THE UNIVERSITY OF HONG KONG 香港大學
faculty of architecture 建築學院

iLab | @ HKURBANlab
the urban big data lab

Linking RFID to BIM

A demystification of research methods

链接RFID和BIM：解密研究方法

A material for Research Methodology, Renmin Univ. of China

为中国人民大学《研究方法》课程编制

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Outline

Section 0 序言

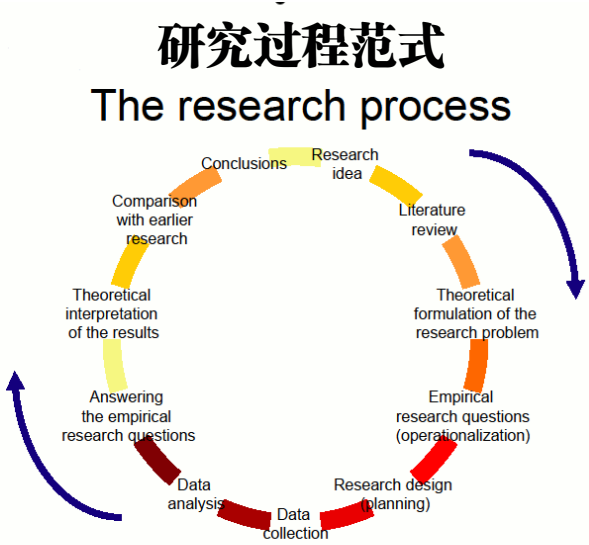
PROLOGUE

0.1 Aim and scope 目的和范畴

- Aim of this presentation 本课件的目的
  - To apply research methods 应用所学研究方法
  - To share a recent study 分享一项最新成果
  - To demonstrate the use of R and SPSS 演示R和SPSS的使用
  - To present a whole research in AECO (Architecture, Engineering, Construction & Operation) 展现完整研究流程
  - To encourage debates on the methods 鼓励方法的讨论
- Scope 范畴
  - The *method* domain 方法范畴
    - Contingency table, correlation, & decision tree, etc.
  - The *application* domain 应用领域
    - AECO

0.2 Rationale of the research design 研究设计逻辑

- Goal: **To** promote *A* in AECO **研究目的：为业界推广*A***
- Data source: Credible **cases** in literature **数据：文献实例**
- Research design **研究设计**
  - 1. Scientific questions decomposition **分解科学问题**
    - (i) *History*: What can be concluded for *A*?
    - (ii) *Future*: What are the trends (*B, C, D*) relating to *A*?
  - 2. Conceptual model formation **组织概念模型**
    - How *A B C D* work together?
  - 3. Data of *A B C D* **数据获取**
    - Number, category, & description in cases → extraction
  - 4. Data analysis **数据分析**
    - Statistics and data analytics (R & SPSS)



0.3 Expected outputs to form a paper 预期论文组织

iLab

Outputs from the research design
预期研究结果

- 1. Scientific questions
- 2. Conceptual model
- 3. Data of *A B C D*
  - 3.1 Source of data
  - 3.2 Extracted data
- 4. Data analysis

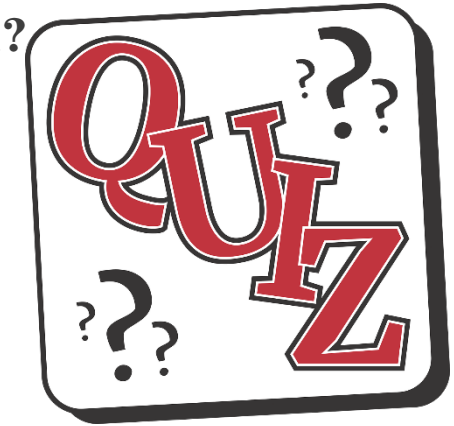
Expertise & insights

Paper organization
论文组织

- 1. Introduction
- 2 Research methods
  - 2.1 Conceptual model
  - 2.2 Literature search
  - 2.3 Data extraction
- 3. Analytical results
- 4. Summarized guidelines
- 5. Conclusion

0.4 A quiz 课堂练习

- Q1: What type is this research? **课堂练习1：此为何种研究?**
  - (A) survey research/literature review **综述**
  - (B) experimental research **实验**
  - (C) meta-analysis **元分析**
  - (D) correlational research **相关性分析**



- Note: To cite the slides/work, you can
  - Cite my paper (under 2nd round review)
    - Xue, F., Chen, K., Lu, W., Niu, Y., & Huang G.Q. (2018). Linking radio-frequency identification (RFID) to building information modeling (BIM): Status quo, development trajectory, and practitioner guidelines. *Automation in Construction*, under review.
  - Freely use the pictures shared under CC-BY/CC-BY-SA

Section 1 简介

INTRODUCTION TO LINKING RFID TO BIM

1.1 Smart construction & beyond 智能建造

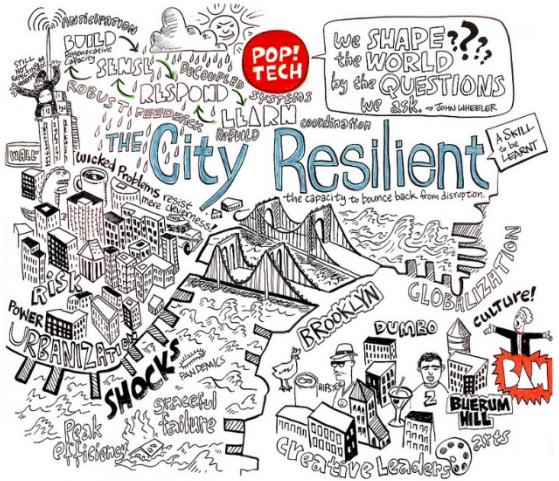
- What is smart construction 何为智能建造
  - *Construction* (*noun*) versus *construction* (*verb*)
  - *Smart*: Context aware, *ad hoc* information-sharing[1]
- A "backward industry" wants to be smart "落后产业"
  - A consensus of global research institutes on future const.[2]
  - Advances in [*smart*] ICT (info. & comm. tech.)

Our focus ⟶ *BIM, RFID*, LiDAR, GPS, UAV, CV, VR/AR, smart phones…

- The vision beyond 长远前景
  - Construction industrialization: *Quality, cost, & "forward"*
  - Smart and resilient city: *For 70% world population by 2050*
  - Robot and AI-assisted future: *Next-gen industrial revolution*

Recent advances in ICT

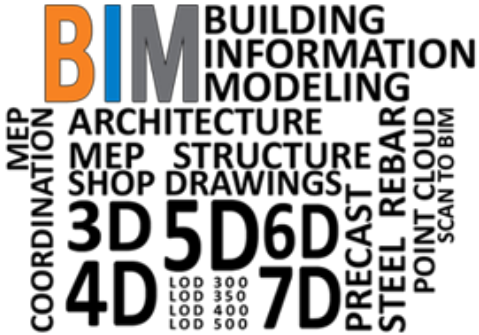
(Some sources shared under CC-BY 2.0/3.0)



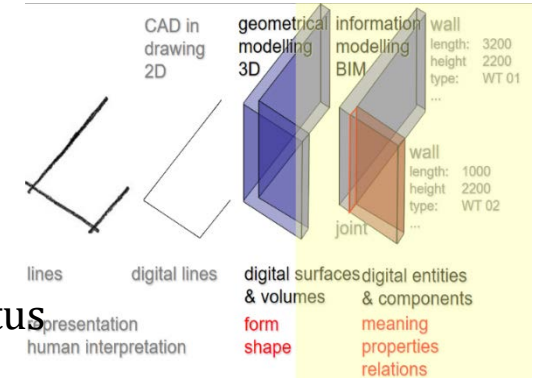
Resilient city comic (Source: flickr, CC-BY 2.0)

1.2 BIM: A shared information hub BIM：信息枢纽

- BIM (building information modeling)[3] 建筑信息模型
  - The digital representation of physical and functional characteristics of a facility
  - A shared *information hub* about a facility serving as a reliable basis for decisions making
  - Evolved from CAD (computer-aided design)[4]
- The "I" in BIM includes[3, 5] 信息包括
  - Constant attributes and relationships of components 静态
    - E.g., As-designed geometry, material, function, …
  - *User's & Dynamic* 动态
    - E.g., occupants, equipment, worker's location, as-is status
    - Risking "blind and deaf" to on-going AECO processes[6]



A word cloud of BIM
(Source: advenser.com)



An evolution view of CAD model/BIM [4]

1.3 RFID: Contactless identification & localization
RFID：非接触式识别和定位

- RFID: Radio-frequency identification **射频识别**
  - Incepted in 1800s (Faraday, Maxwell, Hertz, Tesla, & Marconi)
  - Commercialized in 1960s, the era of civil radar and radio
  - Boomed in recent 20 years, as *one* core technology of IoT
  - Properties: ID (native), time, location, stored, extra sensors …
- Is a (collective) generic term **是一系列技术的统称**

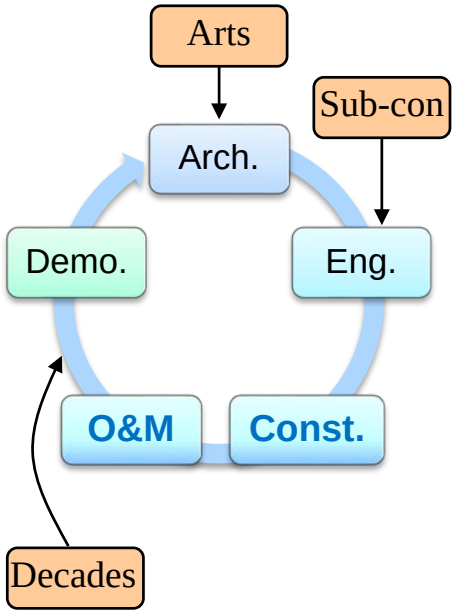
Table 1: The family of RFID systems in different frequencies[7]

Band	LF	HF	UHF	MW	UWB
Frequency	125~134 kHz	13.56 MHz	433, 865~956 MHz	2.45~5.8 GHz	3~10.6 GHz
Comm. Distance(m)	< 2	< 0.2	< 100 (left); < 2 (r)	< 1	< 10
Example applications	Access control	Smart card, NFC	Library, baggage tracking	ETC	Locationing
Approximate tag unit cost (USD)	0.1	5	0.1	20~30	10~15

RFID applications (Some photos from Wikipedia, CC-BY 3.0)

1.4 Linking RFID to BIM 链接RFID和BIM

- Possible work in the life-cycle of construction 生命周期中
  - *Architecture design*: (*None*?)
  - *Engineering design*: RFID selection, plan drawings, testing
  - *Construction*: Component, material, worker, progress, safety…
    - Above two highly related to *construction industrialization*
  - *Operation*: Indoor location, asset management, facility records…
  - *Demolition*: Planning facilitation, as-is calibration, recycling…
- Reported work and cases in literature 文献中报告的研究
  - Almost all cases were conducted in *Const.* to *O&M*
  - A few incepted scenarios mentioned *Eng.* or *Demo.*
  - Stage *Arch.* was not mentioned

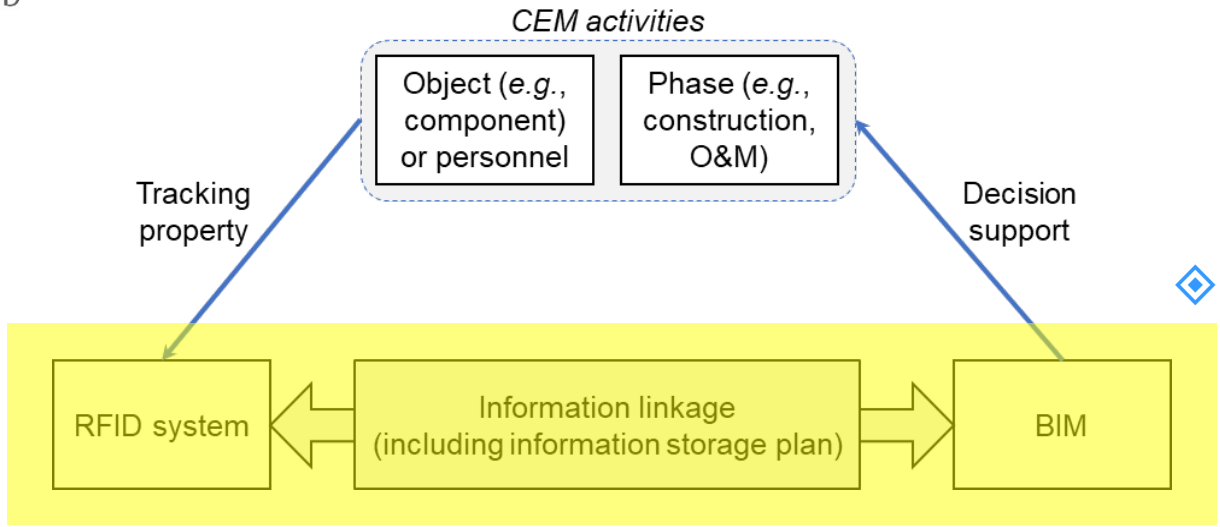


Linking RFID to BIM in different stages of construction life cycle and possible barriers (Popular stages in bold)

Section 2 分析

MODEL AND ANALYSIS (R & SPSS)

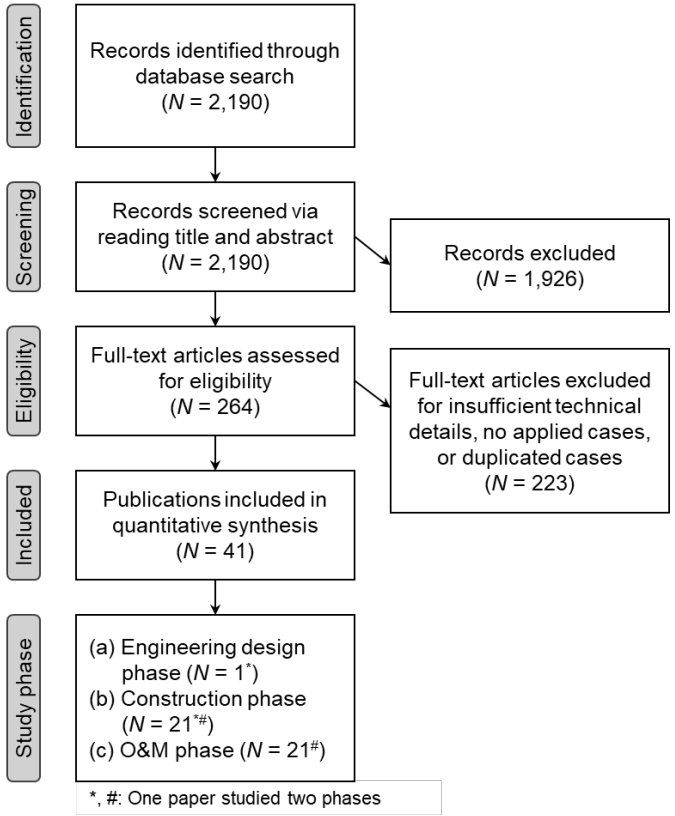
2.1 The conceptual model 概念模型



A conceptual model of linking RFID to BIM
链接RFID和BIM的概念模型

- What comprise of *A*?
  研究目标 *A* 包括?
  - RFID system
  - BIM
  - Information storage **信息**
- Independent variables (*B C D*) **自变量包括**?
  - Phase **生命周期的阶段**
  - Object **对象**
    - Property 属性

2.2 Source of data: The real cases in literature
数据源： 文献中的真实案例



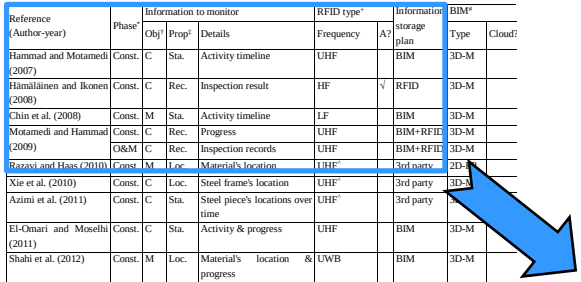
- Cases collection **案例收集**
  - Search "*(RFID OR UWB OR NFC OR "smart card") (construction OR infrastructure OR building) BIM*" from Google Scholar (*N*= 2,190)
  - Screening non-AECO and review papers (*N*= 264)
  - Selecting real cases with details (*N*= 41)
- Data (sample size) **数据（样本数）**
  - *Eng.*: *N*= 1
    - Excluded for insufficient sample size
  - *Const.*: *N*= 21
  - *O&M*: *N*= 21

2.3 Data extraction 数据提取

	Possible options		Explanations
RFID system	Frequency	LF	*125-135 kHz*
		HF	*13.56 MHz*
		UHF	*433 MHz; 865-956 MHz*
		MW	*2.45-5.8 GHz*
		UWB	*3.1-10 GHz*
	Type	active	*with built-in batteries*
		passive	*without built-in batteries*
BIM	Digital representation	3D	*The model is presented in 3D*
		2D	*The model is presented in 2D, like floor plan*
	Cloud-based	Yes	*In the cloud servers that allow remote access.*
		No	*o.w.*
Info. storage plan	Both BIM and RFID tag		
	BIM only		
	RFID tag only		
	third-party database		

- We normalize the cases as samples of **从案例中提取五类数据**
  - RFID
    - Freq. 频率
    - Type 主动？
  - BIM
    - 2D/3D?
    - Cloud 云端？
  - Info. storage
  - Phase
  - Object

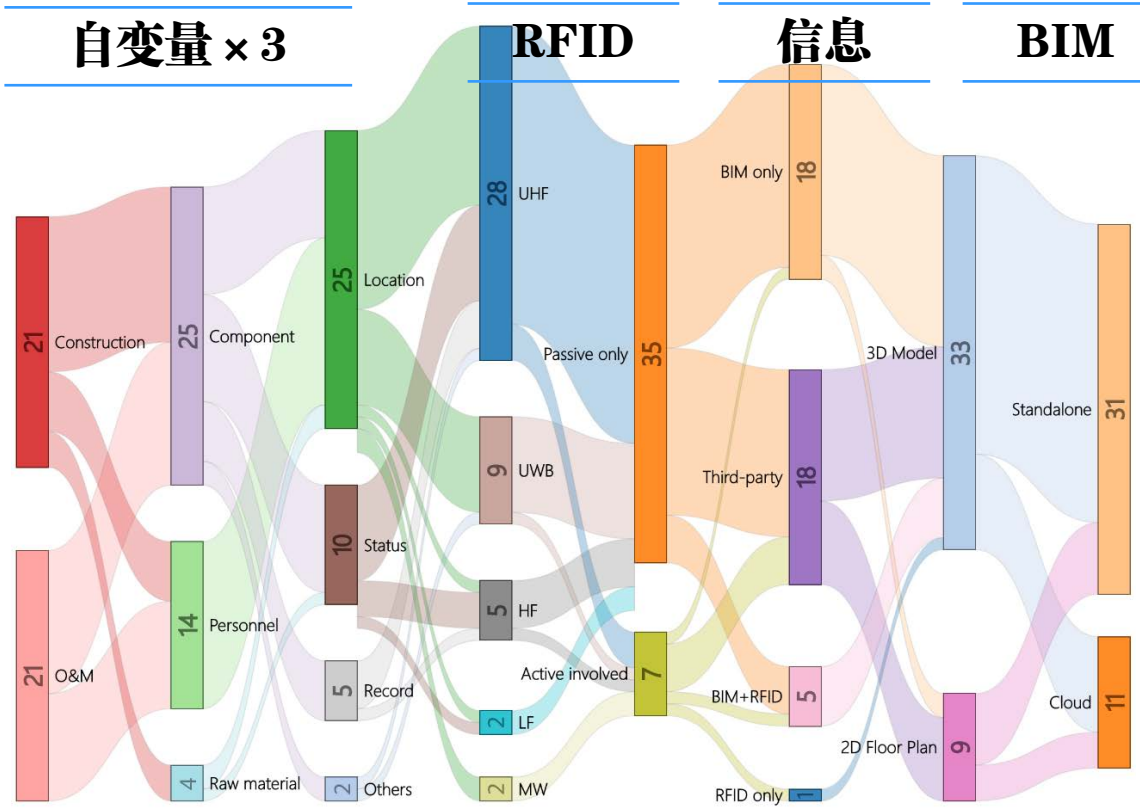
2.3 An overview of extracted data 提取出的数据



Reference (Author-year)	Phase*	Information to monitor			RFID type+		Information storage plan	BIM#	
		Obj†	Prop‡	Details	Frequency	A?		Type	Cloud?
Hammad and Motamedi (2007)	Const.	C	Sta.	Activity timeline	UHF		BIM	3D-M	
Hämäläinen and Ikonen (2008)	Const.	C	Rec.	Inspection result	HF	√	RFID	3D-M	
Chin et al. (2008)	Const.	M	Sta.	Activity timeline	LF		BIM	3D-M	
Motamedi and Hammad (2009)	Const.	C	Rec.	Progress	UHF		BIM+RFID	3D-M	
	O&M	C	Rec.	Inspection records	UHF		BIM+RFID	3D-M	
Razavi and Haas (2010)	Const.	M	Loc.	Material's location	UHF^		3rd party	2D-FP	
Xie et al. (2010)	Const.	C	Loc.	Steel frame's location	UHF^		3rd party	3D-M	
Azimi et al. (2011)	Const.	C	Sta.	Steel piece's locations over time	UHF^		3rd party	3D-M	
El-Omari and Moselhi (2011)	Const.	C	Sta.	Activity & progress	UHF		BIM	3D-M	
Shahi et al. (2012)	Const.	M	Loc.	Material's location & progress	UWB		BIM	3D-M	
Ding et al. (2013)	Const.	P	Loc.	Worker's location	UHF^		BIM	2D-FP	
Ikonen et al. (2013)	Const.	C	Sta.	Activity timeline	HF & UHF		3rd party	3D-M	√
Shahi et al. (2013)	Const.	C	Loc.	Location-based activity	UWB		3rd party	3D-M	
Guo et al. (2014)	Const.	P	Loc.	Safety of a worker's location	UHF^		3rd party	3D-M	
Sattineni (2014)	Const.	P	Loc.	Indoor location	UHF		BIM	3D-M	√
Costin et al. (2015)	Const.	P	Loc.	Worker's location	UHF		BIM	3D-M	
Zhang and Bai (2015)	Const.	C	Strain	Strain and breakage	UHF		BIM+RFID	3D-M	
Fang et al. (2016)	Const.	P	Loc.	Worker's location	UHF		BIM	3D-M	√
Niu et al. (2016)	Const.	C	Sta.	Component's status	UHF^		BIM	3D-M	√
Srewil et al. (2016)	Const.	C	Loc.	Component's location	UHF		BIM	3D-M	√
Mirzaeifar et al. (2017)	Const.	C	Sta.	Logistic status	HF		3rd party	3D-M	√
Zhong et al. (2017)	Const.	C	Sta.	Status and locations	HF & UHF		BIM	3D-M	√
Rueppel and Stuebbe (2008)	O&M	P	Loc.	Fire fighter's location	UHF & UWB		3rd party	2D-FP	√
Cong et al. (2010)	O&M	C	Rec.	Repair record, inventory	UHF	√	3rd party	2D-FP	
Krukowski and Arsenijevic (2010)	O&M	P	Loc.	Indoor location	MW	√	3rd party	2D-FP	√
Meadati et al. (2010)	O&M	C	Sta.	Component's status	UHF		BIM	3D-M	
Petrushevski (2012)	O&M	P	Loc.	User's presence for light control	HF		3rd party	2D-FP	
Shen et al. (2012)	O&M	C	Loc.	Asset's location	LF		BIM	2D-FP	√
Akanmu et al. (2013)	O&M	C	Sta.	Component's status, e.g., failure	UHF^		BIM	3D-M	
Zhang et al. (2013)	O&M	C	Sig.	Visible area of a grid	UWB	√	3rd party	3D-M	
Masoudifar et al. (2014)	O&M	C	Loc.	Facility's location	UWB		3rd party	2D-FP	
Montaser and Moselhi (2014)	O&M	P	Loc.	Indoor location	UHF		BIM	3D-M	
Rafiee (2014)	O&M	P	Loc.	locations of authorized persons	UWB		BIM	3D-M	
Costin and Teizer (2015)	O&M	P	Loc.	Indoor location	UHF		3rd party	3D-M	

- Extracted data in format **数据格式**
  - 42 rows (21+21)
  - 9 columns (except for 'details'; 'reference' → 'Year')
    - Mostly categorical data 大多是非数值型

2.3 A visualization 可视化



- Visualization 可视化
  - RFID
    - Mostly UHF, UWB
    - Mostly passive
  - BIM
    - Mostly 3D
  - Info storage
    - A few in RFID
- Note: in Sankey chart桑基图

2.4 Task 1: 2D/3D vs. time 任务1：2D/3D与时间

- 2D/3D vs. time **时间**
  - (1) Data sample (N = 42)
    - Contingency table 列联表
    - Correlation 相关性
  - (2) Annual sum (N = 11+11)
    - Correlation 相关性
  - (3) Annual ratio (N = 11)
    - Correlation 相关性
- Q2: What are the differences?
  课堂练习2：四种研究的异同？
  - Results **结果**
  - Rationale **原理**

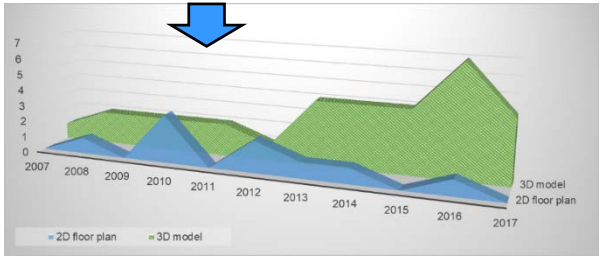
Const. 建设		**O&M. 运维**	
Year	3D	Year	3D
2007	1	2008	0
2008	1	2009	1
2008	1	2010	0
2009	1	2010	0
2010	0	2010	1
2010	1	2012	0
2011	1	2012	0
2011	1	2013	1
2012	1	2014	1
2013	0	2013	1
2013	1	2014	0
2013	1	2014	1
2014	1	2015	1
2014	1	2015	1
2015	1	2016	0
2015	1	2016	1
2016	1	2016	1
2016	1	2016	1
2016	1	2016	1
2017	1	2017	1
2017	1	2017	1

Annual sum 年度总计

Year	3D	2D
2007	1	0
2008	2	1
2009	2	0
2010	2	3
2011	2	0
2012	1	2
2013	4	1
2014	4	1
2015	4	0
2016	7	1
2017	4	0

Annual ratio 年度采用率

Year	3D (%)
2007	100
2008	66.67
2009	100
2010	40
2011	100
2012	33.33
2013	80
2014	80
2015	100
2016	87.5
2017	100



2.4.1 Contingency table 列联表 ($N = 42$)

- *"Is 2D/3D presentation covaried with Year?" "2D/3D是否与年份共变？"*
  - H_0: Not covaried
- Contingency table
  - Open in SPSS, under menu "Analyze"
    - "Descriptive statistics"—"Crosstab"
      (Note: Crosstab = 列联表)
    - Between *Year* and *BIM3D*
  - $\chi^2 = 12.254$ **卡方**
  - Exact significance = 0.27 **精确显著性**
    - NOT Significant 不显著
    - Accept H_0

Const. 建设		O&M. 运维	
Year	3D	Year	3D
2007	1	2008	0
2008	1	2009	1
2008	1	2010	0
2009	1	2010	0
2010	0	2010	1
2010	1	2012	0
2011	1	2012	0
2011	1	2013	1
2012	1	2014	1
2013	0	2013	1
2013	1	2014	0
2013	1	2014	1
2014	1	2015	1
2014	1	2015	1
2015	1	2016	0
2015	1	2016	1
2016	1	2016	1
2016	1	2016	1
2016	1	2016	1
2017	1	2017	1
2017	1	2017	1

Year * BIM3D Crosstabulation

			BIM3D		
			0	1	Total
Year	2007	Count	0	1	1
		Expected Count	.2	.8	1.0
	2008	Count	1	2	3
		Expected Count	.6	2.4	3.0
	2009	Count	0	2	2
		Expected Count	.4	1.6	2.0
	2010	Count	3	2	5
		Expected Count	1.1	3.9	5.0
	2011	Count	0	2	2
		Expected Count	.4	1.6	2.0
	2012	Count	2	1	3
		Expected Count	.6	2.4	3.0
	2013	Count	1	4	5
		Expected Count	1.1	3.9	5.0
	2014	Count	1	4	5
		Expected Count	1.1	3.9	5.0
	2015	Count	0	4	4
		Expected Count	.9	3.1	4.0
	2016	Count	1	7	8
		Expected Count	1.7	6.3	8.0
	2017	Count	0	4	4
		Expected Count	.9	3.1	4.0
Total		Count	9	33	42
		Expected Count	9.0	33.0	42.0

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	Point Probability
Pearson Chi-Square	12.254[a]	10	.268	.270		
Likelihood Ratio	13.240	10	.211	.342		
Fisher's Exact Test	10.146			.327		
Linear-by-Linear Association	2.516[b]	1	.113	.127	.067	.015
N of Valid Cases	42					

a. 21 cells (95.5%) have expected count less than 5. The minimum expected count is .21.

b. The standardized statistic is 1.586.

2.4.2 Pearson's correlation 相关性 ($N = 42$)

- *"Is 2D/3D presentation correlated with Year?" "2D/3D是否与年份相关？"*
  - H_0: Not correlated
- Pearson's correlation **相关性**
  - Open in SPSS, under menu "Analyze"
    - "Correlate"—"Bivariate"
    - Between *Year* and *BIM3D*
    - *Single-tailed*

      Assuming one-direction effect
  - Pearson cor. = 0.248 **相关性：弱**
  - Sig. (1-tailed) = 0.057 **单尾显著性**
    - NOT Significant 不显著

Const. 建设		O&M. 运维	
Year	3D	Year	3D
2007	1	2008	0
2008	1	2009	1
2008	1	2010	0
2009	1	2010	0
2010	0	2010	1
2010	1	2012	0
2011	1	2012	0
2011	1	2013	1
2012	1	2014	1
2013	0	2013	1
2013	1	2014	0
2013	1	2014	1
2014	1	2015	1
2014	1	2015	1
2015	1	2016	0
2015	1	2016	1
2016	1	2016	1
2016	1	2016	1
2016	1	2016	1
2017	1	2017	1
2017	1	2017	1

Correlations

		Year	BIM3D
Year	Pearson Correlation	1	.248
	Sig. (1-tailed)		.057
	N	42	42
BIM3D	Pearson Correlation	.248	1
	Sig. (1-tailed)	.057	
	N	42	42

Pearson cor.	Interpretation
.00 ~ .19	Very weak
.20 ~ .39	Weak
.40 ~ .59	Moderate
.60 ~ .79	Strong
.80 ~ 1.0	Very strong

2.4.3 Correlation on annual sum 年度总计相关性 (*N*=11+11)

- *"Is yearly 2D/3D correlated with Year?"*
  "年度2D/3D使用与年份相关？"
  - H_0: Not correlated
- Pearson's correlation **相关性**
  - Open in SPSS, under menu "Analyze"
    - "Correlate"—"Bivariate"
    - Between *Year* and *Sum3D, Sum2D*
  - *Yearly 3D*
    - Pearson cor. = 0.792 相关性：强
    - Sig. (1-tailed) = 0.002 单尾显著性

      Significant; reject H_0 显著正相关
  - *Yearly 2D：* Insignificant **不显著**

Annual sum
年度总计

Year	3D	2D
2007	1	0
2008	2	1
2009	2	0
2010	2	3
2011	2	0
2012	1	2
2013	4	1
2014	4	1
2015	4	0
2016	7	1
2017	4	0

Correlations

		Year	Sum3D	Sum2D
Year	Pearson Correlation	1	.792**	-.092
	Sig. (1-tailed)		.002	.394
	N	11	11	11
Sum3D	Pearson Correlation	.792**	1	-.114
	Sig. (1-tailed)	.002		.369
	N	11	11	11
Sum2D	Pearson Correlation	-.092	-.114	1
	Sig. (1-tailed)	.394	.369	
	N	11	11	11

**. Correlation is significant at the 0.01 level (1-tailed).

Pearson cor.	Interpretation
.00 ~ .19	Very weak
.20 ~ .39	Weak
.40 ~ .59	Moderate
.60 ~ .79	Strong
.80 ~ 1.0	Very strong

2.4.4 Correlation on annual ratio 年度采用率相关性 (*N*=11)

- *"Is yearly 3D ratio correlated with Year?"*
  "年度3D采用率与年份相关？"
  - H_0: Not correlated
- Pearson's correlation **相关性**
  - Open in SPSS, under menu "Analyze"
    - "Correlate"—"Bivariate"
    - Between *Year* and *Ratio3D*
  - *Yearly 3D ratio*
    - Pearson cor. = 0.176 相关性：极弱
    - Sig. (1-tailed) = 0.302 单尾显著性

      Insignificant 不显著

      Accept H_0

Annual ratio 年度采用率

Year	3D (%)
2007	100
2008	66.67
2009	100
2010	40
2011	100
2012	33.33
2013	80
2014	80
2015	100
2016	87.5
2017	100

Correlations

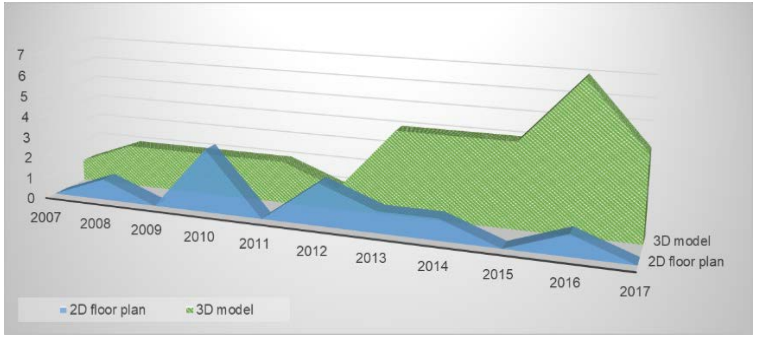
		Year	Ratio3D
Year	Pearson Correlation	1	.176
	Sig. (1-tailed)		.302
	N	11	11
Ratio3D	Pearson Correlation	.176	1
	Sig. (1-tailed)	.302	
	N	11	11

Pearson cor.	Interpretation
.00 ~ .19	Very weak
.20 ~ .39	Weak
.40 ~ .59	Moderate
.60 ~ .79	Strong
.80 ~ 1.0	Very strong

2.4.5 A review of the results 结果回顾

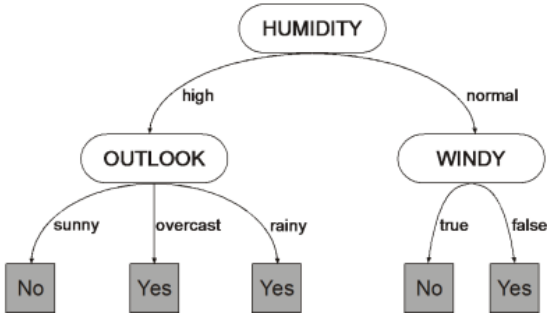
Test	*N*	χ^2	Pearson cor.	Sig.	H_0	Cor.?	Interpret
1	42	12.3		0.270	Accept	No	**共变**
2	42		0.248	0.057	Accept	No	**相关**
3_{3D}	11		0.792	0.002**	Rejected	Yes	**年度总量**
3_{2D}	11		0.092	0.394	Accept	No	**年度总量**
4	11		0.176	0.302	Accept	No	**年度比率**

- Q2: What are the differences?
  课堂练习2：四种研究的异同？
  - **请思考**



2.5 Task 2: Decision tree of *cloud/standalone* 决策树

- Decision tree[10] 决策树
  - Mirrors human decision making 模仿人的决策过程
  - Multivariate analysis 多变量分析 ✓
  - Nonlinear statistical model 非线性统计模型 ✓
  - Easy to interpret, unlike ANN 容易理解 ✓
  - Contains
    - A root node 根结点（起点）
    - Branches 分支结点
    - Leaves 叶结点（终点）
- Application domains 常见领域
  - Machine learning, big data, knowledge engineering, operations research 机器学习，大数据，知识工程，运筹学等



A decision tree of playing outside
户外活动的决策树
(Source: Wikipedia, CC-BY-SA 3.0)

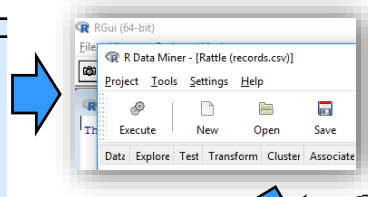
Playing outside：
(1) Humidity= normal AND windy= false;
OR
(2) Humidity= high AND outlook≠ sunny

户外活动：
(1) 湿度正常 且 没有大风； 或者
(2) 湿度高 但 没有暴晒

2.5.1 Mining decision trees with R 用R归纳决策树

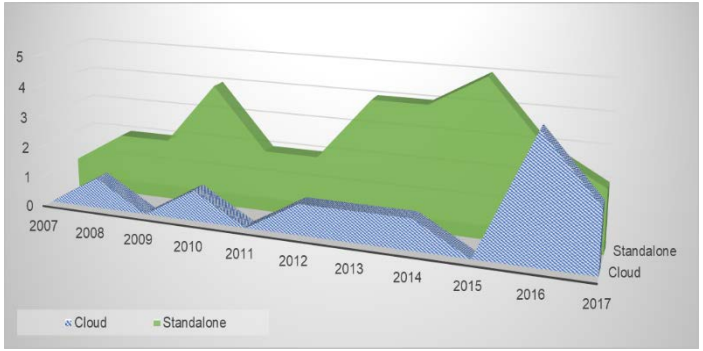
- *"How did literature use cloud/ standalone BIM?"*
  "文献中何时使用云端/单机BIM？"
- Open data in R
  - R: Free scientific packages
  - Run '*rpart*' package
  - Draw with '*rattle*' package
- Result interpretation **结果解读**
  - Cloud **云端:**
    - Phase=Const. AND Property= Status （实时）

Phase	Subject	Property	Cloud ?
Const.	Comp	Status	Standalone
Const.	Comp	Rec	Standalone
Const.	Mat	Status	Standalone
Const.	Comp	Rec	Standalone
Const.	Mat	Loc	Standalone
Const.	Comp	Loc	Standalone
Const.	Comp	Status	Standalone
Const.	Comp	Status	Standalone
Const.	Mat	Loc	Standalone
Const.	User	Loc	Standalone
Const.	Comp	Status	Cloud
Const.	Comp	Loc	Standalone
Const.	User	Loc	Standalone
Const.	User	Loc	Cloud
Const.	User	Loc	Standalone
Const.	Comp	Other	Standalone
Const.	User	Loc	Cloud
Const.	Comp	Status	Cloud
Const.	Comp	Loc	Cloud
Const.	Comp	Status	Cloud
Const.	Comp	Status	Cloud
O&M	User	Loc	Cloud
O&M	Comp	Rec	Standalone
O&M	Comp	Rec	Standalone
O&M	User	Loc	Cloud
O&M	Comp	Status	Standalone
O&M	User	Loc	Standalone
O&M	Comp	Loc	Cloud
O&M	Comp	Status	Standalone
O&M	User	Loc	Standalone
O&M	Comp	Other	Standalone
O&M	Comp	Loc	Standalone
O&M	User	Loc	Standalone
O&M	User	Loc	Standalone
O&M	User	Loc	Standalone
O&M	User	Loc	Standalone
O&M	Comp	Loc	Standalone
O&M	Comp	Rec	Standalone
O&M	User	Loc	Cloud
O&M	Comp	Loc	Standalone
O&M	Comp	Loc	Standalone
O&M	Comp	Loc	Standalone

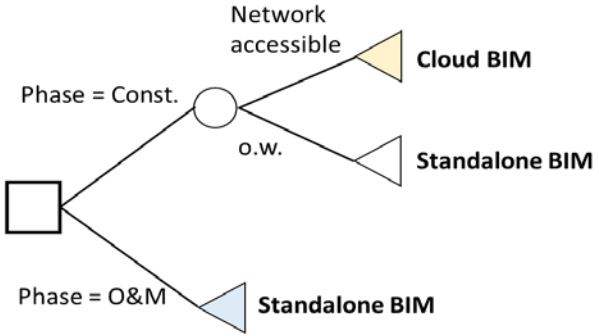


2.5.2 Decision tree pruning 修剪决策树

- Drawbacks of the decision tree **缺点**
  - Biased from *outdated* cases back to 10 years ago
    陈旧数据导致决策规则偏颇
- Complement **补完**
  - Needs pruning for future use
    为未来应用修剪决策树
    - With recent stablished trends in industry
      使用最新确立的工业趋势
- Pruned tree **修剪后的决策树**
  - Cloud **云端**:
    - All scenarios in construction phase if having available network
      建造阶段（实时要求高）且 有可用网络

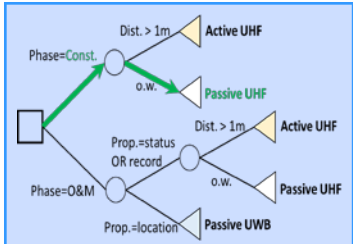
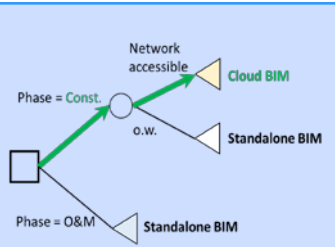
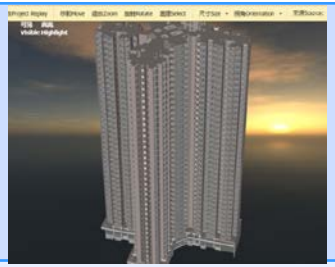
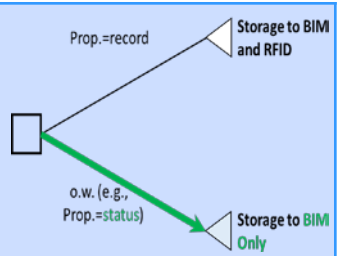
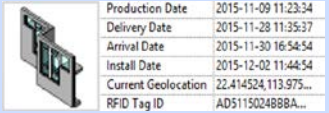


A recent burst of cloud BIMs
云端BIM已趋于流行



Pruned decision tree
修剪后的决策树(面向智能建造)

2.6 A final guideline 最终编成的实用指南

				
1. Select an RFID	2. Adopt the RFID	3. Select a BIM	4. Adopt the BIM	5. Select a storage
				
6. Data schema extension	7. RFID installation	8. Training workers	9. Info. gateway	10. Decision support

Section 3 讨论

DISCUSSION

3 Further discussion 进一步讨论

- Q1: What type is this research? **课堂练习1：此为何种研究？**
  - (A) survey research/literature review **综述**✓
  - (B) experimental research **实验** ×
  - (C) meta-analysis **元分析（分析的分析）**✓
  - (D) correlational research **相关性分析**✓
- Q2: What are the differences? **课堂练习2：四种研究的异同？**
  - Results **结果**
  - Rationale **原理**
- Q3: Any limitations in this research? **课堂练习3：本研究局限性在……？**
  - Data **数据**
  - Methods **方法**

(Source: Wikipedia, CC-BY-SA 3.0)

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Thank You !
感谢!