Economics of Building:
Material and Technology Choices

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31 January 2020

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- Why is the cost of building different in different cities around the world?
- Influence of factor inputs to construction: labour, capital and resources
- What materials – technologies - systems are used in different countries?
- Is there an optimum mix, technology adoption, construction system?
- Can we use this information to improve the industry: increase employment, improve productivity, increase profits, and stimulate national economy?

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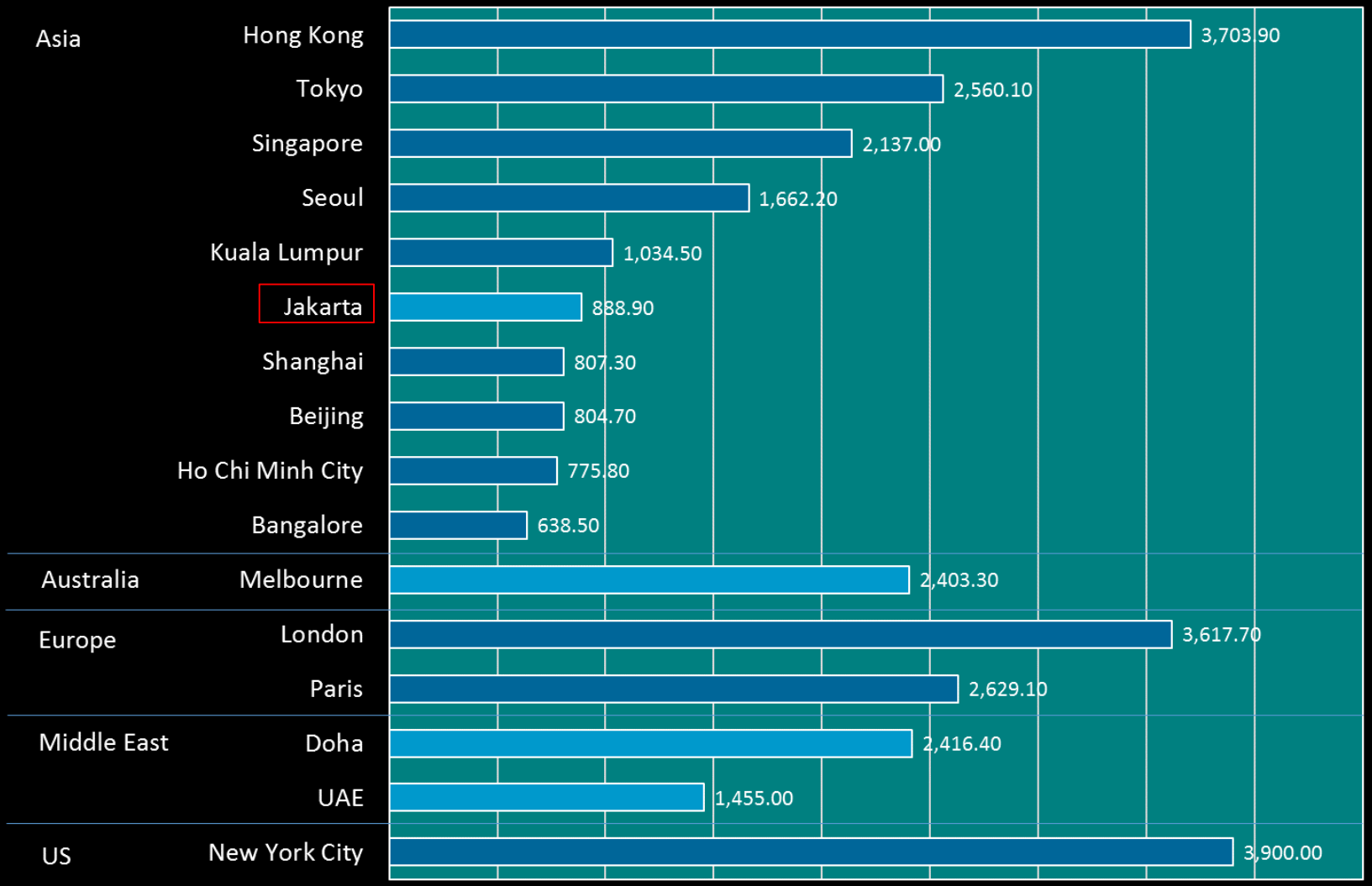
variation in building cost across major cities (US$)
(average of 6 building types, land cost not included)



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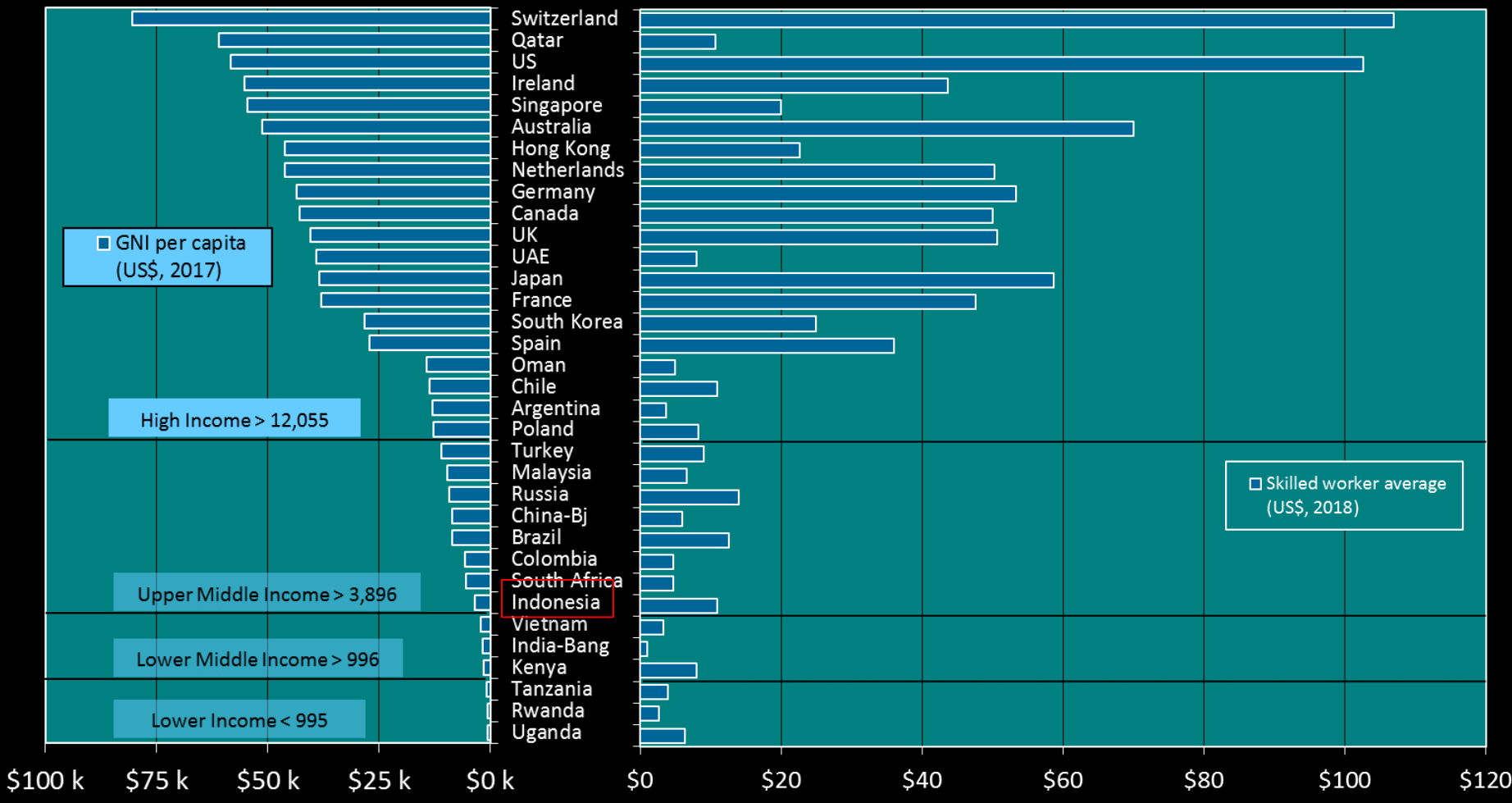
skilled worker wages vs GNI per capita (US$)



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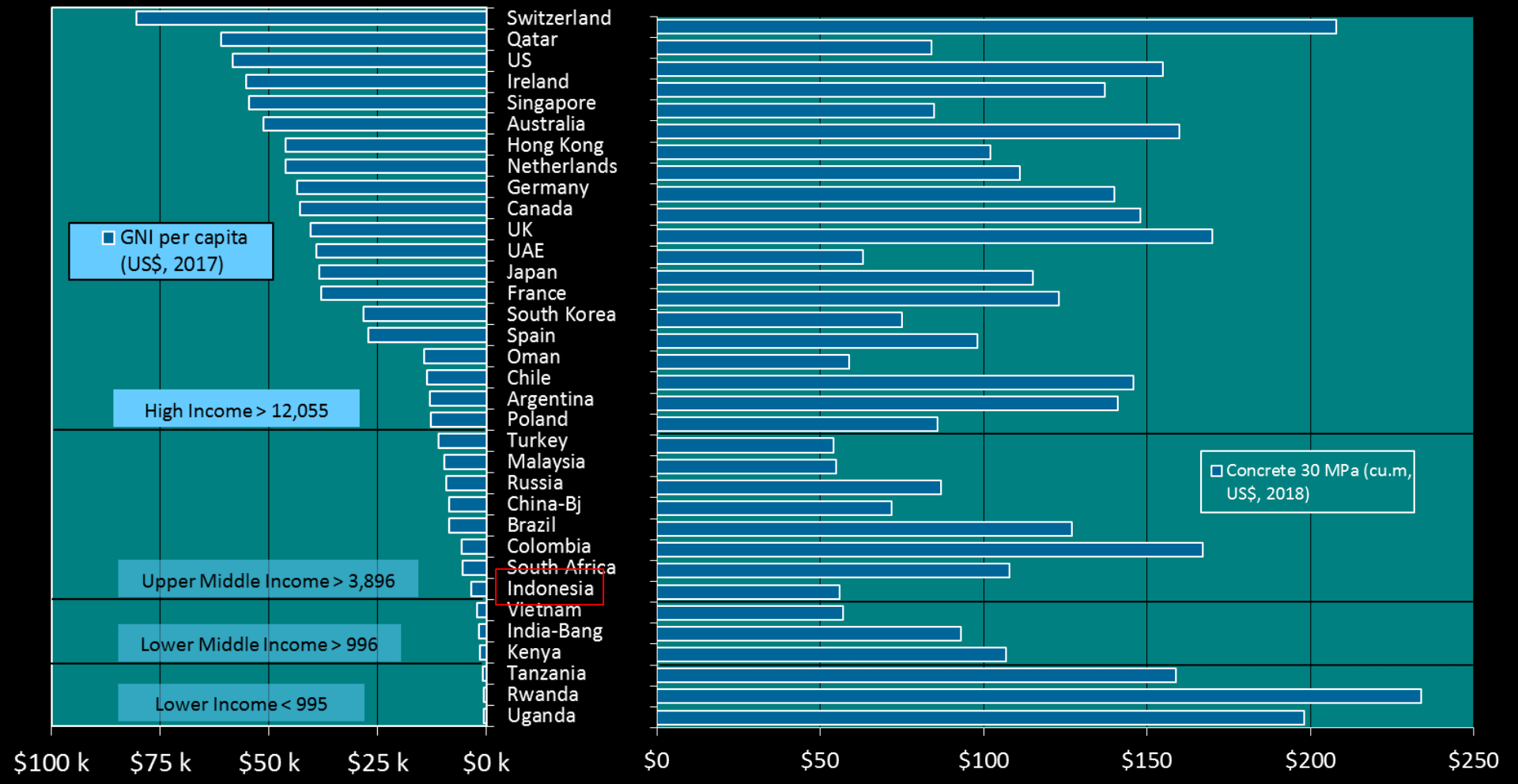
concrete cost vs GNI per capita (US$)



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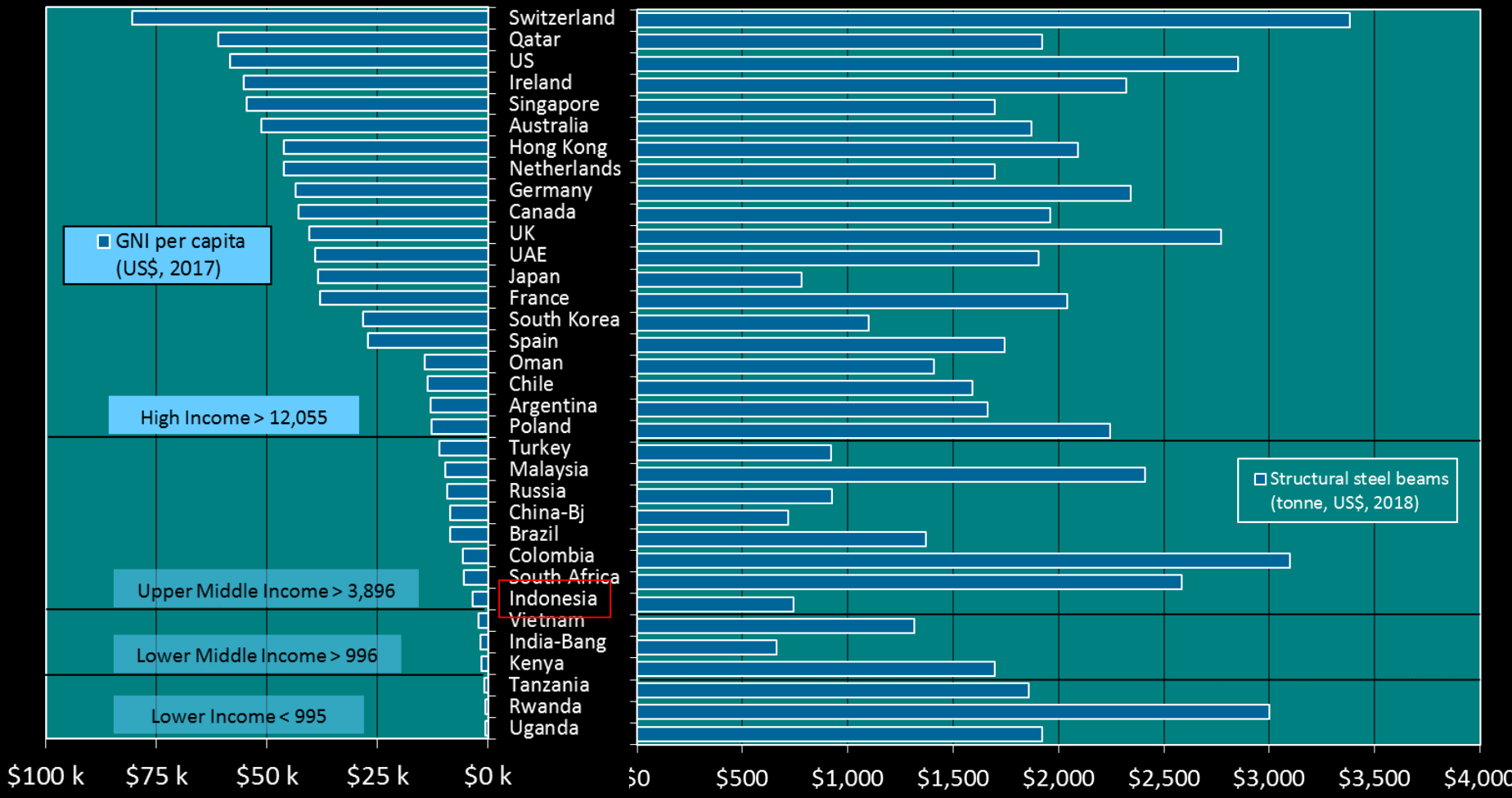
structural steel cost vs GNI per capita (US$)



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from US$ to local currency to ratios

Existing comparisons:

- US$ comparison may not be appropriate
- We can use PPP adjustments more accurately reflect purchasing power

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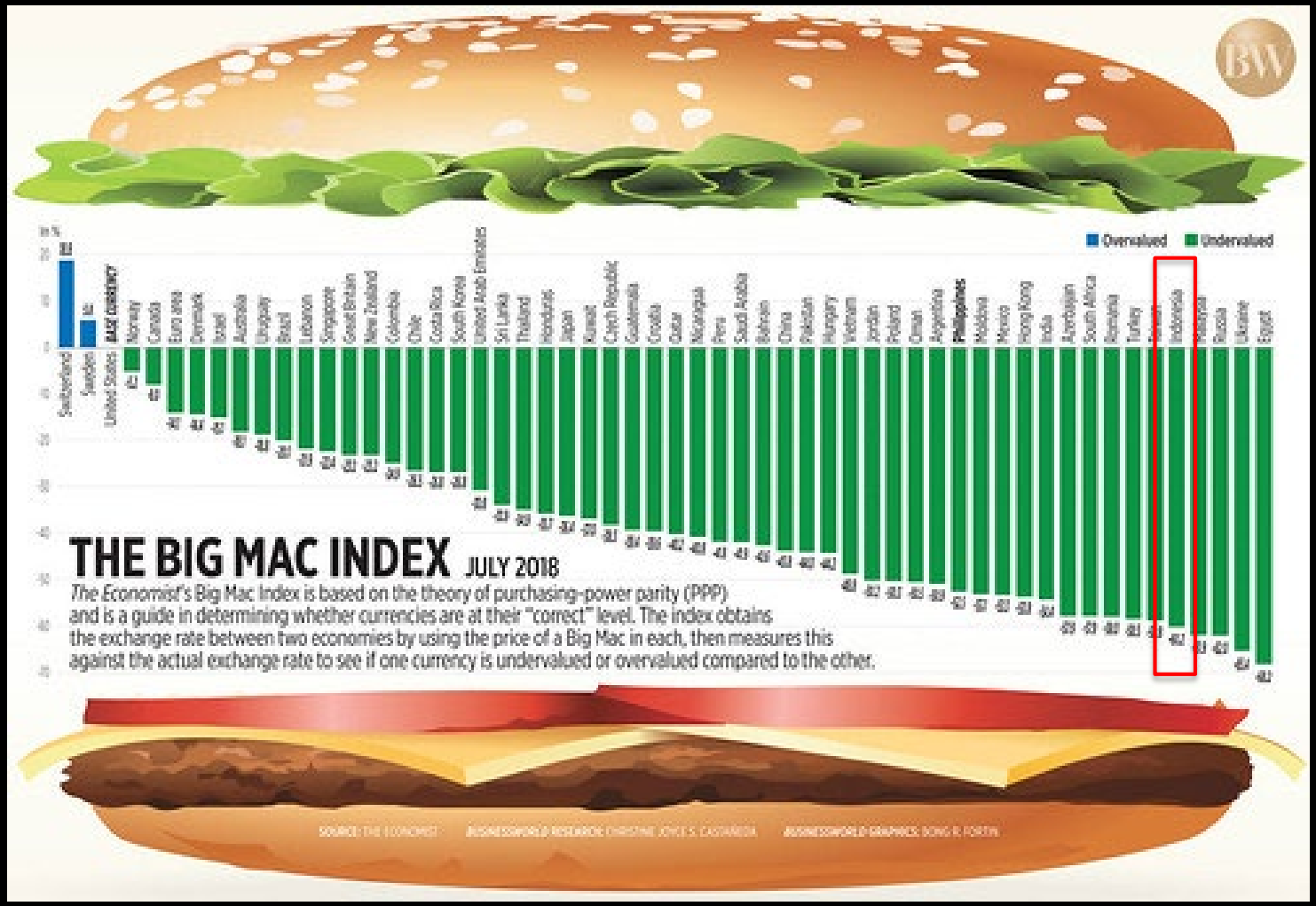
from US$ to local currency to ratios



from US$ to local currency to ratios

Alternatively, a new measure:

- examine basic input costs
  - labour, material, equipment hire (technology)
  - are all in local currency
- derive cost indices (remove effect of currency!)
- correlates technology choice to cost indices
- examines implications for industry development

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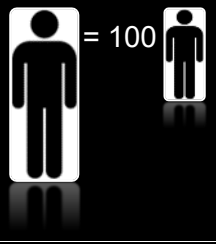
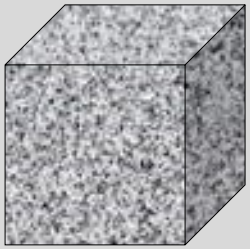


concrete to labour cost ratio

	Australia	Malaysia	Indonesia	India
concrete (1 m^3) 	2.3	8.5	40	75
steel (1 m.ton) 	13.6	164	453	527

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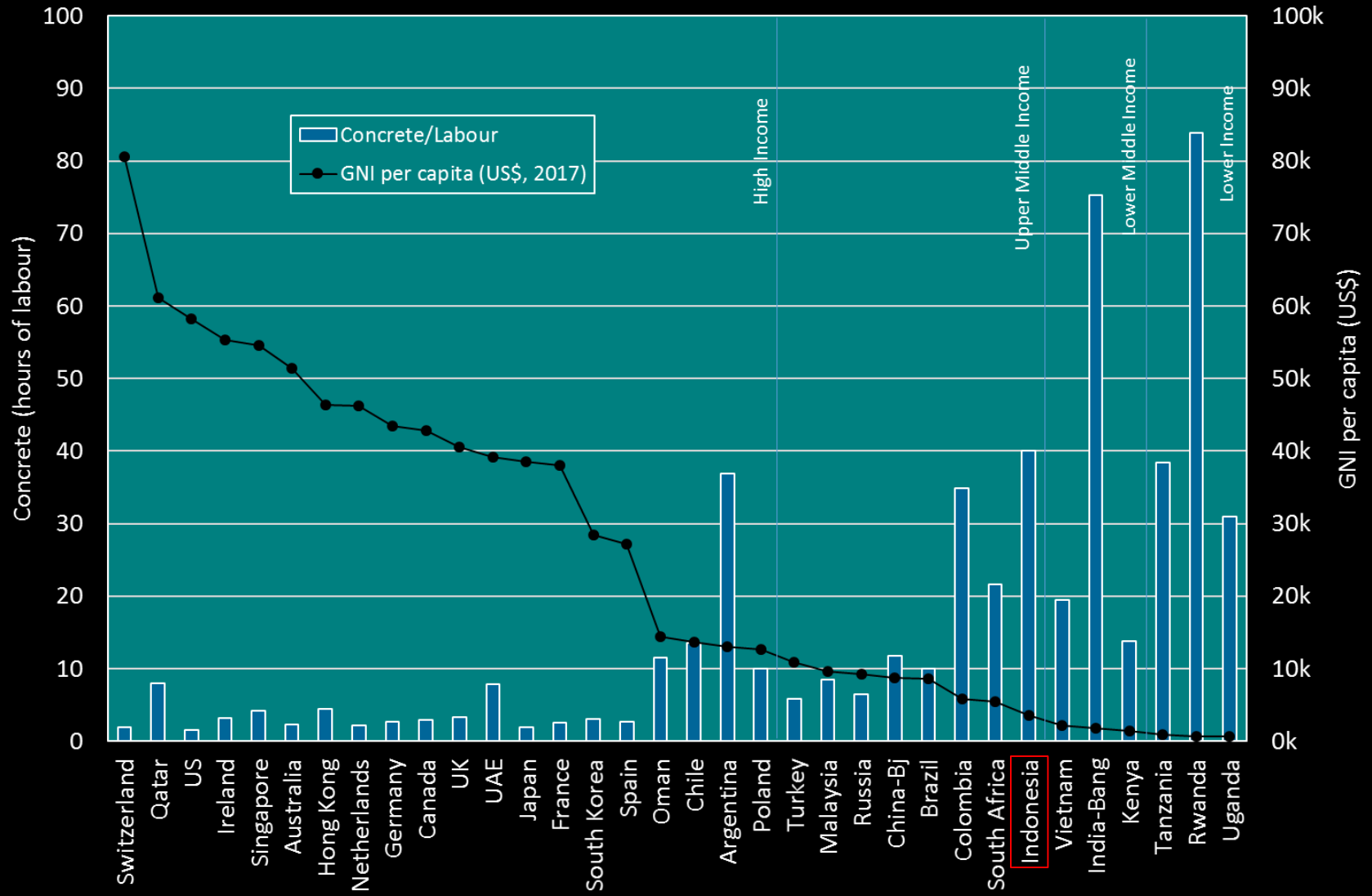
concrete-to-labour cost ratio



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concrete-to-labour cost ratio

- labour is expensive in high-income countries, and
- concrete is expensive in lower-income countries

- utilise more concrete in high-income countries, and
- utilise more labour in lower-income countries

- countries with cheaper migrant labour distort concrete/labour ratio

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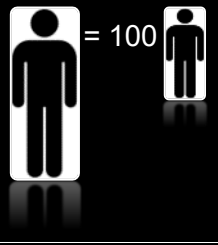
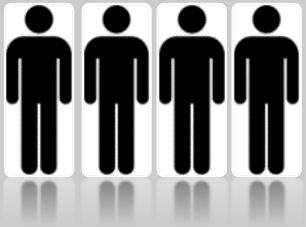
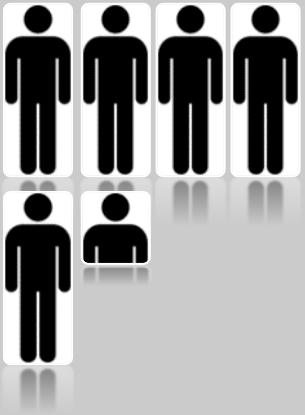
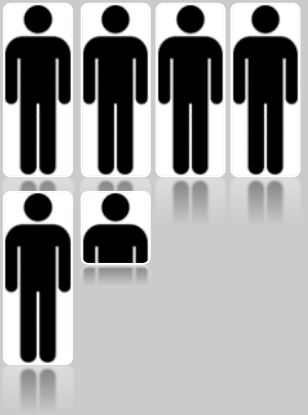


structural steel-to-labour cost ratio

	Australia	Malaysia	Indonesia	India
structural steel (1 ton) 	 27	 375	 533	 534

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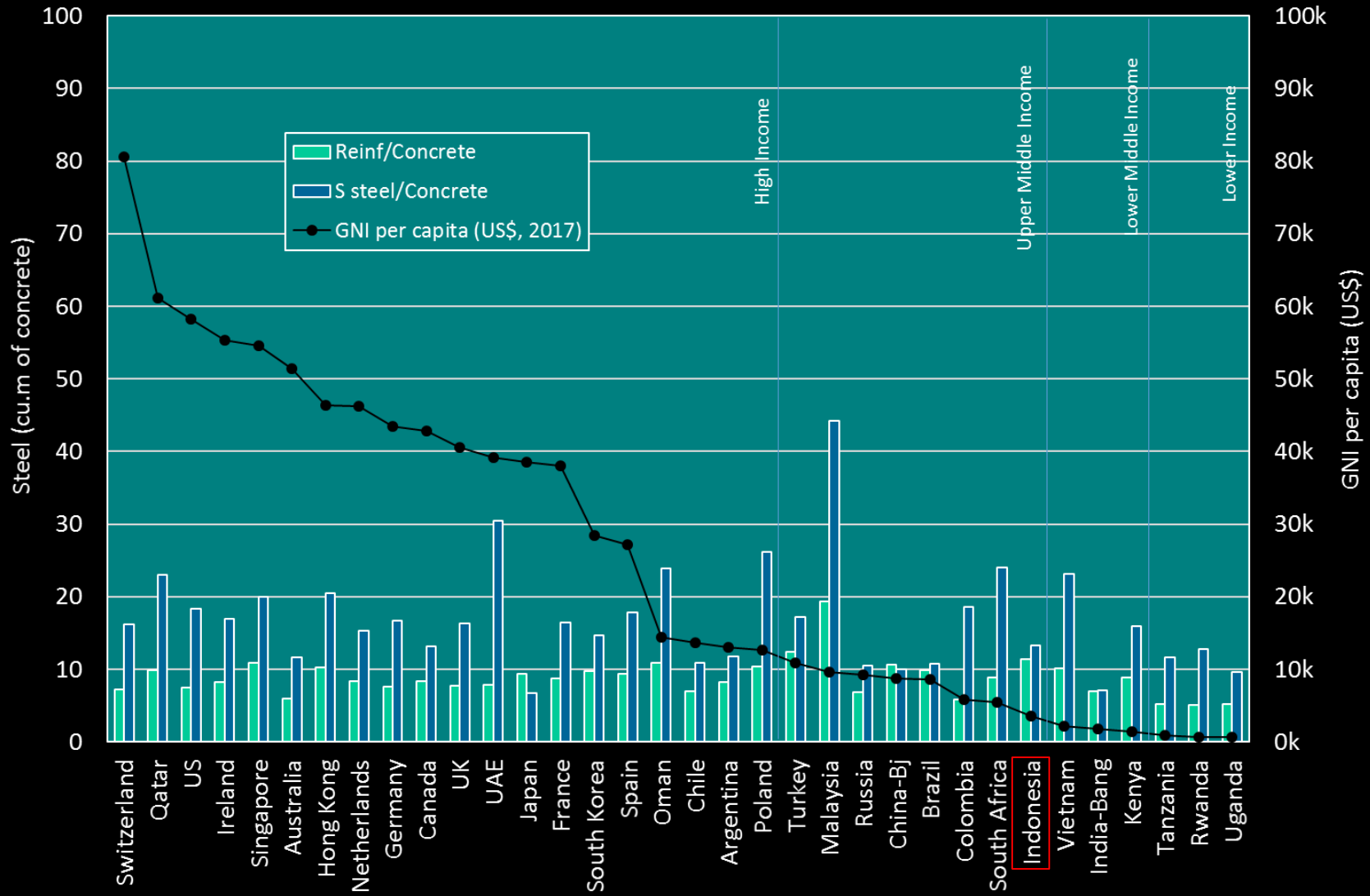
steel-to-concrete cost ratios



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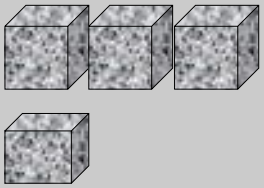
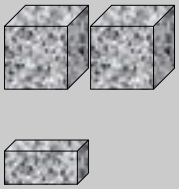
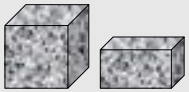
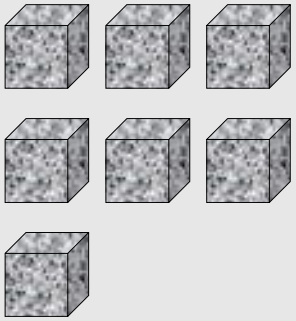
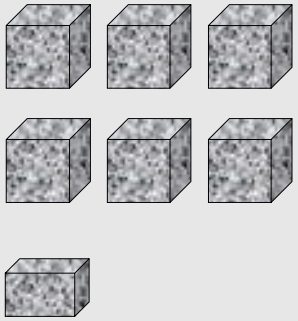
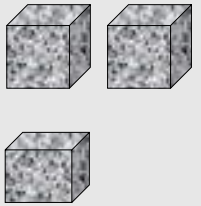
brick-to-concrete cost ratio

	Australia	Malaysia	Indonesia	India
bricks (1000 pcs) 	 3.9	 2.1	 0.7	 1.0
timber (100m) 	 1.4	 7.0	 6.7	 2.8

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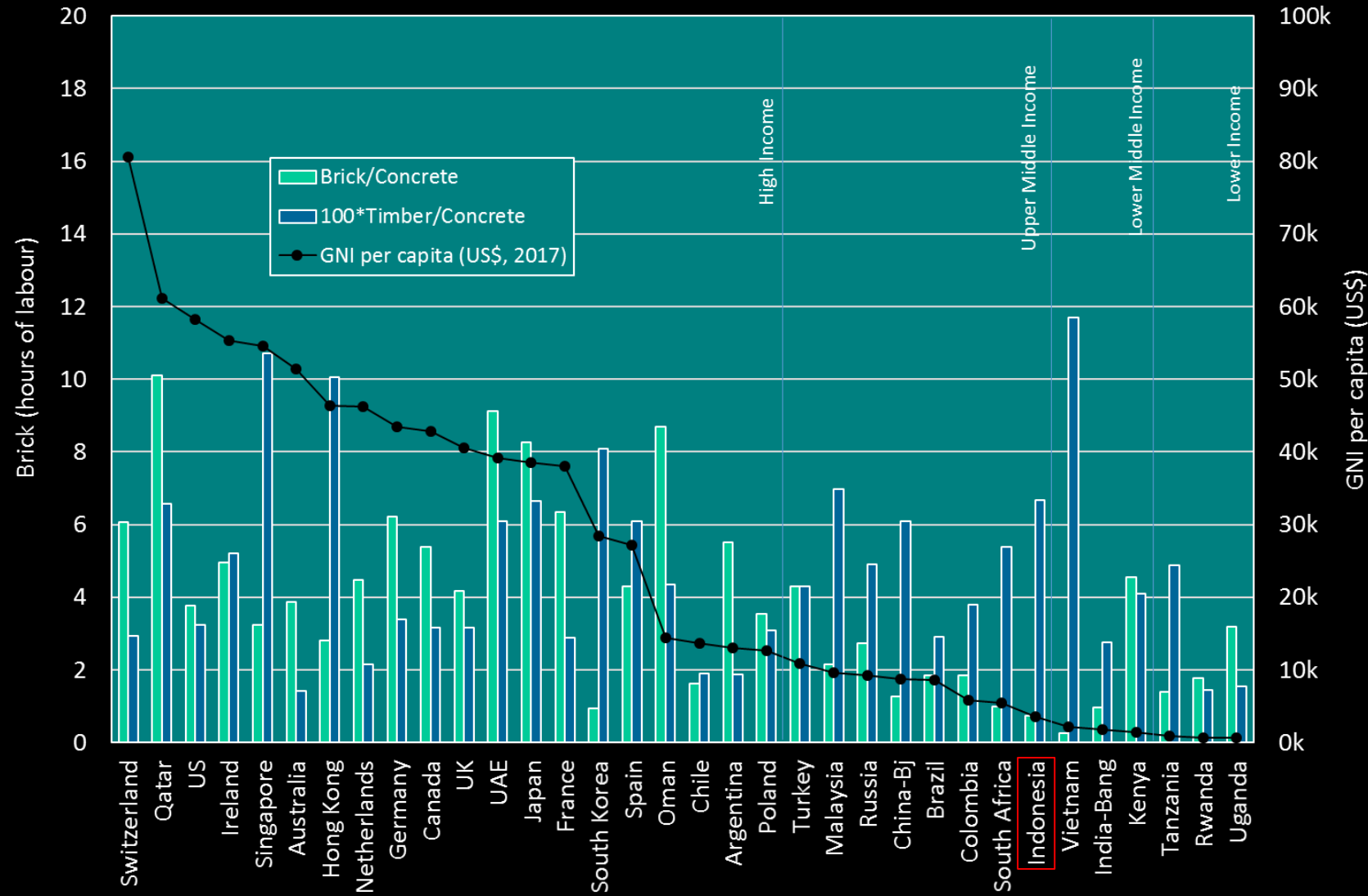
bricks and timber-to-concrete cost ratios



material cost ratio

- net exporters of steel exhibit lower steel costs

- where bricks are imported, cost can be extremely high – Qatar, UAE and Oman
- bricks are relatively cheap in middle- and lower-income countries – naturally available, low technology

- where natural supply of native timber is abundant, timber cost is low

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structural steel vs concrete buildings globally

Country	AUS	SIN	USA	CAN	GER	UK	UAE	SKR	RUS	TUR	CHN	IND
Structural steel/Concrete Ratio	12.2	20.0	17.1	13.3	16.7	14.8	28.8	11.6	9.3	11.0	7.3	8.5
Tall Buildings | Materials												
a. composite	14	8	50	5	8	18	9	39	3	1	186	2
b. concrete	222	98	342	242	37	28	326	204	442	75	186	96
c. concrete/steel	3	0	14	0	0	2	1	2	0	0	1	0
d. masonry	0	0	0	0	0	0	0	0	0	0	0	0
e. steel	0	1	43	1	2	7	1	4	2	1	10	0
f. steel/concrete	0	1	19	1	0	1	4	1	0	0	7	1
Total	239	108	468	249	47	56	341	250	447	77	390	99
Median height (m)	109	135	146	118	88	90	163	163	82	143	220	133
Percentage (a) &(e)	6%	8%	20%	2%	21%	45%	3%	17%	1%	3%	50%	2%
Percentage (b)	93%	91%	73%	97%	79%	50%	96%	82%	99%	97%	48%	97%
Percentage (c) & (f)	1%	1%	7%	0%	0%	5%	1%	1%	0%	0%	2%	1%

Number and percentage of structural materials for completed tall buildings in various countries from 2000 until 2016 (Source: CTBUH)

steel-to-concrete cost ratio

- when steel-to-concrete ratio is high (ie. steel is expensive), less steel and more concrete is utilised
- when steel-to-concrete ratio is low (ie. steel is cheap), more steel and less concrete is utilised (there are exceptions)

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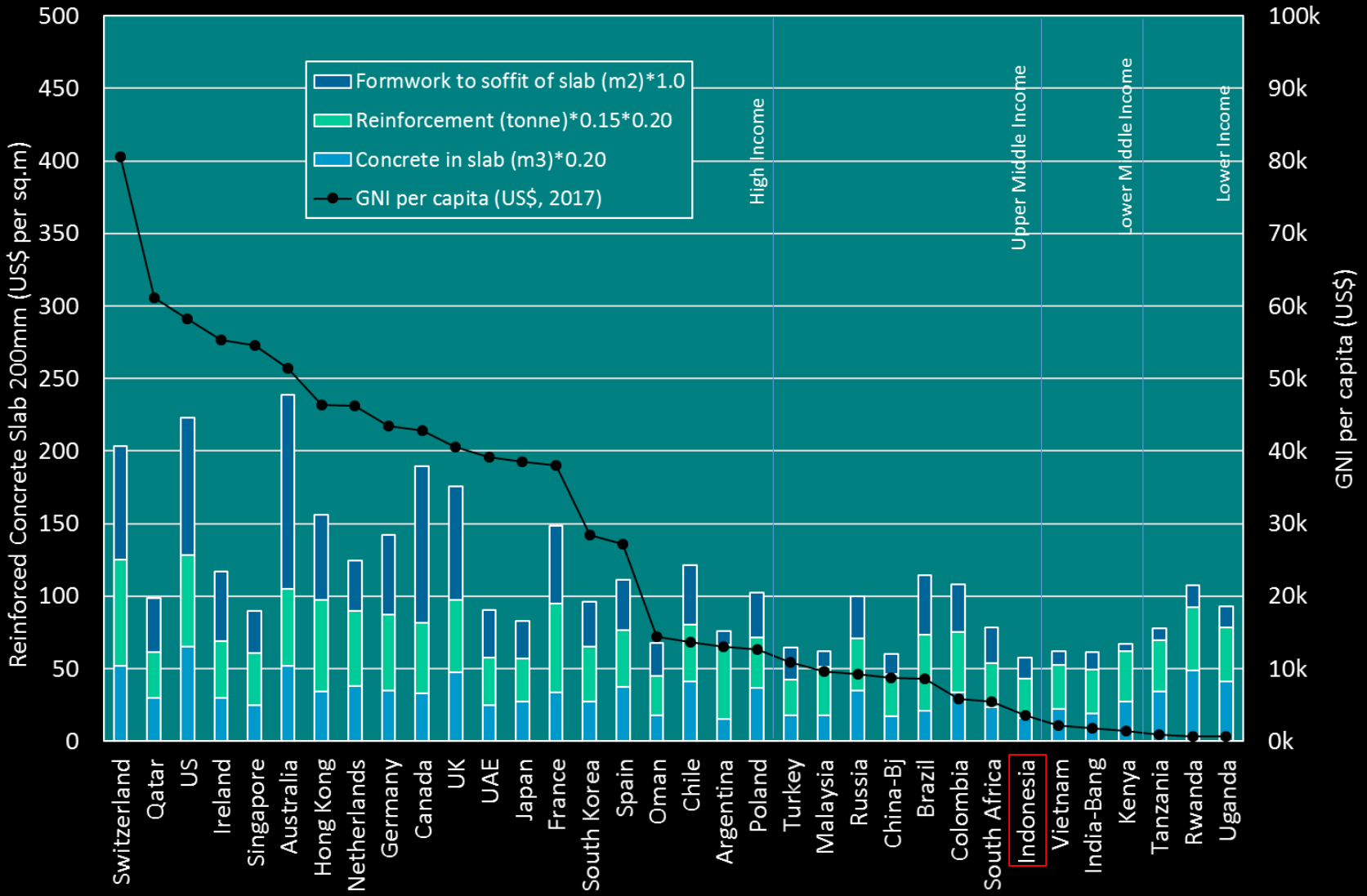
reinforced concrete slab (USD)



reinforced concrete slab (USD)

- formwork cost is significant in high income countries due to high labour cost
- formwork cost is small in lower income countries due to lower labour cost
- countries with migrant workers exhibit lower formwork cost

- high labour cost countries will utilise more technology to save on labour – should lower- or middle-income countries adopt more technology?

reinforced concrete slab (USD)

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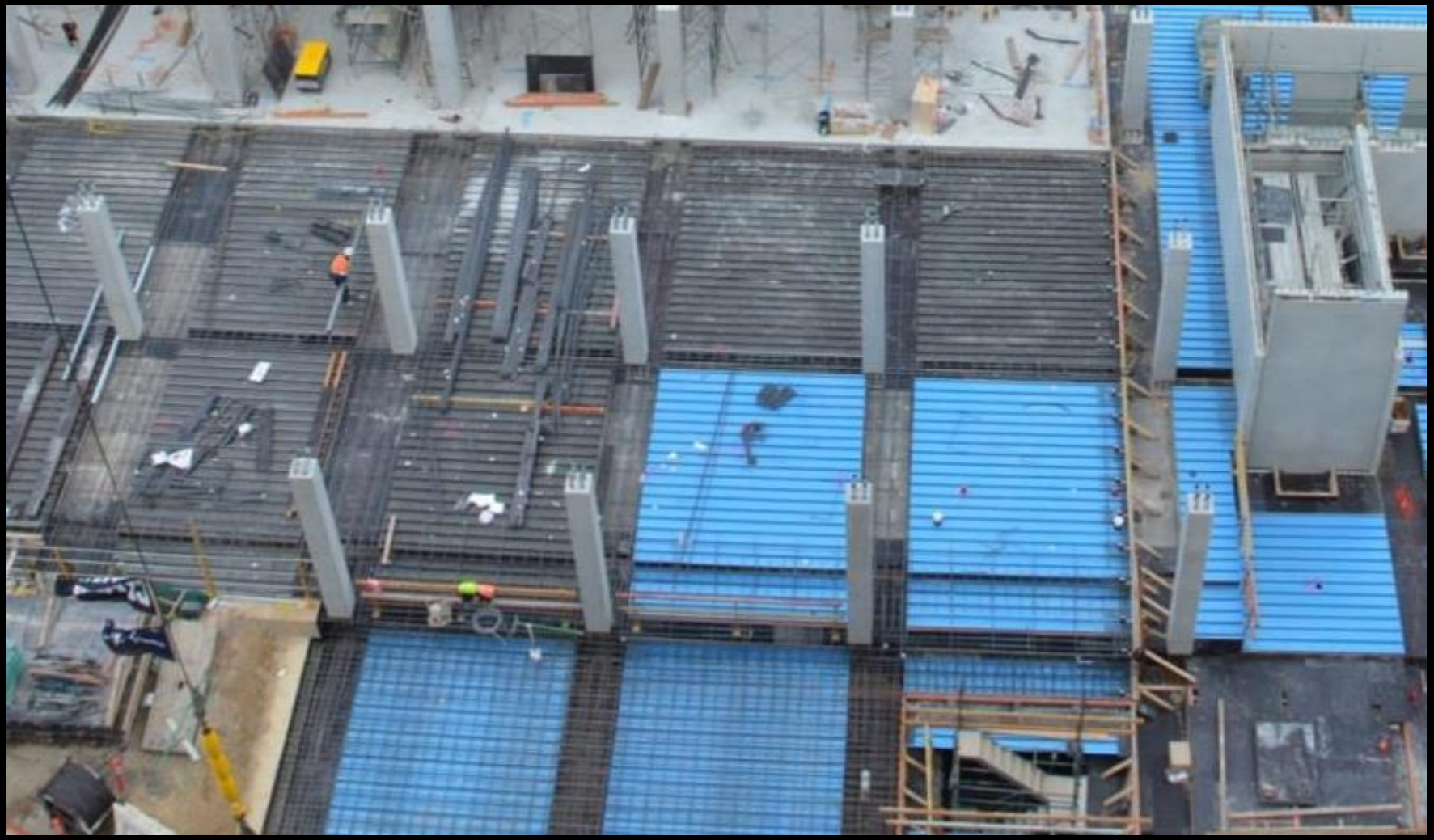
reinforced concrete slab (USD)



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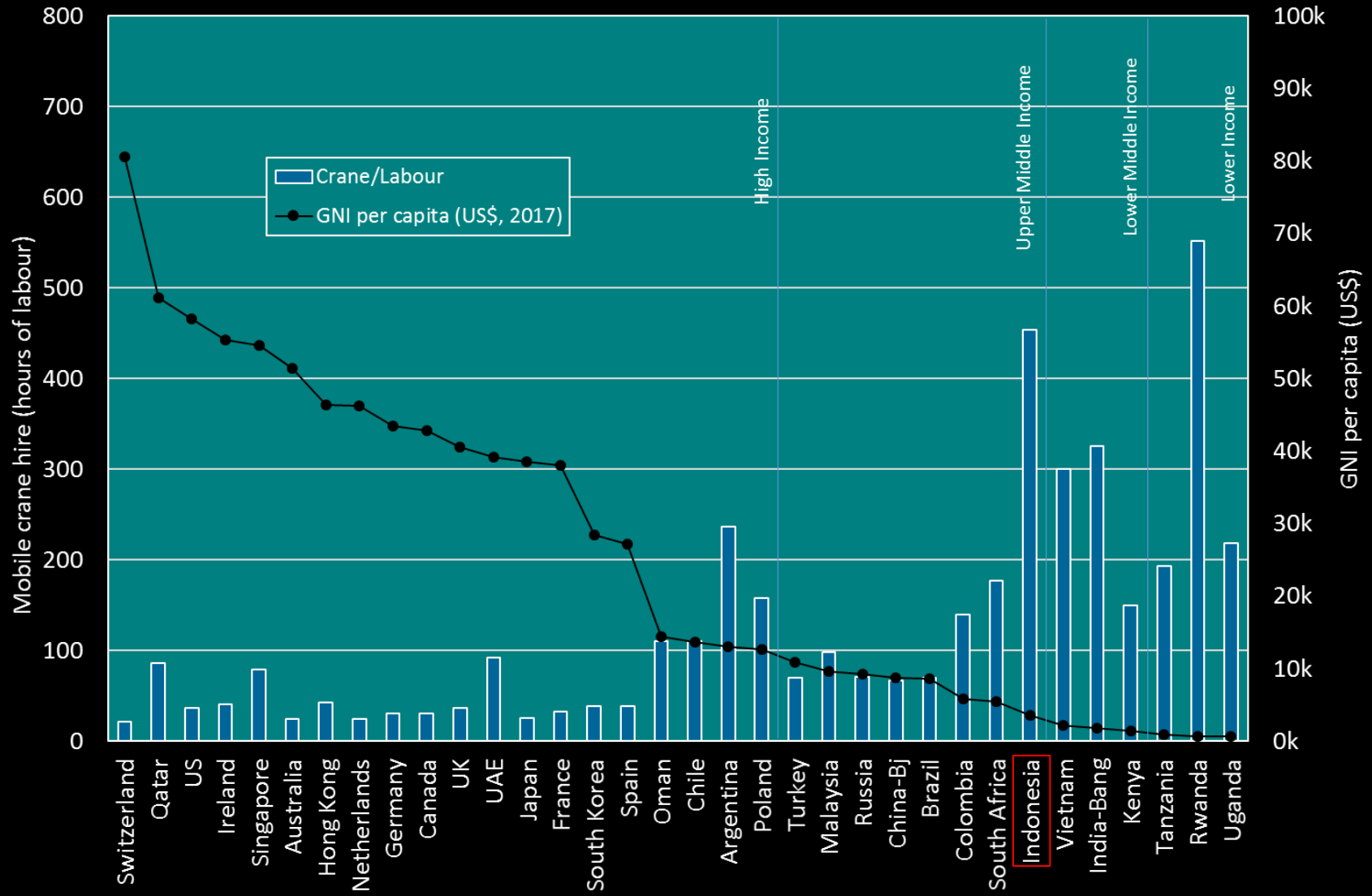
mobile crane-to-labour cost ratio



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mobile crane-to-labour cost ratio

- technology is expensive in lower-income countries – should they utilise more labour instead of investing in technology

- what are the implications for industry development?
- if near to full employment, then invest in technology (comparative advantage)
- if no full employment, then invest in up-skilling, raise worker income levels, create more value add

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longitudinal study: Melbourne, Australia

Reinforced concrete beam and slab

Reinforced concrete slab with metal formwork

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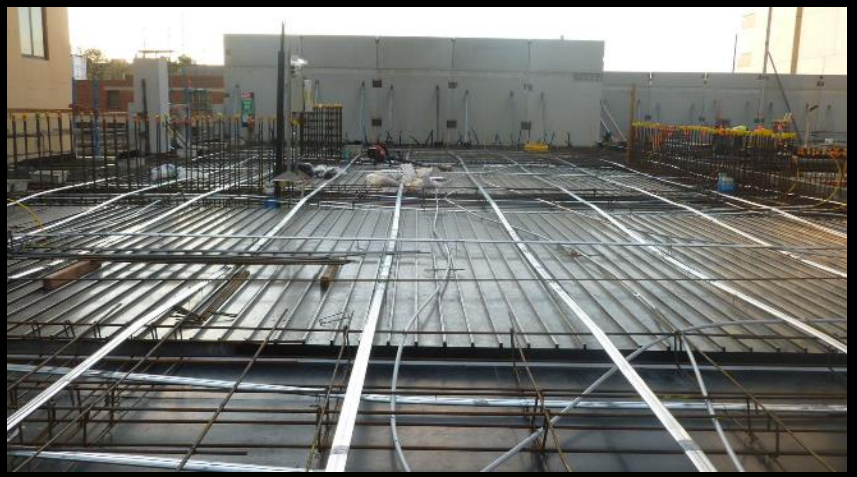
longitudinal study: Melbourne, Australia

Post-tensioned concrete slab with metal formwork



Precast concrete hollowcore planks, inverted-T beams, precast columns

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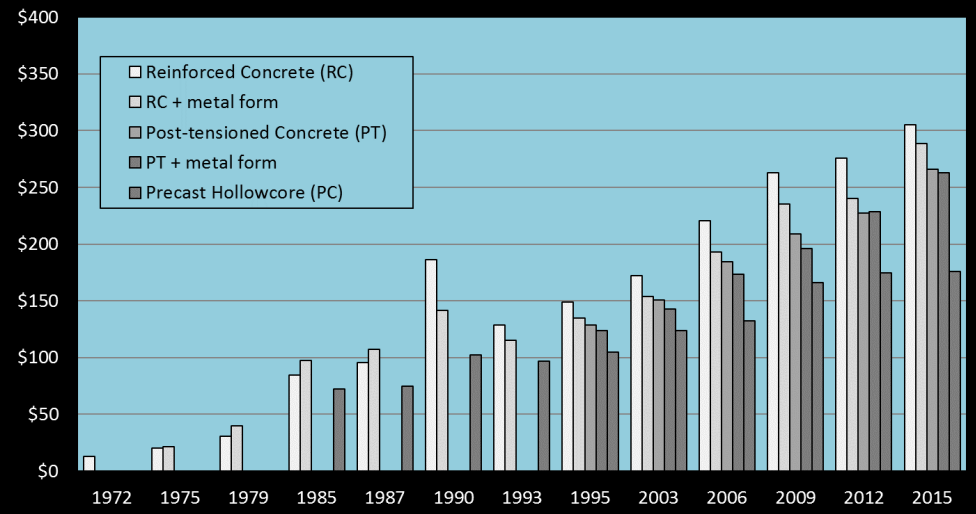
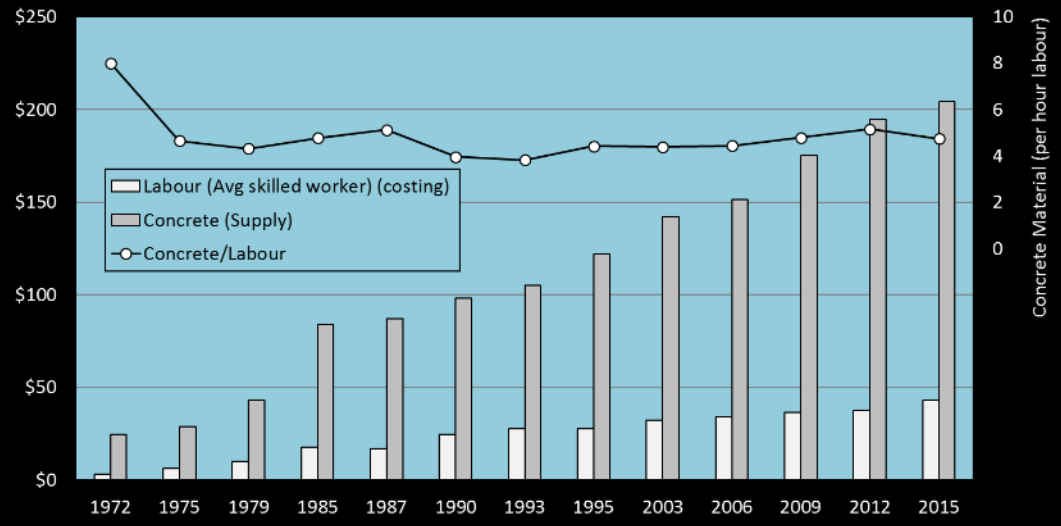
longitudinal study: Melbourne, Australia





Increase in wages and concrete supply rate compared to five flooring systems in Melbourne (note that x-axis is not to scale)

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longitudinal study: Melbourne, Australia

- labour rate increases 6.3% annually from 1972 to 2015
- concrete rate increases 5.0% annually

- concrete-to-labour cost ratio falls from 8.0 to 4.73

- labour intensive methods of construction become more expensive
- labour saving (capital intensive) methods of construction become more competitive

- transition from labour-intensive to labour-saving methods is clear – middle-income countries need to be aware of these transition points

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longitudinal study: Melbourne, Australia

Year	1970 1974	1975 1979	1980 1984	1985 1989	1990 1994	1995 1999	2000 2004	2005 2009	2010 2014	2015 2016
Structural steel/concrete Ratio (average for 5-year period)	6.8	8.8	-	11.5	13.5	12.0	8.6	13.9	13.3	10.2
Tall Buildings | Materials										
a. composite	3	13	7	5	10	5	1	5	5	3
b. concrete	5	14	27	24	39	34	54	68	71	29
c. concrete/steel	1	1	0	0	0	0	0	0	3	0
d. masonry	0	0	0	0	0	0	0	0	0	0
e. steel	11	15	1	2	2	0	0	0	0	0
f. steel/concrete	0	0	0	0	0	1	0	0	0	0
Total	20	43	35	31	51	40	55	73	79	32
Percentage steel & composite	70%	65%	23%	23%	24%	13%	2%	7%	6%	9%
Percentage concrete	25%	33%	77%	77%	76%	85%	98%	93%	90%	91%
Percentage combined conc./steel	5%	2%	0%	0%	0%	3%	0%	0%	4%	0%

Number and percentage of structural materials for completed tall buildings in Australia from 1970 until 2016 (Source: CTBUH)

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longitudinal study: Melbourne, Australia

- steel-vs-concrete cost ratio in Australia was low in 1970-74 but increased to more than 13 after 2005
- when steel-to-concrete ratio is low, more tall buildings were made out of steel
- when steel-to-concrete ratio is high, more tall buildings were made out of concrete

- choice of building technology based on material cost ratios
- use locally abundant materials (cement, bricks and timber) – value add remains in country
- use imported materials and technology judiciously – value add is lost overseas

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cross-laminated timber

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theoretical framework

- use Cobb-Douglas production function where

$$Y = AL^{\beta}K^{\alpha}$$

total production = *f*(labour, capital, materials, …)

- It follows that

cost (per sq. metre) = *f1*(labour cost, capital cost, material cost, …)

value add (per sq. metre) = *f2*(labour cost, capital cost, material cost, …)

industry development agenda

labour
- invest in training and up-skilling
- improve overall output per worker and labour productivity

materials
- use locally available materials – increase value add to economy
- grow local supply chains but maintain resource efficiency
- encourage sustainable practices

technology
- invest in pertinent technologies that enhances quality and productivity
- adopt digital tools judiciously: BIM, CAD, automation

theoretical framework

industry development agenda

firms

- invest training of professionals and managers
- shift to high knowledge content, modern methods of construction
- build capacity in all areas of operations
- invest in occupational health and safety
- invest in quality assurance programmes

national

- one of the largest economic sectors
- develop national strategy for industry development
- domestic benchmarking for best practices

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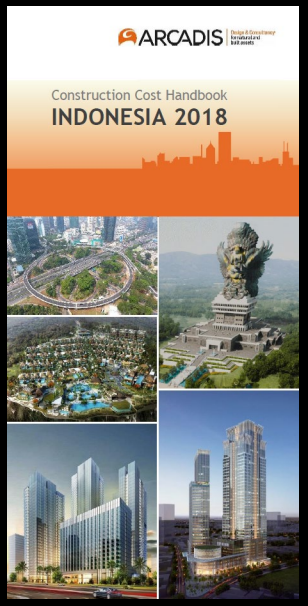
sources of cost data



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