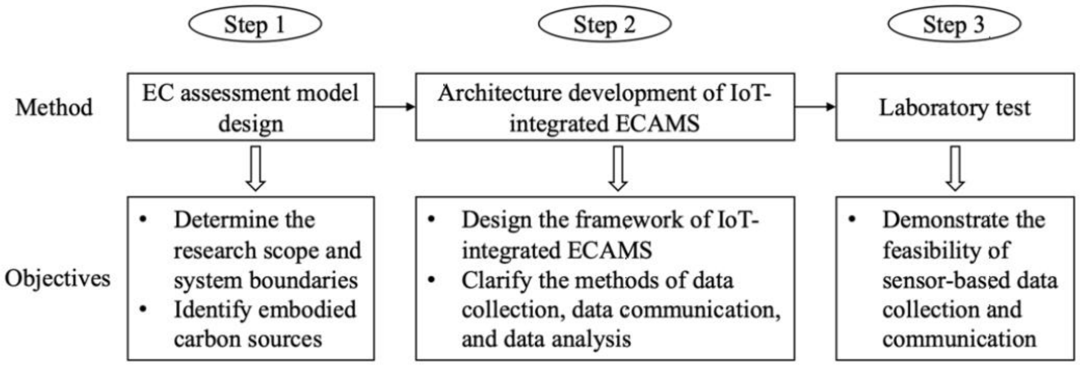


圖 13　Jiayi Xu 等人預鑄建築之實體碳排放物聯網評估與監測研究方法與流程

(資料來源：Jiayi Xu et al, Internet of Things (IoT)-Integrated Embodied Carbon Assessment and Monitoring of Prefabricated Buildings)

該研究首先參酌相關研究建立碳評估模型(圖 11) ，第二階段則將 IoT 設備(RFID、加速度傳感器和全球定位系統 (Global Positioning System, GPS))整合於預鑄構件,並用於自動實時數據收集,所蒐集的數據將通過程式撰寫(Application Programming Interface, API)後，與 BIM 和碳評估模型連結(圖 12)。該研究隨後以實驗室測試的方式，證明所提出的系統有助於更有效和準確地估計預鑄建築的實體碳排放，可協助業者探索有效的減碳策略。

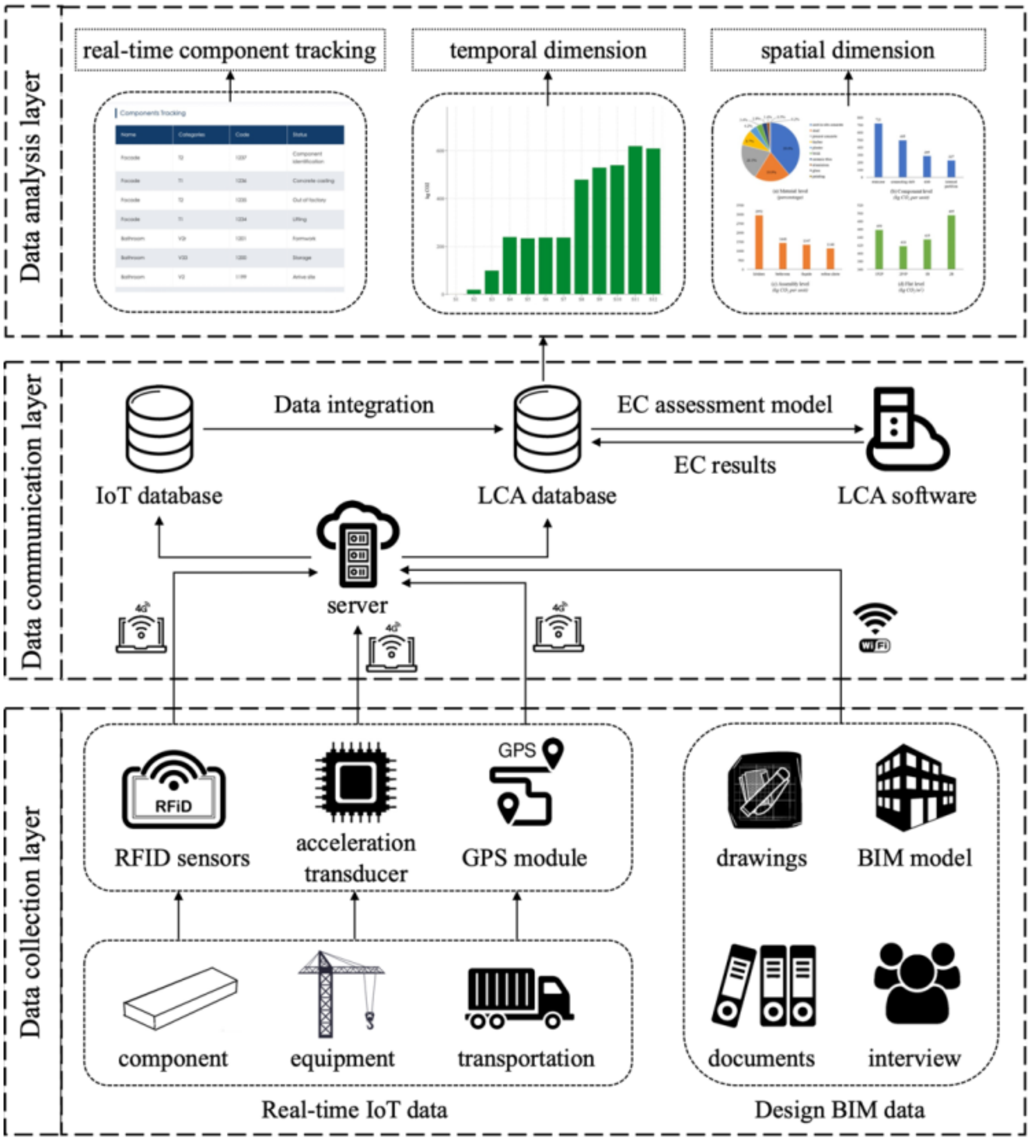
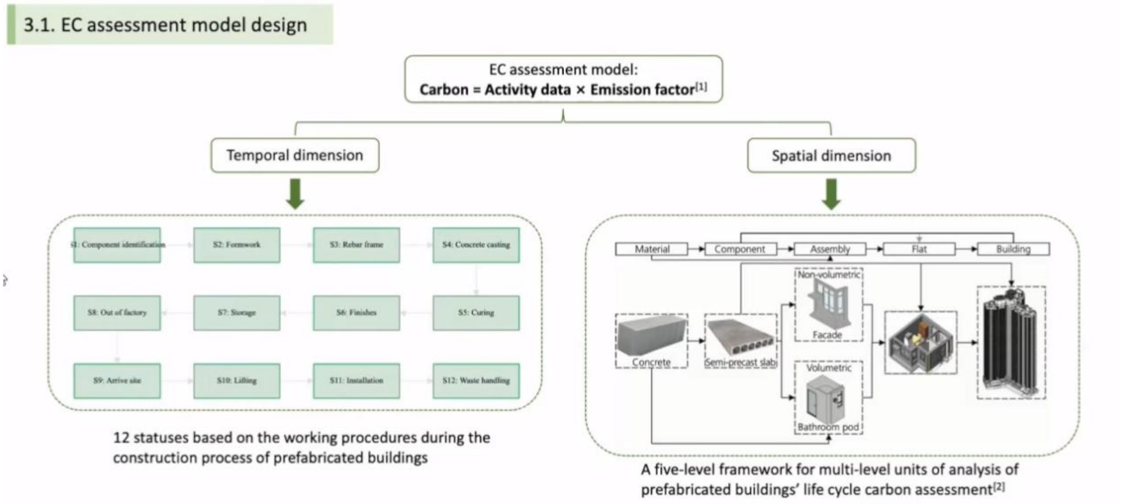


圖 14　Jiayi Xu 等人提出之實體碳排放評估系統架構

(資料來源：Jiayi Xu et al, Internet of Things (IoT)-Integrated Embodied Carbon Assessment and Monitoring of Prefabricated Buildings)

該研究透過前述方法，於實驗室已驗證可評估預鑄購件之部件識別、模板、鋼筋框架、混凝土澆注、養護、飾面、儲存、出廠、到達現場、吊裝、安裝和廢棄物處理等 12 種工項 (圖 13)。從空間維度上，採用五級框架評估材料、構件、裝配、平面和建築等 5 層面的碳評估結果。



3.1. EC assessment model design

EC assessment model:
Carbon = Activity data × Emission factor[1]

Temporal dimension

S1: Component identification
S2: Formwork
S3: Rebar frame
S4: Concrete casting
S5: Curing
S6: Finishes
S7: Storage
S8: Out of factory
S9: Arrive site
S10: Lifting
S11: Installation
S12: Waste handling

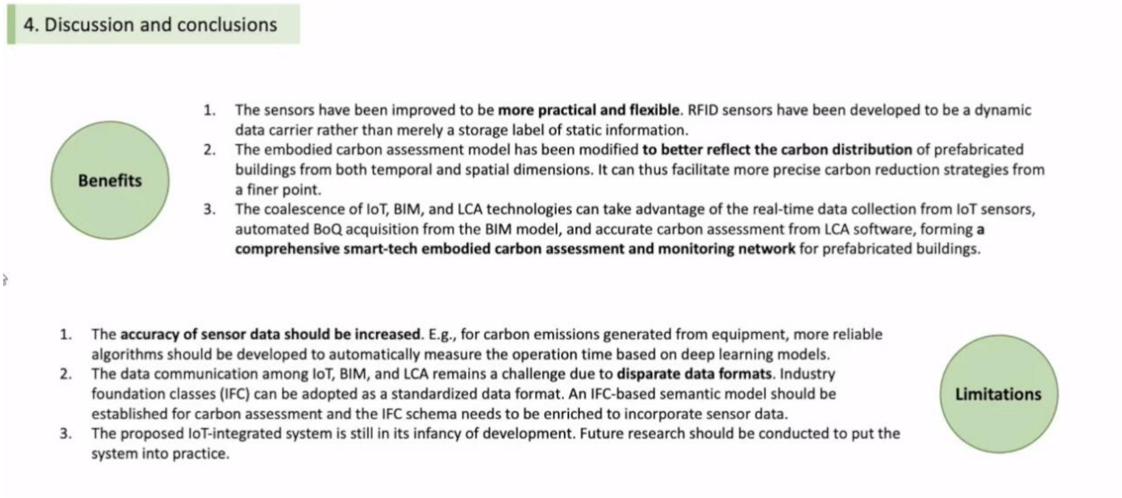
12 statuses based on the working procedures during the construction process of prefabricated buildings

Spatial dimension

A five-level framework for multi-level units of analysis of prefabricated buildings' life cycle carbon assessment[2]

圖 15 Jiayi Xu 等人說明該研究之實體碳排放評估範疇

(資料來源：視訊會議錄影截圖)



4. Discussion and conclusions

Benefits

1. The sensors have been improved to be **more practical and flexible**. RFID sensors have been developed to be a dynamic data carrier rather than merely a storage label of static information.
2. The embodied carbon assessment model has been modified **to better reflect the carbon distribution** of prefabricated buildings from both temporal and spatial dimensions. It can thus facilitate more precise carbon reduction strategies from a finer point.
3. The coalescence of IoT, BIM, and LCA technologies can take advantage of the real-time data collection from IoT sensors, automated BoQ acquisition from the BIM model, and accurate carbon assessment from LCA software, forming **a comprehensive smart-tech embodied carbon assessment and monitoring network** for prefabricated buildings.

Limitations

1. The **accuracy of sensor data should be increased**. E.g., for carbon emissions generated from equipment, more reliable algorithms should be developed to automatically measure the operation time based on deep learning models.
2. The data communication among IoT, BIM, and LCA remains a challenge due to **disparate data formats**. Industry foundation classes (IFC) can be adopted as a standardized data format. An IFC-based semantic model should be established for carbon assessment and the IFC schema needs to be enriched to incorporate sensor data.
3. The proposed IoT-integrated system is still in its infancy of development. Future research should be conducted to put the system into practice.

圖 16 Jiayi Xu 等人說明該研究之實體碳排放評估系統架構效益與限制

(資料來源：視訊會議錄影截圖)

Jiayi Xu 等人於結論中指出該系統有助於預鑄建築的碳排放估算，可供業者實施精準的減碳策略。然而，本研究僅在實驗室針對預鑄構件驗證，未來應於更多元的工程型態與現場實務驗證，並建立數據庫進行分析(圖 14)。

(四) 後疫情時代建築環境控制

COVID-19 的疫情自 2020 年以來以蔓延肆虐全球，迄今仍未見緩和，本報告摘譯 Amna Salman 等人於「Establishing Indicators for Reducing the Transmission of Airborne Viruses in Buildings」研究指出，疫情除了經影響了建

築環境中的所有行業，但設施管理 (Facility Management, FM) 部門受到的打擊最大。該研究說明，在疫情開始發展時，大多數設施管理人員不知道如何最大限度地減輕病毒傳播(圖 15)，並且無法維持建築物的全部功能。儘管許多建築管理單位立即成立臨時的任務群組來提出可行的解決方案，其中大多是反應性措施，其有效性尚不完全清楚。

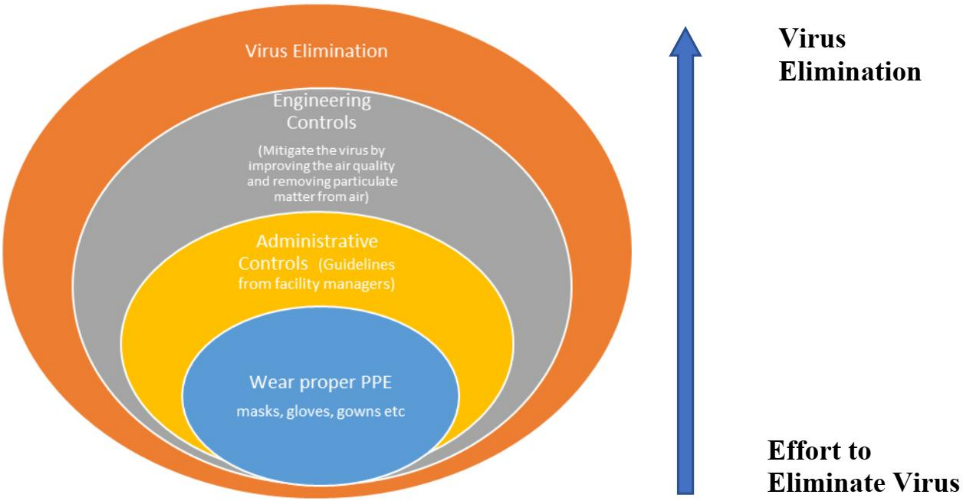


圖 17 Amna Salman 等人參考美國疾病管制署建議整理之疫情散播阻斷路徑

(資料來源：Amna Salman et al, Establishing Indicators for Reducing the Transmission of Airborne Viruses in Buildings)

過去的研究提出了後疫情時代的建築環境控制應採多層防禦，其中涉及建築師、設施經理、機械工程師、醫療保健專業人員、流行病學家、病毒學家和建築商之間的密切合作。因此需要進一步跨學科研究研討減少病毒在室內傳播的指標。Amna Salman 等人於文獻回顧中(圖 16)提出了工程控制、設計控制、空氣消毒策略以及最新技術的使用，並透過專家訪談方式，探索合適的評估指標。該研究未來將建立一個評估系統，以應對下一次疫情的爆發。

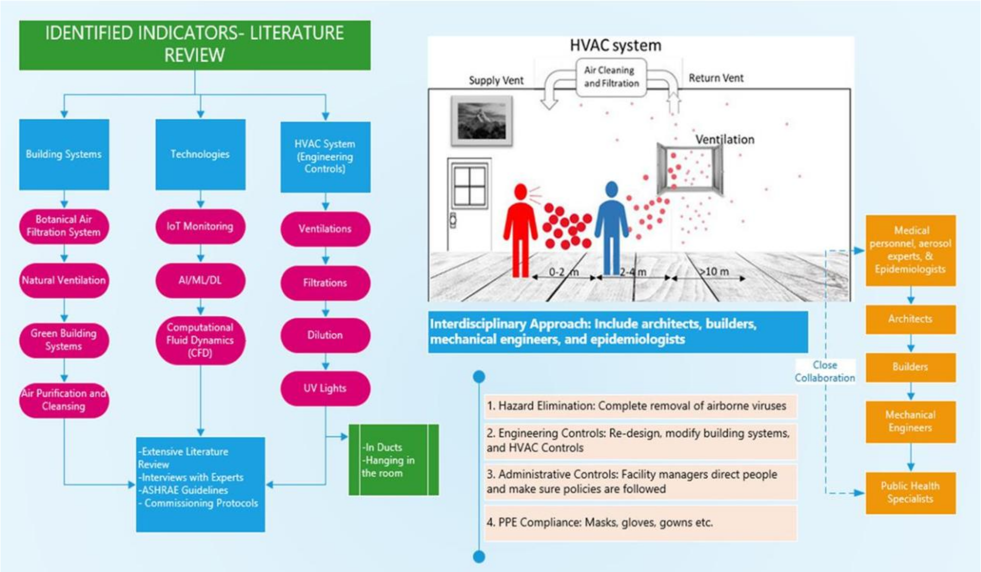
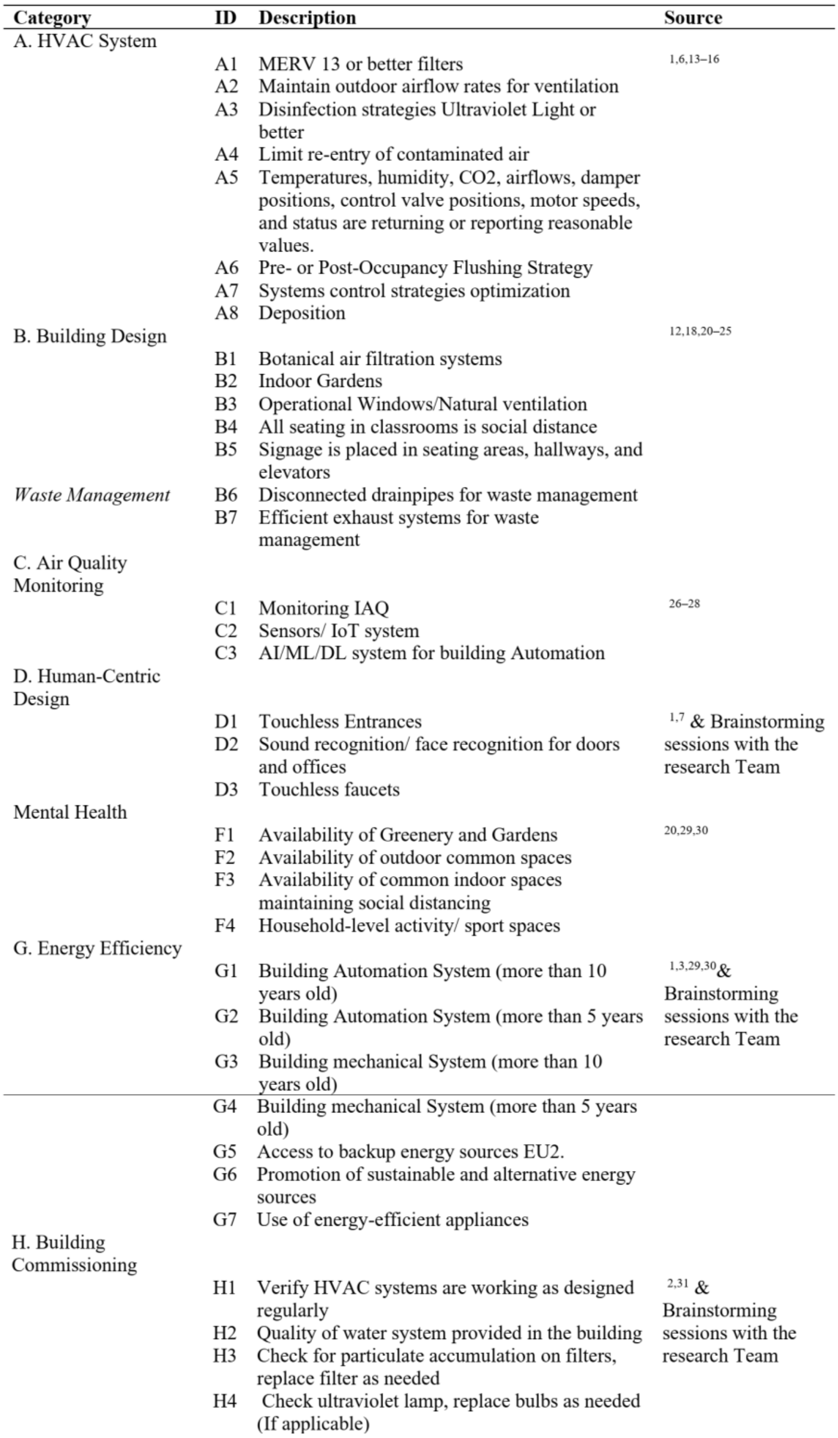


圖 18　Amna Salman 等人彙整文獻整理之疫情散播因素

(資料來源：Amna Salman et al, Establishing Indicators for Reducing the Transmission of Airborne Viruses in Buildings)

Amna Salman 等人於研究結論說明，從 COVID-19 中吸取的教訓是，我們需要採取積極主動的策略來緩解病毒，而不是被動應對。為了減少空氣傳播的病毒在建築物中的傳播，現有文獻中提出了各種控制策略，包括源頭控制、通風、空氣淨化、空氣過濾、室內空氣質量監測、熱像儀、非接觸式建築系統、自然通風、室內設計改變和建築調適。但是，沒有確定的標準可供建築物所有者和設施管理者用來評估建築物對疫情爆發的準備情況。由於尚未有系統的框架或一套指導方針可供建築物所有者或設施管理者用來評估建築物應對疫情的準備情況，該研究通過文獻回顧、腦力激盪會議和與設施管理人員的訪談，篩選出可以減輕空氣傳播病毒傳播的指標(表)，預期可識別每個關鍵要素，並在未來提供一個量化系統評估每個規定要素的表現。

表 7　Amna Salman 等人篩選出可減輕空氣傳播病毒傳播的指標



Category	ID	Description	Source
A. HVAC System			
	A1	MERV 13 or better filters	[1,6,13–16]
	A2	Maintain outdoor airflow rates for ventilation	
	A3	Disinfection strategies Ultraviolet Light or better	
	A4	Limit re-entry of contaminated air	
	A5	Temperatures, humidity, CO2, airflows, damper positions, control valve positions, motor speeds, and status are returning or reporting reasonable values.	
	A6	Pre- or Post-Occupancy Flushing Strategy	
	A7	Systems control strategies optimization	
	A8	Deposition	
B. Building Design			[12,18,20–25]
	B1	Botanical air filtration systems	
	B2	Indoor Gardens	
	B3	Operational Windows/Natural ventilation	
	B4	All seating in classrooms is social distance	
	B5	Signage is placed in seating areas, hallways, and elevators	
Waste Management	B6	Disconnected drainpipes for waste management	
	B7	Efficient exhaust systems for waste management	
C. Air Quality Monitoring			
	C1	Monitoring IAQ	[26–28]
	C2	Sensors/ IoT system	
	C3	AI/ML/DL system for building Automation	
D. Human-Centric Design			
	D1	Touchless Entrances	[1,7] & Brainstorming sessions with the research Team
	D2	Sound recognition/ face recognition for doors and offices	
	D3	Touchless faucets	
Mental Health			
	F1	Availability of Greenery and Gardens	[20,29,30]
	F2	Availability of outdoor common spaces	
	F3	Availability of common indoor spaces maintaining social distancing	
	F4	Household-level activity/ sport spaces	
G. Energy Efficiency			
	G1	Building Automation System (more than 10 years old)	[1,3,29,30]& Brainstorming sessions with the research Team
	G2	Building Automation System (more than 5 years old)	
	G3	Building mechanical System (more than 10 years old)	
	G4	Building mechanical System (more than 5 years old)	
	G5	Access to backup energy sources EU2.	
	G6	Promotion of sustainable and alternative energy sources	
	G7	Use of energy-efficient appliances	
H. Building Commissioning			
	H1	Verify HVAC systems are working as designed regularly	[2,31] & Brainstorming sessions with the research Team
	H2	Quality of water system provided in the building	
	H3	Check for particulate accumulation on filters, replace filter as needed	
	H4	Check ultraviolet lamp, replace bulbs as needed (If applicable)	

(資料來源：S Schützenhofer et al, Improvement of environmental sustainability and Circular Economy through construction waste management for material reuse)

肆、心得與建議

2022 國際建築大會 (CIB World Building Congress 2022, WBC 2022)，因國際間受到COVID-19 疫情影響，以實體及視訊會議同步方式舉行，本計畫改以視訊會議方式參加。獲致心得與建議如下：

一、心得

依本次會議發表之論文中可看出，全球綠建築永續發展之趨勢，目前著重在聯合國用續發展目標(Sustainable Development Goals, SDGs)、聯合國氣候變遷大會對於淨零排放的目標、循環經濟，以及肆虐全球的 COVID-19 疫情的衝擊，各國皆針對這些議題進行相關策略之研究，以落實在政策中來改善整體後疫情時代的生活環境。

而我國為因應氣候、社會環境變遷與國際間的永續發展趨勢，本所長期推動「生態」、「節能」、「減廢」、「健康」之綠建築，同時依據總統政見(5+2)循環經濟創造節能、減廢與減排之循環經濟體系，促進環境資源永續利用，提升生活環境品質；並與內政部「建構永續宜居環境」之施政目標整合，以「永續綠建築節能減廢技術研發與應用」、「健康綠建築室內環境科技發展」、「永續環境與生態城市發展」、「永續綠建築法規與教育推廣」為研發主軸，辦理「永續健康綠建築環境科技計畫(112-115)」，發展符合我國 2050 淨零排放路徑及臺灣氣候條件與生態環境之綠建築科技與技術，提供科技研發課題規劃參考。

因此，本次參與 2022 國際建築大會(WBC2022)，得以蒐集到來自全球各國在防疫、循環建築、淨零排放等相關策略之文獻，經綜整與本所創新循環綠建築研究業務較為密切相關的研究，包括：低碳排、低環境衝擊、循環利用、能源、水資源及室內環境健康等，皆能進一步幫助本所了解國外發展現況與趨勢，可做為我國健康永續綠建築發展之參考，以提升我國創新科技研發能力，提供民眾安居生活環境的同時，也能帶動健康永續綠建築與國際接軌。

二、 建議

本所辦理「創新循環綠建築環境科技計畫(108-111)」即將屆滿，藉由本次會議資料蒐集發現，目前國際間用續綠建築發展趨勢著重於永續發展策略、循環經濟及 COVID-19 防疫，因此針對本所後續推動下一期科技計畫，提出下列建議：

建議一

參考 WBC 2022 研究成果，並持續追蹤國際間永續綠建築、淨零建築路徑策略發展趨勢與我國政策需求，滾動檢討科技計畫研究成果，供下一期科技計畫課題規劃參考。

執行時程：立即可行之建議

主辦機關：內政部建築研究所

為使未來科技計畫之規劃符合國際發展趨勢與我國政策需求，除參考本次 WBC2022 有關循環經濟、再生建材、建築碳足跡與防疫健康建築研究成果外，亦應持續廣泛蒐集最新文獻資訊，以供下一期科技計畫之課題與發展架構規劃參考。

建議二

持續參與永續綠建築及淨零建築相關國際活動與會議，掌握國際永續發展趨勢。

執行時程：中長期性建議

主辦機關：內政部建築研究所

持續編列出國計畫參與國際會議(如近期淨零建築國際會議或中期預定於美國印第安那州的普渡大學舉辦之 2025 年度世界建築大會（World Building Congress 2025），關注全球各國最新永續綠建築與淨零建築節能減碳政策、健康防疫等建築案例及研究議題，掌握最新國際永續綠建築技術發展趨勢，以利做為下一期科技計畫研究課題規劃之參考。

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