The Hong Kong Polytechnic University
香港理工大學

Hong Kong Concrete Institute
香港混凝土學會
HKCI

ANNUAL SEMINAR 2020
MAIN THEME: Modular Integrated Construction – Issues and Solutions

MiC – New Era of Building Construction

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Presentation Agenda

1. **Introduction & Current Technology Gaps**
2. Benefits and Challenges of MiC
3. State-of-the-Art
4. MiC: Impact of Several Factors
5. Lessons Learned from Other Countries
6. Concluding Remarks

Hong Kong Housing Problem

HK Population: 7.37Millions

HA provided public rental housing (PRH) to 2.0 million people, 28% until Mar 2018

Target: 460,000 units (2017 – 2027)

- **HA capacity to build 193,600 units in 10 years.**
- **Falling short of 266,400 units**
- **Shortage of skilled labor**
- **MiC is the solution to achieve such target**

Limitations of Prefabricated Components Approach

Two decades in HK

- Cannot cope with the set target and demand of units.
- High transportation cost.
- High probability of damages.
- Need installation equipment, skilled labor, and additional supervision.

Government Public Policy Towards MiC

- **In 2018, HKSAR in its public policy gave the green light for full scale promotion of MiC, to enhance the productivity and cost-effectiveness of projects.**

- **In the same public policy address, HKSAR encouraged the adoption of MiC in public projects and asserted on stakeholders collaboration to push further in adoption of MiC.**

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- **Benefits and Challenges of MiC**

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- State-of-the-Art

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- MiC: Impact of Several Factors

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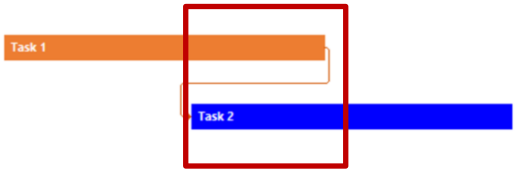
MiC Advantages in Hong Kong

- Time.
- Sustainable & Clean.
- Technology-based manufacturing.
- Quality.
- Safety.
- Faster operation.
- etc

MiC Advantages in Hong Kong

TIME SAVING

- Overlapping between on-site and off-site.



- MiC can eliminate almost 80% of the construction site activities.

- MiC can cut down construction duration by 40% Vs. conventional.

MiC Advantages in Hong Kong

Benefits of MiC from Case Studies

S/N	Benefits	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
1	Shortens construction time	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
2	Cost reduction		✓								
3	Improved quality									✓	
4	Improved safety (zero accidents)									✓	
5	Enhanced sustainability						✓				✓

Note: C1 = Victoria Hall; C2 = Mini Sky City; C3 = NTU North Hill Residence Hall; C4 = Crowne Plaza Changi Airport hotel extension; C5 = Folsom Fairfield Inn; C6 = NTU Nanyang Crescent Hostel; C7 = Woodlands Nursing Home; C8 = Yuzana low-cost housing projects; C9 = Brownstone Executive Condominium; C10 = The Clement Canopy

Time Saving (Ave 25%)

Project	Year of completion	Country	% change in construction time
Victoria Hall	2009	UK	-40%
Mini Sky City	2015	China	-40%
NTU North Hill Residence Hall	2015	Singapore	-6%
Crowne Plaza Changi Airport hotel extension	2016	Singapore	-17%
Folsom Fairfield Inn	2016	USA	-30%
NTU Nanyang Crescent Hostel	2017	Singapore	-20%
Woodlands Nursing Home	2017	Singapore	-20%
Yuzana low-cost housing projects	2018	Myanmar	-40%
Brownstone Executive Condominium	2018	Singapore	-10%
The Clement Canopy	2019	Singapore	-25%

GARANTEED TIME SAVING

✓ Very important advantage for Hong Kong

Extra Cost (Ave +10%)

Project	Year of completion	Country	% change in construction cost
Mini Sky City	2015	China	-30%
NTU North Hill Residence Hall	2015	Singapore	18%
Crowne Plaza Changi Airport hotel extension	2016	Singapore	12.50%
Folsom Fairfield Inn	2016	USA	0%
The Clement Canopy	2019	Singapore	7.50%

MiC Advantages in Hong Kong

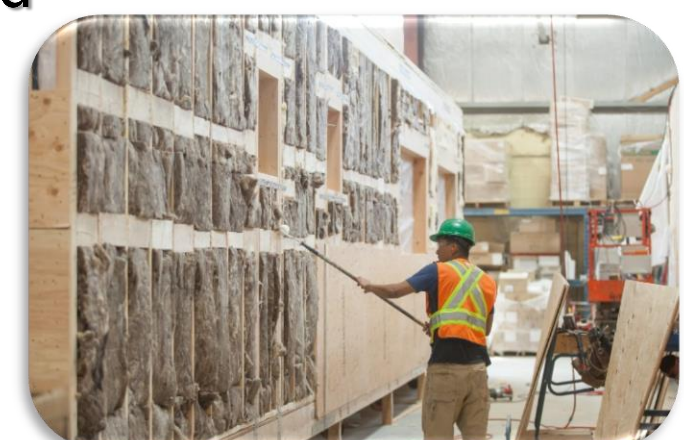
SUSTAINABILITY

- Reduction in noise & disruption by $\boxed{30 - 50\%}$.
- 76% of researchers confirmed that MiC reduces wastage.
- Decrease CO_2 emissions due to the reduction of transportation.
- Modular home reduced energy consumption by 4.6% and CO_2 by 3% over a 50-year life.

MiC Advantages in Hong Kong

QUALITY & TECH-BASED OPERATIONS

- Controlled & protected environment
- Better TQM application
- Workers have better learning curves.
- High building specifications easily applied



MiC Challenges in Hong Kong

- ◆Design & Standards.
- ◆Manufacturing.
- ◆Transportation.
- ◆Awareness.
- ◆Procurement.

Critical Challenges of MiC

Criteria	Sub-Criteria
Project Characteristic (PC)	Site access
	On-site storage area
	Productivity
	Initial cost
	Legal requirement
Transportation Aspect (TA)	Transportation method
	Distance between site and factory
	Road network capability or capacity
Stakeholder Collaboration (SC)	Contractor capability and experience
	Fabricator capability and experience
	Owner willingness
	Design freeze
	Coordination among practitioners

MiC Challenges in Hong Kong

Criteria	Challenges	Geometric mean	Rank
PC	Site access	0.0785	4
	On-site storage area	0.0674	5
	Productivity	0.0613	6
	Initial cost	0.0587	7
	Legal requirement	0.017	13
TA	Transportation method	0.1237	2
	Distance between site and factory	0.0584	8
	Road network capability or capacity	0.1398	1
SC	Contractor capability and experience	0.0173	11
	Fabricator capability and experience	0.0172	12
	Owner willingness	0.0227	10
	Design freeze	0.0993	3
	Coordination among practitioners	0.0306	9

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- Introduction & Current Technology Gaps

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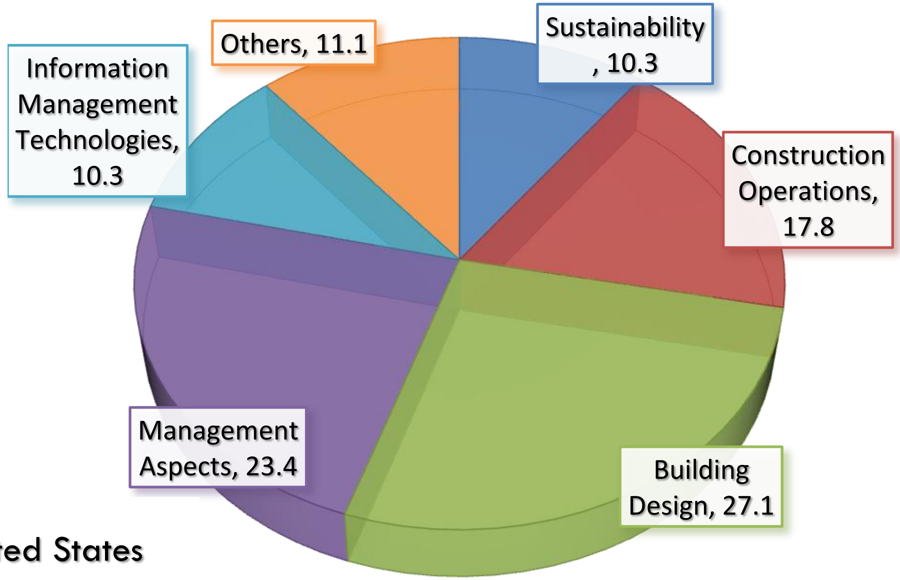
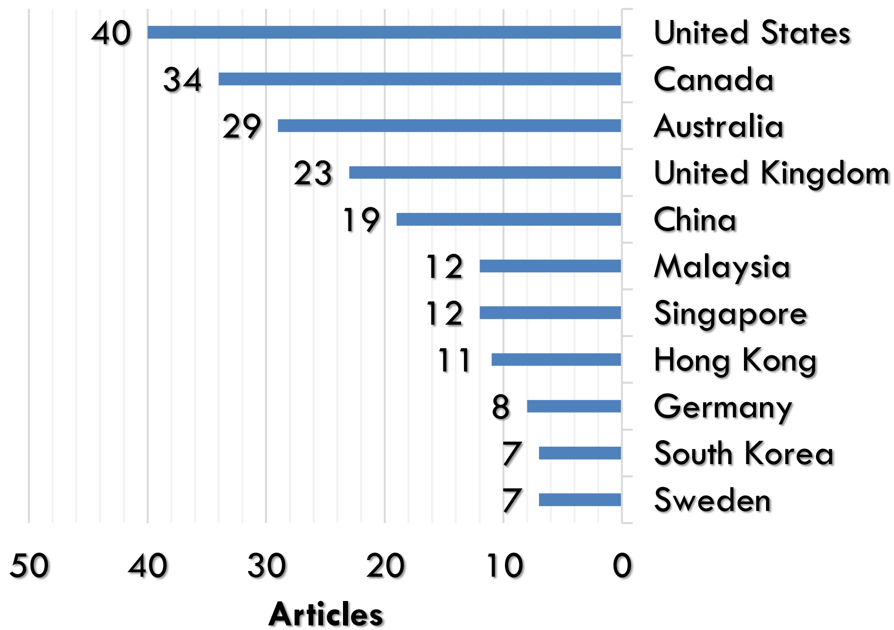
State-of-the-Art

RESEARCH STATUS

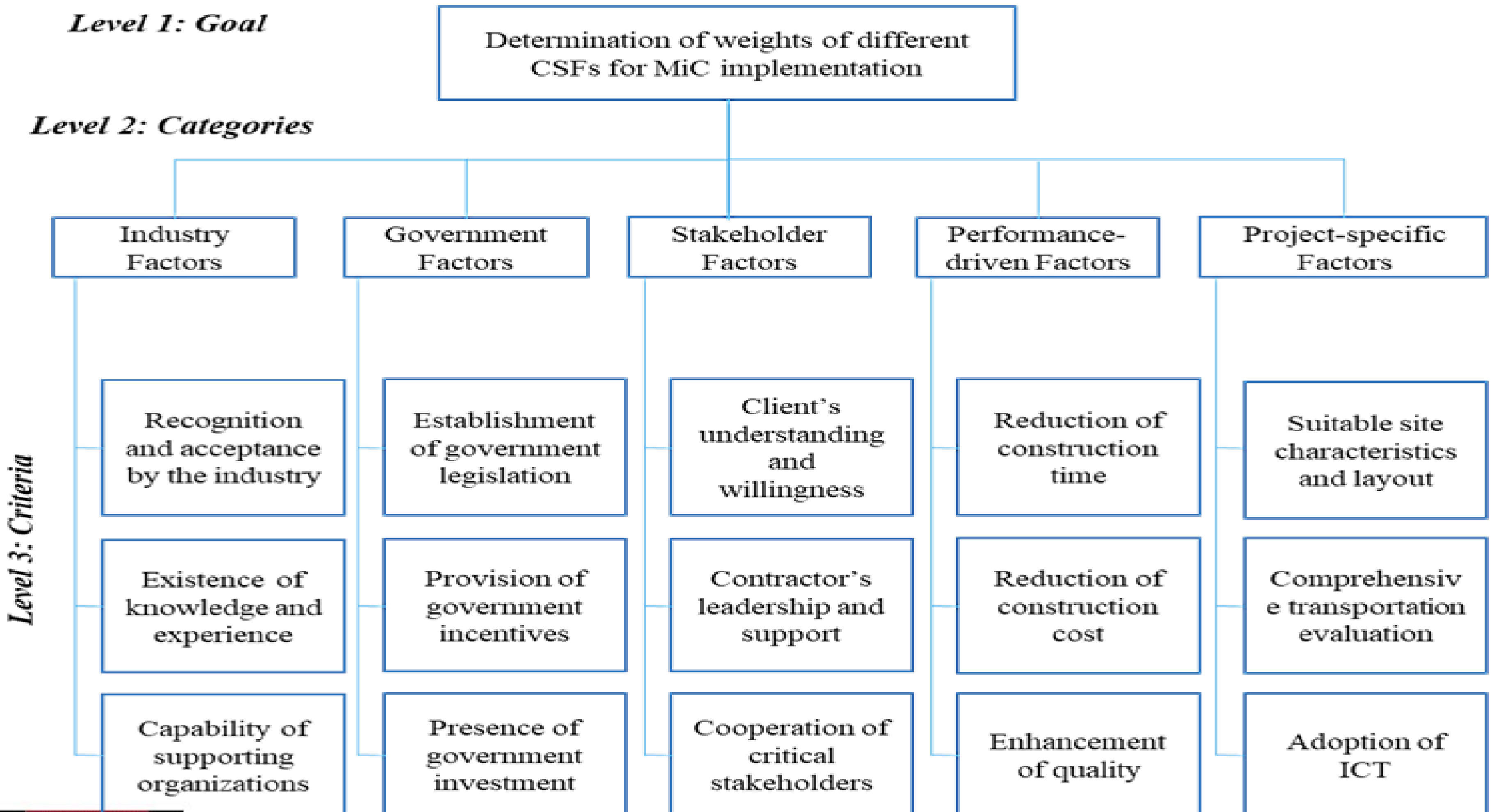
- 27% Building Design
- 23.4% Management
- 17.8% Construction Operations





State-of-the-Art

SUCCESS FACTORS



Ranking of CSFs for MiC adoption in Hong Kong

Aggregated global weights and ranking of CSFs

Categories	CSFs	Aggregated Global Weights	Rank
Industry Factors (I)	Recognition and acceptance by industry (I1)	0.025	12
	Existence of knowledge and experience (I2)	0.027	10
	The capability of supporting organizations (I3)	0.033	9
Government Factors (G)	Establishment of government legislation (G1)	0.068	3
	Provision of government incentives (G2)	0.055	5
	Presence of government investment (G3)	0.051	6
Stakeholder Factors (S)	Client's understanding and willingness (S1)	0.071	1
	Contractor's leadership and support (S2)	0.026	11
	Cooperation of critical stakeholders (S3)	0.025	12
Performance-driven Factors (PD)	Reduction of construction time (PD1)	0.046	8
	Reduction of construction cost (PD2)	0.048	7
	Enhancement of Quality (PD3)	0.022	15
Project-specific Factors (PS)	Suitable site characteristics and layout (PS1)	0.070	2
	Comprehensive transportation evaluation	0.057	4
	Adoption of ICT	0.023	14

Critical Success Factors for MiC projects

- ***D1: Project related factors***
  - F1: Complexity of the project
  - F2: Availability of service/facilities of MiC
  - F3: Availability of logistics and transportation for MiC
  - F4: Availability and proximity of MiC manufacturers
- ***D2: Client's factors***
  - F5: Financial Capability
  - F6: Time Capability
  - F7: Excessive changes during construction
- ***D3: Project team factors***
  - F8: Competence
  - F9: Commitment
  - F10: Cooperation
  - F11: Availability of installation equipment and technology for MiC
- ***D4: Procurement factors***
  - F12: Transparency in Procurement
  - F13: Competitive procurement and tendering method
- ***D5: External factors***
  - F14: Industry-related factors
  - F15: Economic
  - F16: Government policies and regulations
  - F17: Social

Rankings of Critical Success Factors

Category	Critical Success Factors	Local Weights	Global Weights	Ranking
D1	F1: Complexity of the Project	0.1566	0.0263	16
	F2: Availability of service/ facilities for MiC	0.2613	0.0438	13
	F3: Availability of logistics and transportation	0.2796	0.0469	11
	F4: Availability and proximity of MiC manufacturers	0.3026	0.0508	10
D2	F5: Financial Capability	0.4627	0.1625	1
	F6: Time Capability	0.3569	0.1253	2
	F7: Excessive changes during construction	0.1804	0.0633	3
D3	F8: Competence	0.2787	0.0538	9
	F9: Commitment	0.1731	0.0334	15
	F10: Cooperation	0.2323	0.0448	12
	F11:Availability of installation equipment and technology for MiC	0.3159	0.0609	5
D4	F12: Transparency in procurement	0.48	0.0589	6
	F13: Competitive procurement and tendering method	0.51	0.0626	4
D5	F14: Industry-related issues	0.2268	0.0383	14
	F15: Economic	0.3282	0.0554	7
	F16: Government policies and regulations	0.3266	0.0552	8
	F17: Social	0.1184	0.0199	17

State-of-the-Art

Benefits of BIM applications ranking results in Hong Kong MiC Industry

BIM apps in MiC	Mean score values	Rank	AHP values	Rank
3D Visualization	4.19	2	0.11	4
Clash Detection	4.51	1	0.19	1
Better Communication and Coordination	4.17	3	0.17	2
Analysis, Simulation, and Optimization	3.70	4	0.13	3
Parametric Modelling	3.06	5	0.10	5
Quantities Take-off and Cost Estimation	2.68	6	0.09	6
Improved Pre-Fabrication Level	2.23	8	0.07	7
Scheduling and Logistic Planning	2.32	7	0.07	7
Assembly Training with BIM	2.19	9	007	7

State-of-the-Art

Barriers of BIM implementation to Hong Kong MiC Industry

BIM barriers in MiC	Mean score values	Rank	AHP values	Rank
AEC Professionals Resistant to Change	3.55	3	0.14	4
High Initial Cost	3.94	2	0.26	2
Insufficient Training and Lacking BIM Professionals	4.15	1	0.30	1
Legal Responsibilities and Liability Issues	2.83	5	0.10	5
Lack of Collaborations Between Parties	3.47	4	0.19	3

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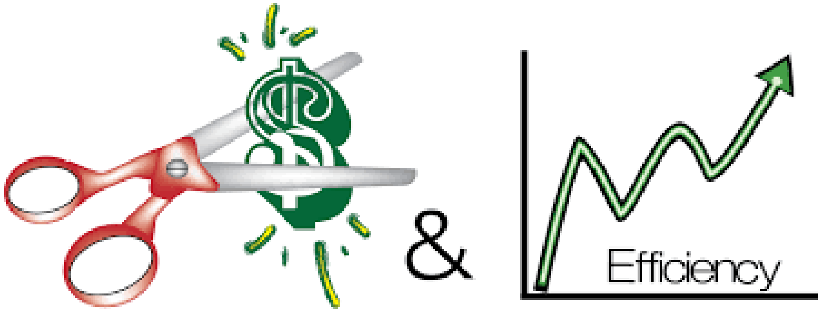
MiC: Impact of Several Factors

Logistics and Transportation: JUST IN TIME(JIT) in MiC

- JIT is the delivery of the required material, quantity, and quality on the required time.

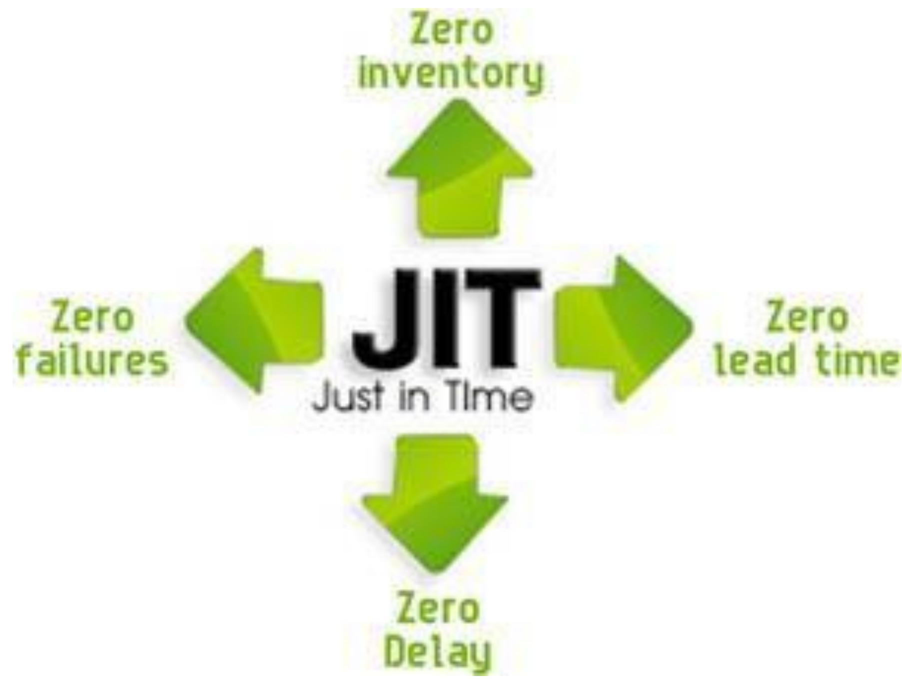
  Advantages:

  - Increase of efficiency.
  - Reduction of waste and costs (inventory costs).



MiC: Impact of Several Factors

JIT CHALLENGES



1- Reliable suppliers.

2- Stable production (no breakdown).

3- Collaborative supply chain by information sharing.

TOYOTA

- Toyota took 15 years to perfect JIT.
- How long it will take from MiC stakeholders?

MiC: Impact of Several Factors

JIT CHALLENGES

Transport problem

1- Prefabricated components

2- Panelized construction

3- MiC

4- Civil infrastructure

Complexity/Size

+

+

MiC: Impact of Several Factors

JIT CHALLENGES

To apply JIT, we need:

Transportation planning

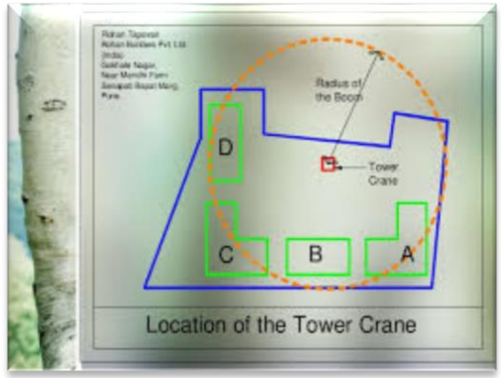
Inventory planning

Information management

MiC: Impact of Several Factors

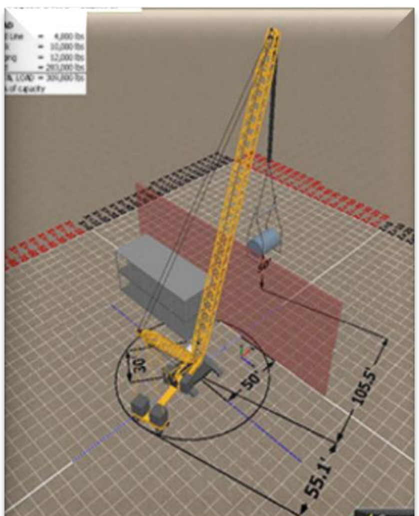
CRANE OPERATION IN MiC

No. of cranes?

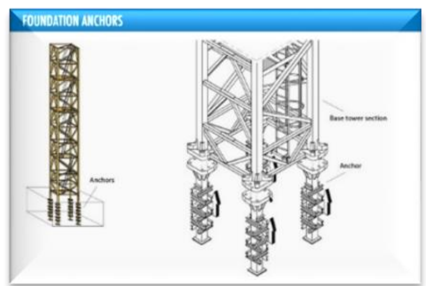


Crane location?

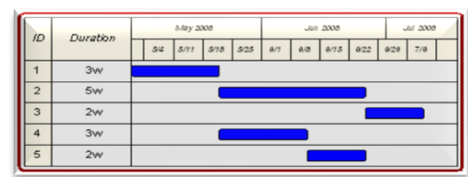
Location of pick-up point?



Motion planning (to avoid collisions)?



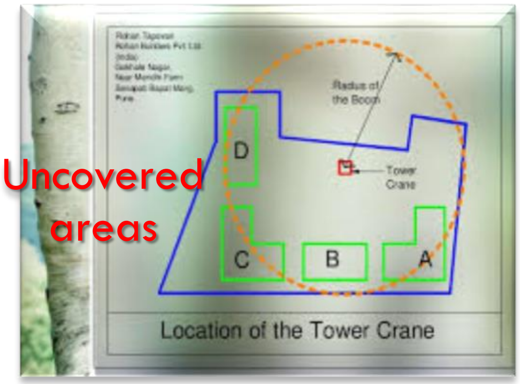
Design of foundation and lateral support?



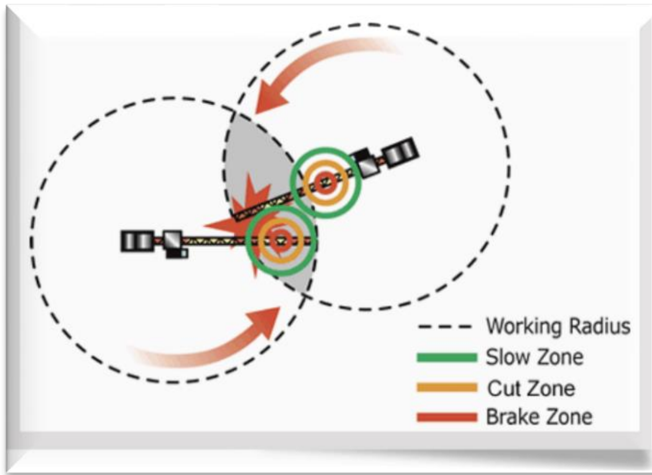
Sequence of lifting activities?

MiC: Impact of Several Factors

OBJECTIVES OF CRANE OPERATION IN MiC



Cover of all supply &demand areas

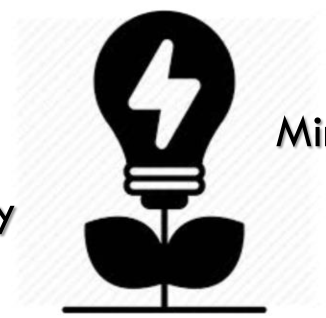


Avoid collisions between cranes

Avoid collisions with power lines

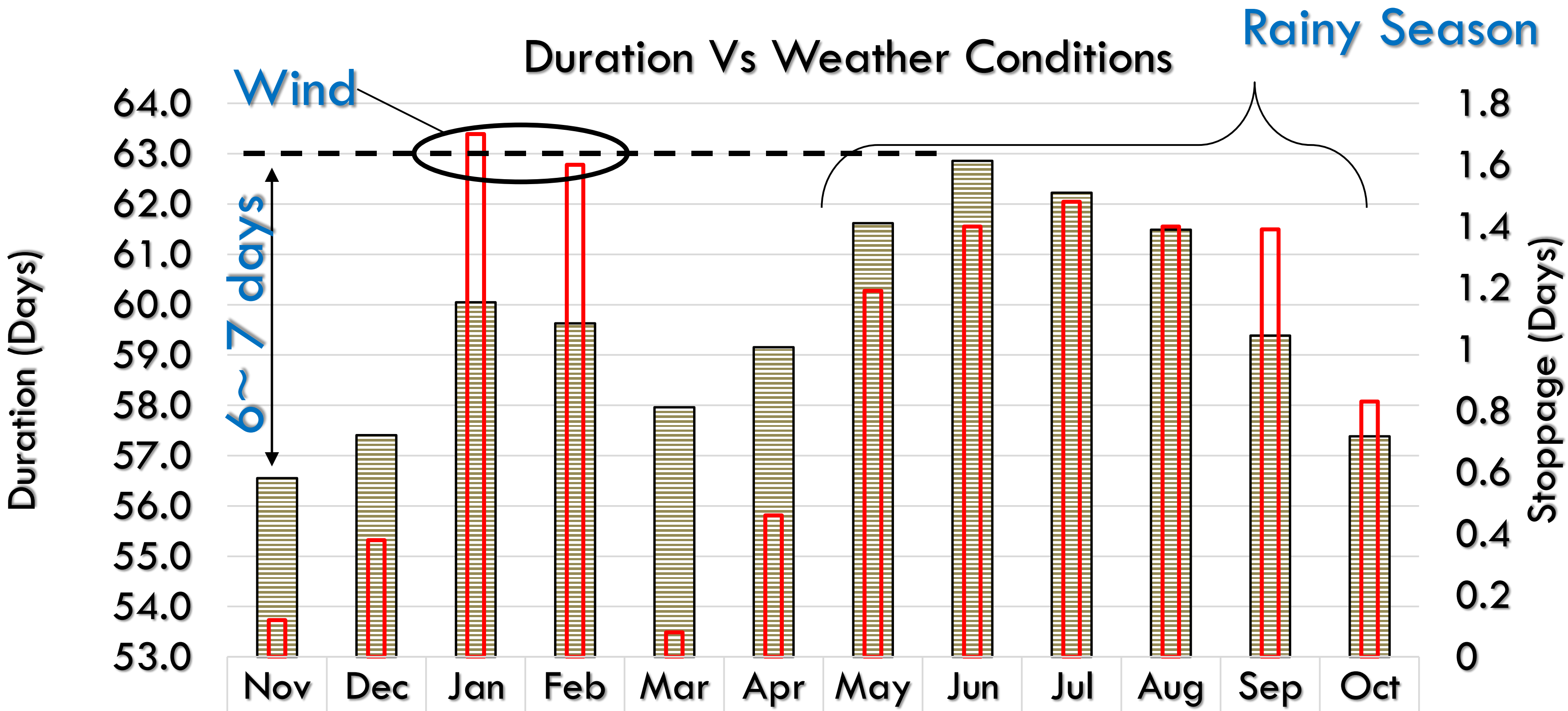
Minimize time

Maximize productivity



Minimize energy

WEATHER IMPACT



	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Duration	56.6	57.4	60.0	59.6	58.0	59.2	61.6	62.9	62.2	61.5	59.4	57.4
Stoppage	0.12	0.38	1.7	1.6	0.08	0.46	1.19	1.4	1.48	1.4	1.39	0.83

✓ Proper planning of MiC installation stage can achieve 10% reduction in installation duration

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Lessons Learned from Other Countries

Table 1
Summary of policies concerning modular construction.

	Item	Source
Mainland China	1. Opinions on Further Promoting the Development of Assembled Buildings	Document
	2. Implementation Opinions on Accelerating the Modernization of the Construction Industry and Promoting the Upgrade of the Construction Industry	Document
Hong Kong	1. 2018 Policy Address and Policy Agenda	Document
	2. 2017 Policy Address and Policy Agenda	Document
	3. Construction Innovation and Technology Fund (CITF)	Website
Singapore	1. Building Control (Buildability and Productivity) Regulations 2011	Document
	2. 1st Construction Productivity Roadmap	Document
	3. 2nd Construction Productivity Roadmap	Document
	4. Integrated Construction and Prefabrication Hub (ICPH)	Website
	5. Prefabricated Prefinished Volumetric Construction (PPVC)	Website
	6. Construction Productivity and Capability Fund	Website
	7. Building Innovation Panel (BIP)	Website

Table 2
Summary of specifications concerning modular construction.

	Item	Hierarchy
Mainland China	1. Specification for design of prefabricated monolithic modular building (Exposure Draft) (abbreviated as Specification for design)	Association's standards
	2. Specification for construction and acceptance of prefabricated monolithic modular building (Exposure Draft) (abbreviated as Specification for construction and acceptance)	
	3. Specification for isolation technology of prefabricated monolithic modular building (Exposure Draft) (abbreviated as Specification for isolation technology)	
Hong Kong	1. PNAP ADV-36 Appendix A: Design Requirements for Modular Integrated Construction (Building Department, 2017)	Regulations
	2. PNAP ADV-36 Appendix B: Quality Control and Supervision of MiC (Building Department, 2017)	
Singapore	1. Design for Manufacturing and Assembly-Prefabricated Prefinished Volumetric Construction (Guidebook)	Technical specifications

Policy Comparison of China, Hong Kong and Singapore

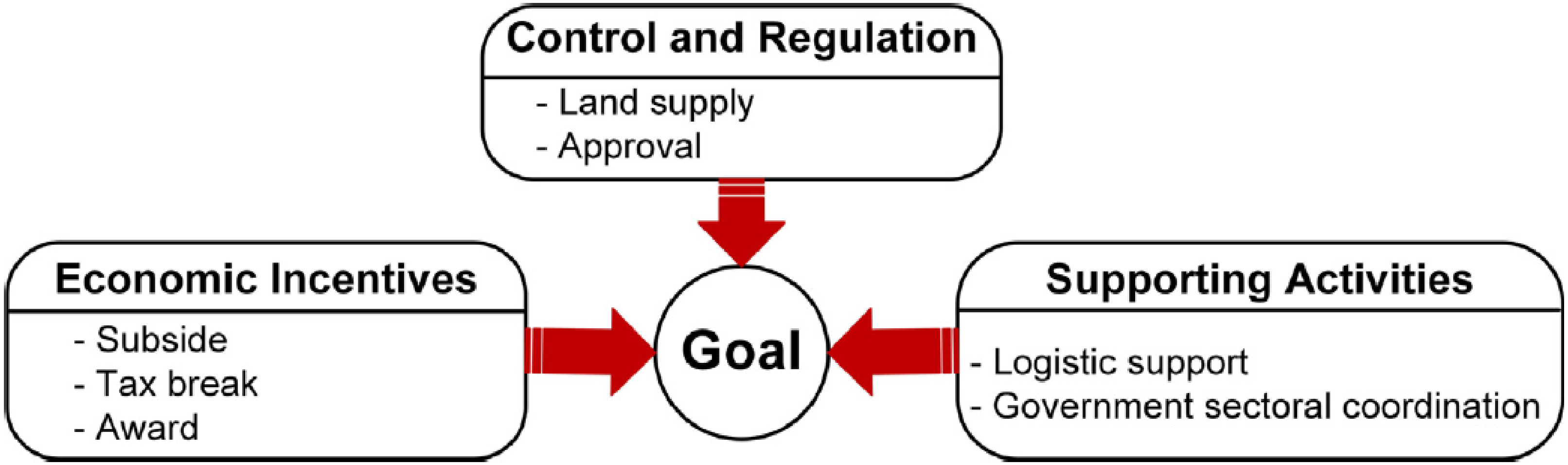

Fig. 3. The analysis framework of policies.

All policies aim to directly increase the supply of modular buildings in the market, or to provide a lenient environment to develop modular buildings, which then indirectly increase the supply.

The government issued related policies

The government did not issue related policies

As of Dec. 2018

		mainland China	Hong Kong	Singapore
Goal	Goal			
Control and regulation	Land supply			
	Approval			
Economic incentive	Subside			
	Tax break			
	Award			
Supporting activities	Logistic support			
	Government sectoral coordination			

Lessons Learned from Other Countries

Project: **Victoria Hall**

Location: **England**

No. of Floors: **25**

Use of Building: **Student Accommodation**

Status: **Completed 2009**

Modules: **824** each, **10** to **25** tons

Achievements

- ✓ Duration: **32 weeks using eight workers**
- ✓ Rate: **7** modules per day, **15** modules in peak
- ✓ Time saving: **over 50 weeks**
- ✓ Landfill: **reduction by around 70%**

Lessons Learned from Other Countries

Project: **Clement Canopy**
Location: **Singapore**
No. of Floors: **40**
Use of Building: **Residential**
Status: **Completed 2019**
Modules: **1,866** modules, **65%** superstructure, **27** tons, **40-tons tower cranes**

Achievements

- ✓ Height: **140 meters, highest MiC concrete.**
- ✓ Wastage: **reduction 70% onsite & 30% offsite.**




Lessons Learned from Other Countries

Project: **461 Dean Street, “Atlantic Yards”/ “Pacific Park”**
Location: **New York, US**
No. of Floors: **32**
Use of Building: **Residential**
Status: **Completed 2016**

Achievements

- ✓ Height: **109 meters, 1st MiC high-rise tower**
- ✓ Modules: **930, 225 different designs**

Features

- New plant “FCModular”, 4 modules per day.
- Bathroom assembly was most laborious task.
- Special trucks & JIT.

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Concluding Remarks

- MiC is revolutionizing the construction industry.
- MiC is a suitable solution for housing problem in Hong Kong.
- Requires effort to harness its benefits.
- Requires thorough feasibility studies, design management and proper planning.
- Advanced techniques (JIT, BIM, IoT, etc.).

4D Visualization of Module Assembly

Thank You

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