

Integrating Lean Construction and Sustainability via a System Dynamics framework (Paper ID-187)

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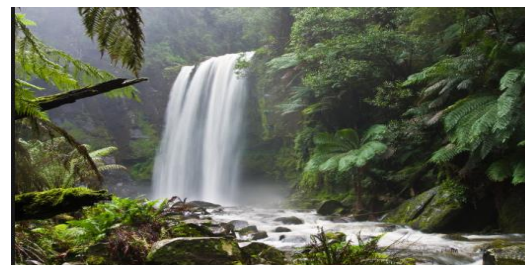
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Sustainable development and the construction industry

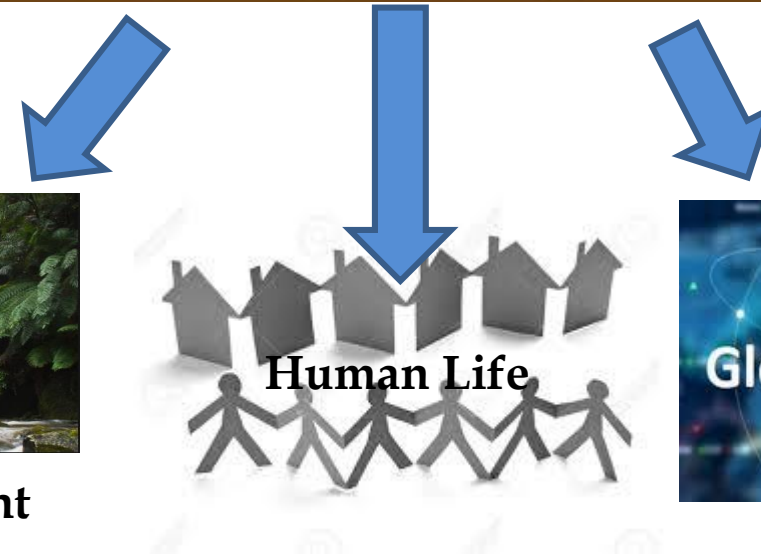
Sustainable development refers to development that promotes economic growth to fulfil the needs of the present generation, and sustain resources for the future (Source-WCED 1987)



Source-Krishna et al. 2017



Natural Environment



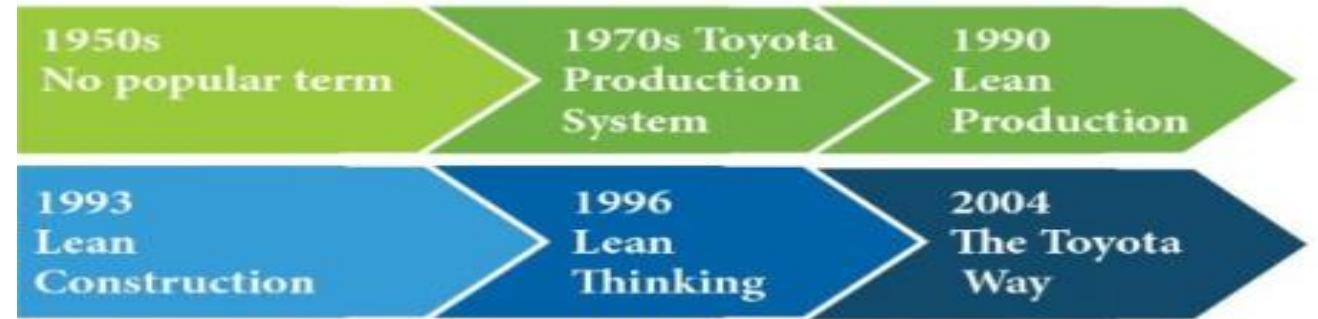
Challenges for the construction Industry

- Low productivity levels
- Revenue risks
- Lack of skilled workforce
- Project delays
- Slow technology adoption



Source:-Nam and Tatum 1988, Hussin et al. 2013

Lean Construction- A solution to many issues



Source:-<https://www.irishbuildingmagazine.ie/2016/04/27/understanding-lean-and-lean-construction-in-ireland/>

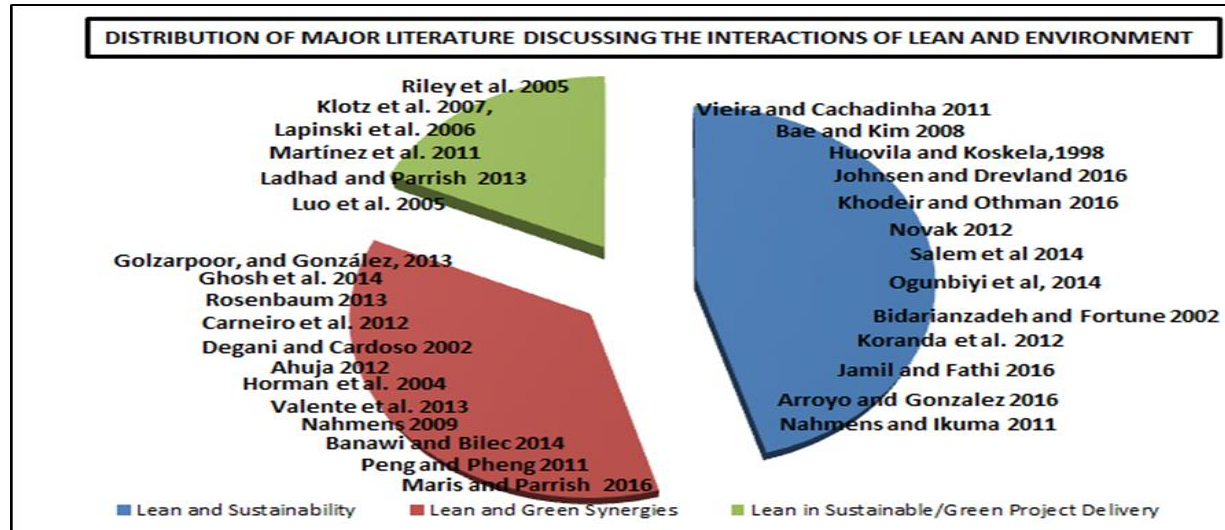
- Lean construction promoted a behavioral change in the industry, with potential benefits in the form of improved productivity, reduced wastage, reduced cost and inventory, improved work flows and higher profits (*Koskela et al. 2002*)
- Lean thinking hence, contrasts the conventional approach in construction by directing attention to flow and value



Several studies have also opined that lean construction has a very close relationship with sustainability

Source:-Huovila and Koskela 1998, Nahmens and Ikuma 2011, Carvalho et al. 2017

Lean and Sustainability literature



Classification of Lean Literature

Lean + Sustainability
 Lean + Green
 Lean + Green Project Delivery

LITERATURE ON LEAN AND SUSTAINABILITY

Relationship matrices

Khodeir and Othman 2016, Carneiro et al. 2012

Empirical Investigation

Lapinski et al. 2006, Ogunbiyi 2014, Carvalho et al. 2017

Case studies:-Influence of lean tools on sustainability parameters

Koranda et al. 2012, Rosenbaum et al. 2013, Ghosh et al. 2014

Conceptual models

Banawi and Bilec 2014

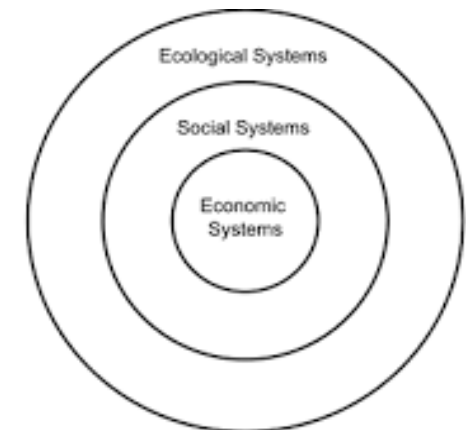
Lean and Green conventions for evaluating delivery of green projects

Klotz et al. 2007, Martinez et al. 2011

Need for a comprehensive integration framework

- **Fragmented approach** in the understanding of lean construction and sustainability inhibits the evaluation of the influence of their integration on overall sustainable development.
- Most of the proposed integrated frameworks **lack a triple bottom line approach**.
- It leads to **biased inferences** about whether lean construction and sustainability are complimentary or contrary in nature
- Demands the need of an approach that **holistically views the interlinkages between different elements of lean construction and sustainability** and further helps in visualizing the feedback *relationship* involved between the two concepts

Systems thinking is a promising approach.



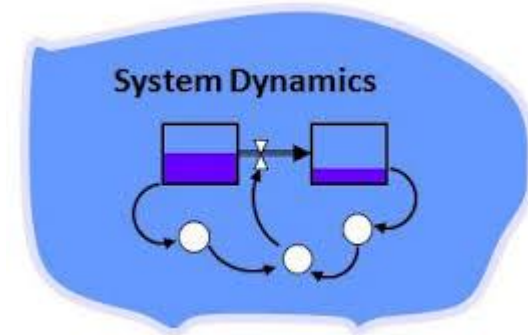
Systems Thinking

- **What is systems thinking AND why is it a suitable approach to integrate lean and sustainability using systems thinking?**
- Systems thinking is a holistic approach to analysis that evaluates how the components of a system interrelate and how they behave over time.
- Systems thinking helps in understanding and interpreting the interdependencies and complex interactions between various entities in a system (Anderson and Johnson 1997).
- Interaction between the lean components and their influence on different sustainability parameters and their interdependencies over time can be better understood through systems thinking approach.

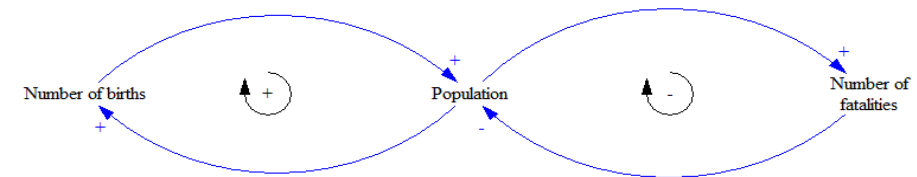


System Dynamics

- ❑ System dynamics (SD) modeling that evolved from systems thinking was developed by Forrester (1958) as a method to visualize and analyze complex dynamic systems using computer based simulations.
- ❑ It enables in formulating policies according to the analysis of the dynamics involved, and helps in deciphering a system's core structure and comprehending its behavior over time.



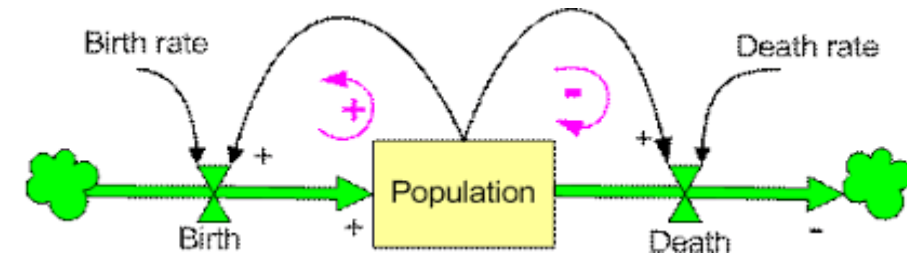
- ❑ **Causal loop diagram** is an important aspect of SD-visual representation of the feedback loops in a system.



Causal loop Diagram

Stock Flow Diagrams

- ❑ A stock (e.g., biomass, GHG, population) is the term for any entity in the system that accumulates or depletes over time
- ❑ A flow changes the rate of accumulation of the stock .



Stock Flow Diagram

System Dynamics



- *Why system dynamics is applicable to the construction sector?*

The complexity and highly dynamic nature associated with the sector causes numerous feedback interactions.

Application of system dynamics in this domain

Decision making in the design phase of buildings and in assessing the building lifecycle energy performances

Thomas et al. 2016

Manage and forecast construction and demolition waste

Hao et al. 2008

For evaluating lean performance in the manufacturing sector.

*Krishnamurthy and Chan 2013,
Omogbai and Salonitis 2016*

Modelling the causes of rework and propose policy interventions

Aiyetan and Das 2015

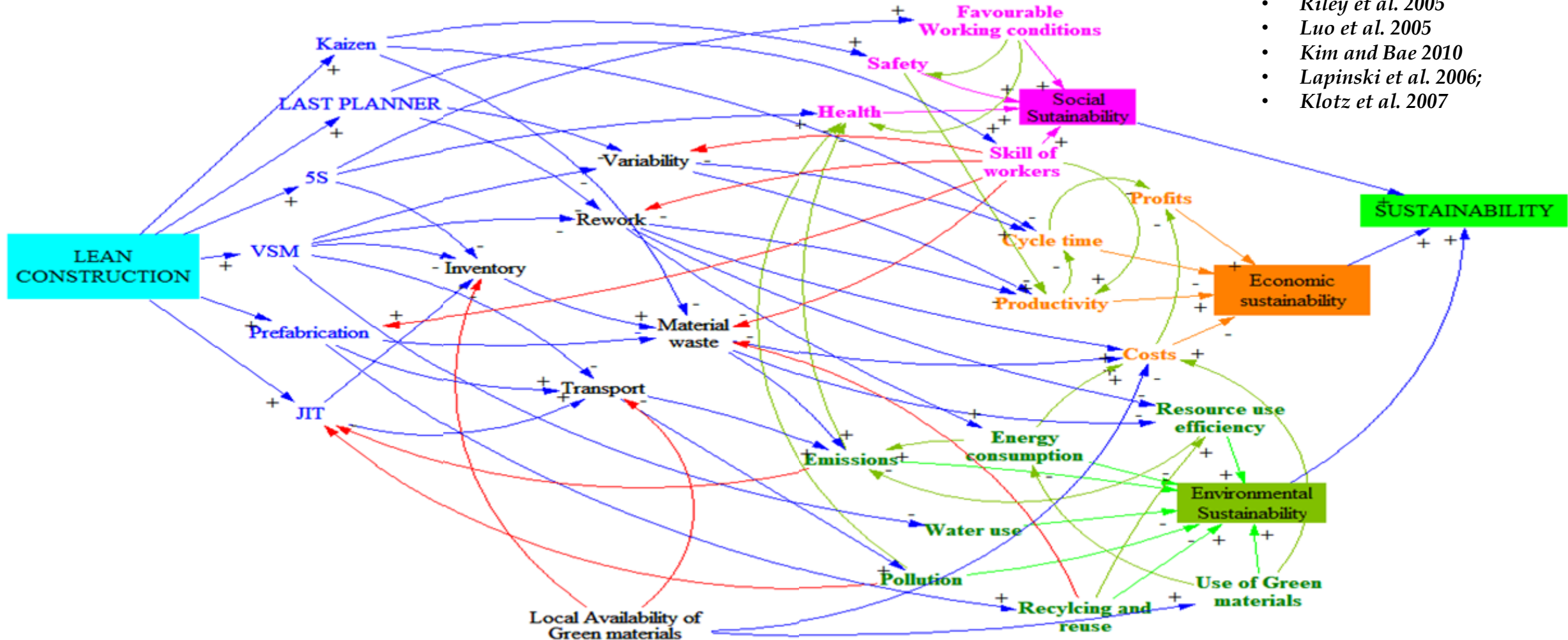
Policy interventions to reduce the environmental impact, and for assessing the sustainability of projects

Shen et al. 2005, Zhang et al. 2014

SD provides a suitable platform to observe the complete network of influences between various parameters of lean construction and sustainability and evaluate it as an integrated system.

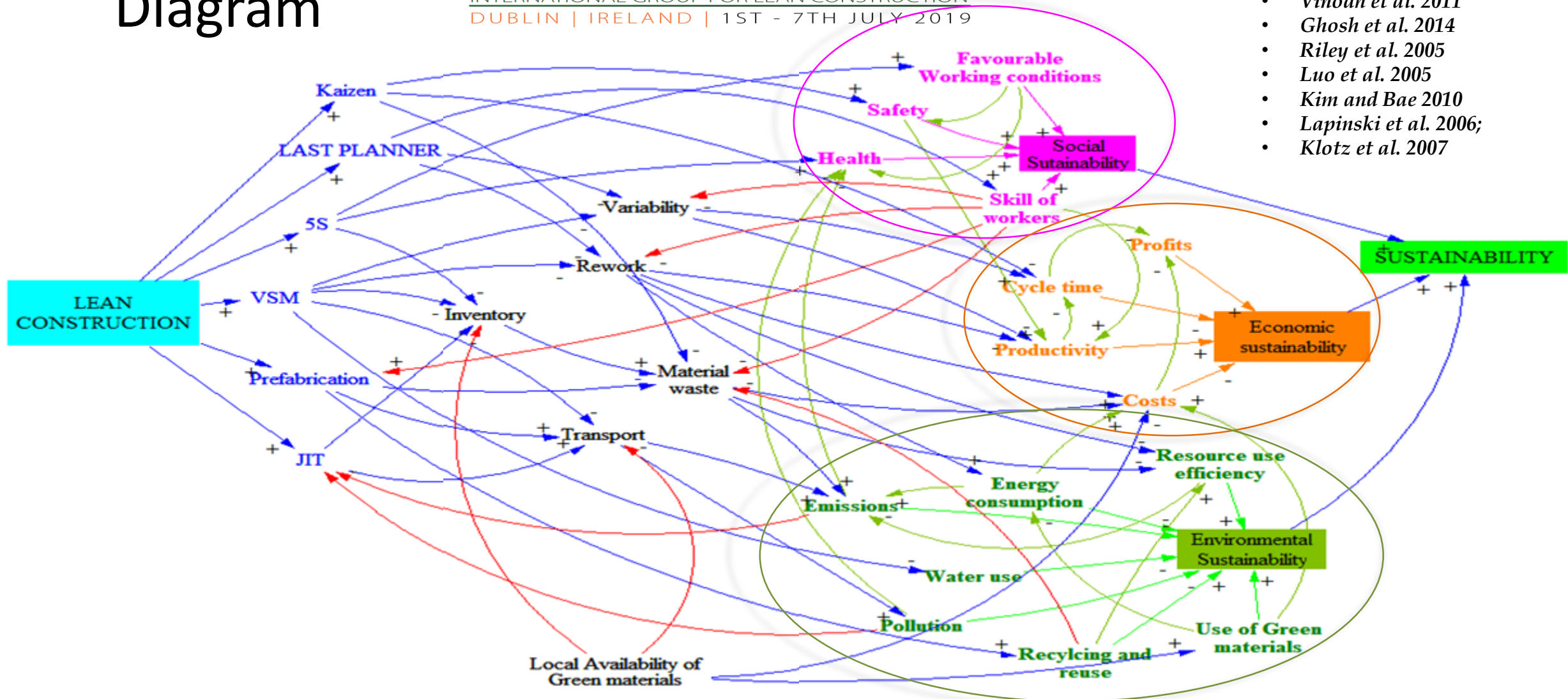
Causal Loop Diagram

- Bae and Kim 2008
- Peng and Pheng 2011
- Vieira and Cachadinha 2011
- Vinodh et al. 2011
- Ghosh et al. 2014
- Riley et al. 2005
- Luo et al. 2005
- Kim and Bae 2010
- Lapinski et al. 2006;
- Klotz et al. 2007

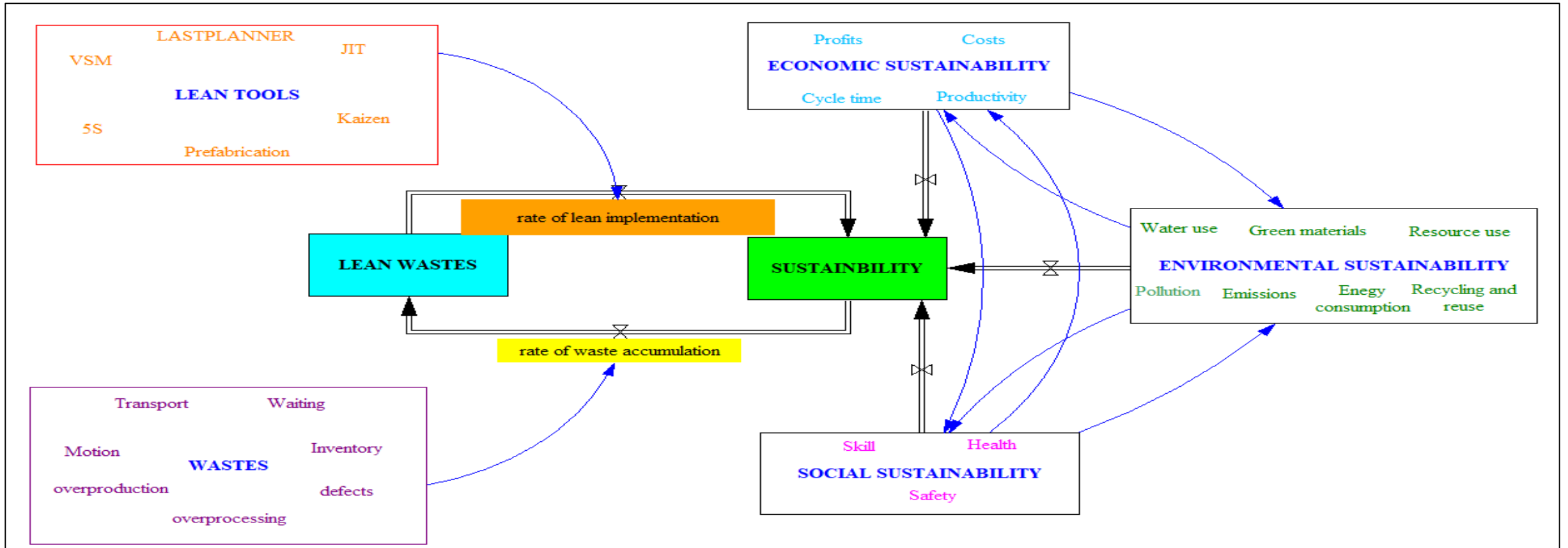


Causal Loop Diagram

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Conceptual framework based on SD to integrate lean construction and sustainability



Discussion

- Developing a SD framework - helps to **quantitatively measure the impact** of implementing lean practices to achieve sustainability in construction sites.
- Helps in visualizing the mutual influences of integrating lean and sustainability through a **triple-bottom-line approach**
- Actual implementation strategy - **modelling each of the lean tools** individually and capturing its influence on the different sustainability parameters.

Conclusion



- Systems approach could serve as a **supporting tool for industry practitioners** to develop a better understanding of the scale of lean implementation required to achieve sustainability in construction sites.
- The framework aims to aid in **comprehending the behavior of the complex interrelationships** between lean construction and sustainability in a **more systemic and unified manner** through a triple bottom line approach.
- This research is part of an **on-going study** that is currently adopting SD as a tool to evaluate and quantify the impact of lean practices on sustainability and vice versa.
- Limitation:-**Conceptual** outline based on SD to analyze lean and sustainability as an integrated system is proposed.

Future scope

- Developing **computational models** to obtain quantitative measures for lean and sustainability integration.
- Focus on exploring the **long-term impacts and dynamic influences** of lean practices on sustainability in the construction sector

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THANK YOU

Example for implementing SD

- For example:- **Just-in-Time Delivery**
- Adopting such a modeling approach -helps in optimizing the JIT delivery schedules - to balance the goals of lean and sustainability.
- Trade-off between emissions due to JIT and waste due to inventory to be balanced

Number of
trips

Fuel
Consumption

Inventory
stock

Material waste generated due to excessive
inventory

Optimizing JIT using SD

