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ESTABLISHING A LINK BETWEEN THE LAST PLANNER SYSTEM® AND SIMULATION: A CONCEPTUAL FRAMEWORK

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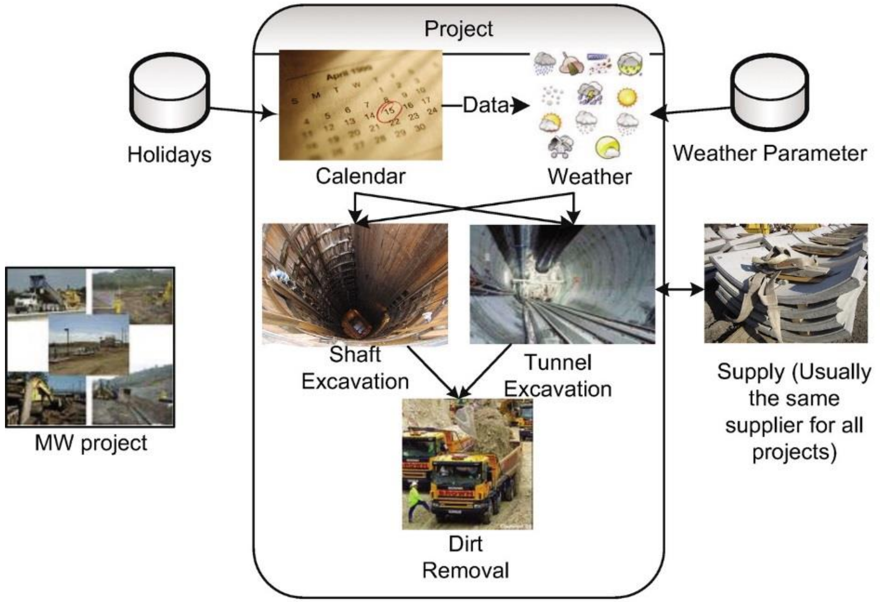
Construction projects

- Complex & Dynamic
- Interrelated activities
- Different stakeholders with variant backgrounds and objectives
- High level of risk and uncertainty
- Many constraints: tight schedule – limited budget –regulations
- Different types of resources

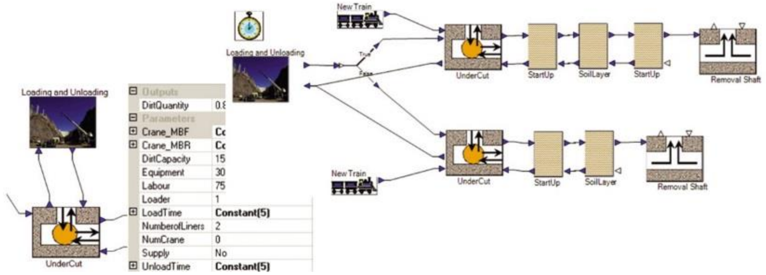
Source: City Rail Link official Facebook page (07/09/2017)

Computer simulation is able to:

- Model complex activities
- Include different resources
- Account for risks
- Represent the surrounding environment such as weather, traffic, and ground condition




```
Select Case myevent
 Case "OrderMaterial"

  newentity = ob.cloneEntity(entity)
  ob.ScheduleEvent(newentity,
"Material",ob("Duration").Value)
  ob("NumRequest").Value = ob("NumRequest").Value
+ 1
  ob("Record").SetRC(ob("NumRequest").Value,5)
  NewEntity("NumRequest") =
ob("NumRequest").Value


ob("Record").SetValueRC(NewEntity("NumRequest")-
1 ,1  ,NewEntity("Quantity"))

 Case "Material"

  for each Load in SimEnvironment.Elements.Values
   if load.ElementType = Entity("ElementType")
then
     if Load("Name").Value =
Entity("ProjectName") and Load.ID =Entity("ID")
then
       Load(Entity("MaterialName")).Value =
       Load(Entity("MaterialName")).Value +
Entity("Quantity")
       Load(Entity("Request")).Value = "No"

Load.ScheduleEvent(Entity,Entity("Event"),Entity(
"EventDuration"))
     end if
   end if
 next

end select
```



AbouRizk, S. (2010)

History of Construction Simulation Research

1960s

First use of simulation in construction management

1973

CYCLONE (Halpin 1973)

1996

Stroboscope (Martinez 1996)

1999

Simphony (Hajjar and AbouRizk 1999)

2019

- COSYE (AbouRizk and Hague 2009)
- Integration with BIM (Lu and Olofsson 2014)
- Hybrid modelling (Peña-Mora et al. 2008)
- Data-driven simulation models (Akhavian and Behzadan 2018)
- VR/AR-based simulation models (Kamat Vineet et al. 2011).

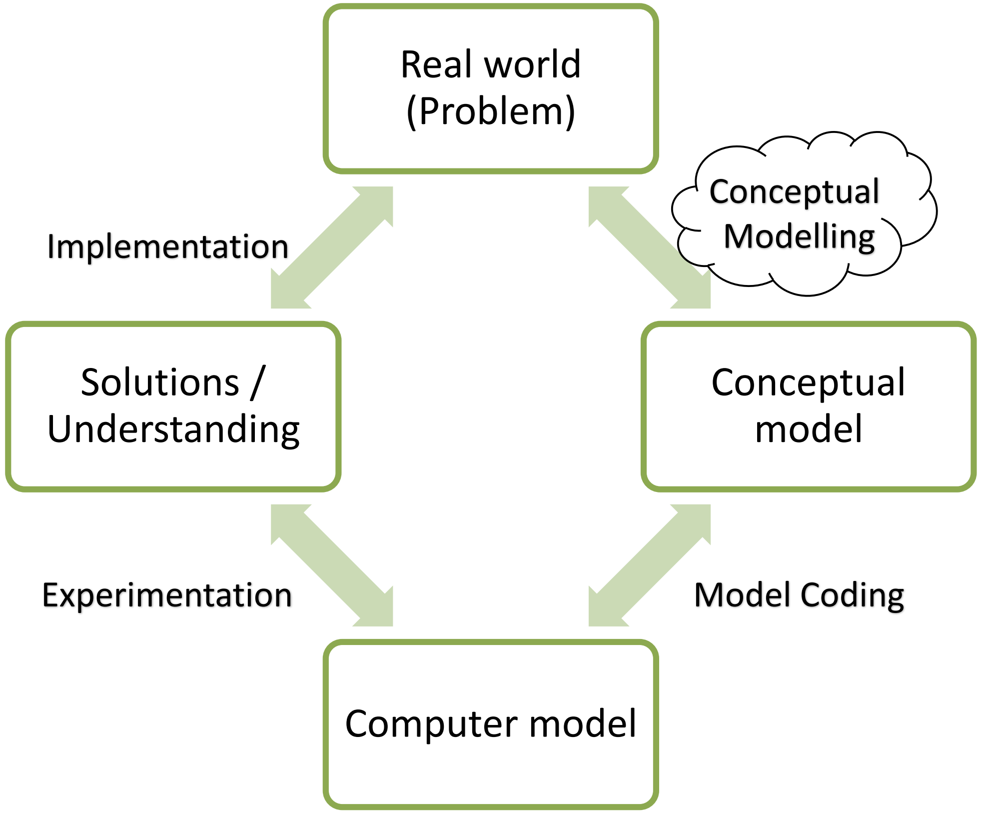
The Application Gap

- Construction industry has shown a consistent **reluctance and skepticism** to adopt simulation as a decision-support tool. Industry practitioners have preferred to solve the problems **intuitively and in an ad-hoc** manner (Koskela 2000; González et al. 2013).
- This gap poses a **'dilemma'** that requires particular attention in construction research (AbouRizk 2010).
- Among reasons identified for the gap is the need to **acquire knowledge of different domains** such as manufacturing engineering and computer science to conduct simulation studies, which is typically **not available** for most construction practitioners (Leite et al. 2016).
- Consequently, in order to leverage better industrial adoption, **it is essential to align the process of simulation modelling with recent practices of construction management**.

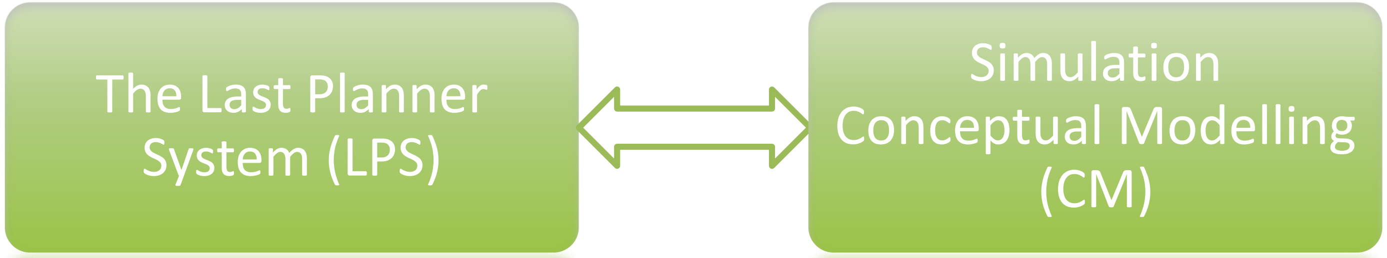
- **Conceptual modelling** incorporates the **planning phase of simulation** studies as it provides a software-independent description of the simulation model (Robinson 2014).

- Van der Zee (2012) concluded that **aligning Conceptual modelling with engineering management** environment can help in **integrating simulation modelling into engineering practices**.

- The **LPS was selected for the integration** as it is a well-established construction planning methodology which has gained popularity within the industry due to its ability to **stabilise construction production and to increase plan reliability** (González et al. 2008).



Computer Simulation studies lifecycle (Robinson 2014)

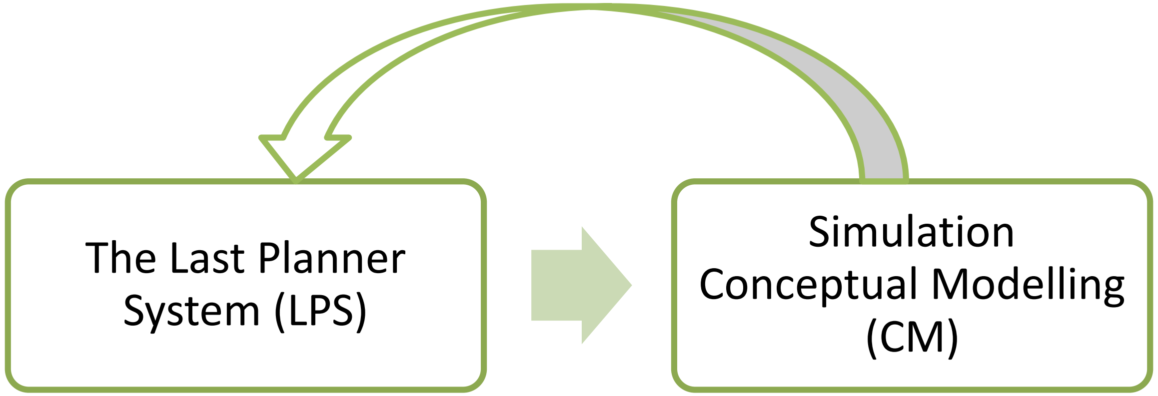


- The **granularity of information** in both methods follows a **hierarchical** way to breakdown the plan **from a high-level** abstract representation of the project **to a detailed operation design**.

- The LPS implementation structure is composed of **a number of steps at different planning levels,** which makes the integration to CM a feasible avenue of development for the LPS in the construction simulation domain.

- Both techniques **include collaborative activities** that encourage the **engagement of stakeholders** to promote **transparency and trust building** (Hamzeh et al. 2015; Van der Zee 2012).

- Another motivation for the integration is the proven benefits of CM in **stimulating creativity** (Kotiadis et al. 2014), which matches the **group creativity techniques** required to implement several activities in the LPS (Daniel 2017).



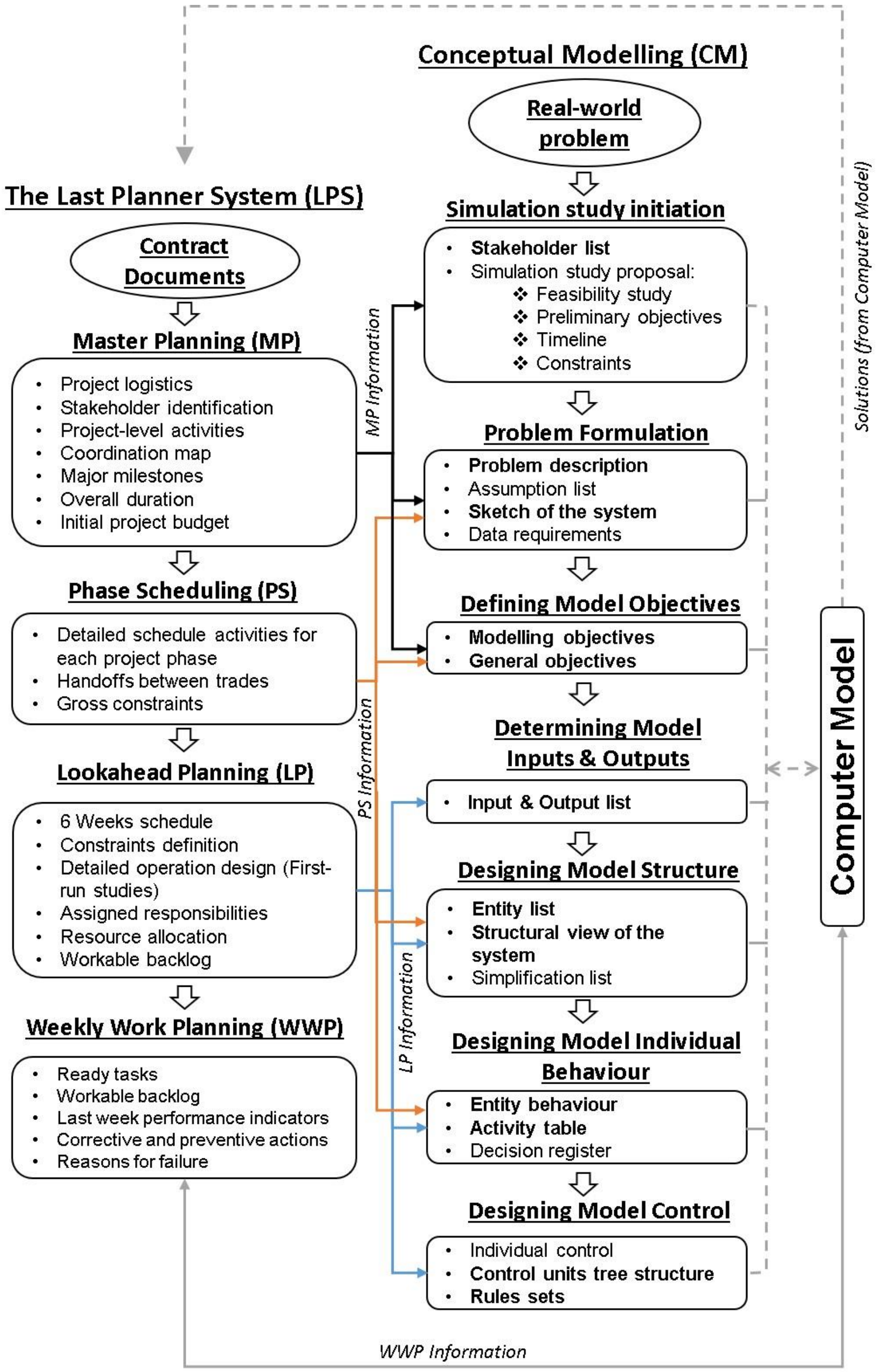
(Ballard et al. 2007; Hamzeh et al. 2015)

(Furian 2015; Abdelmegid et al. 2017)

- Visualising the LPS and CM side by side helped in **revealing the link** between them by identifying the **similarities in processes and information**.

- The **CM** framework **pulls** all the required **information from** different stages in the **LPS** to build the model. Then, **solutions are fed back to the LPS** through the implemented **computer model**.

- Due to the creative effort in CM, **solutions for the problems in hand can spark during the CM process** thus diminishing the need to proceed with the full computer modelling study (Robinson 2014).



CASE STUDY

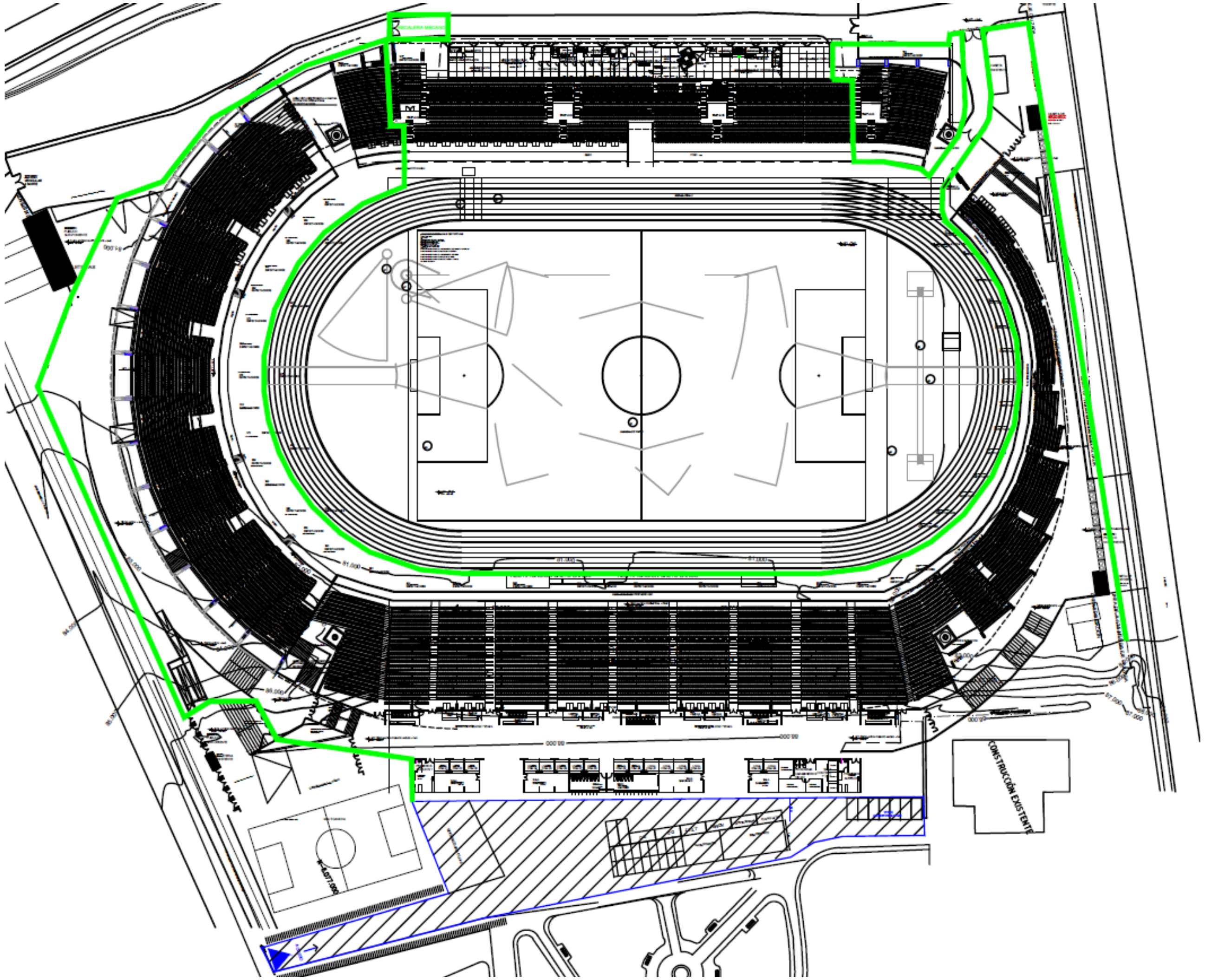
- The integrated LPS/CM framework has been applied in a case study of a construction project to **expand and renovate a multi-use public stadium in Chile**.
- The **LPS was fully implemented** to plan and control the project with **detailed documentation** of each level.
- The project included **several construction activities** such as demolition, earthwork, reinforced concrete construction, steel structure erection, and finishing.
- The scope of the case study was limited to the **reinforced concrete operations** for building foundations, columns, and walls.

CASE STUDY

- Delays in reinforced concrete operations were repeatedly reported due to the **lack of labour and materials, poor coordination between resources, and bad weather**.

- Reinforced concrete activities were **scattered between 11 site locations**.

- Therefore, the main problem identified for this case study was **the need for effective coordination and optimised allocation of resources to avoid delays and disruptions.**



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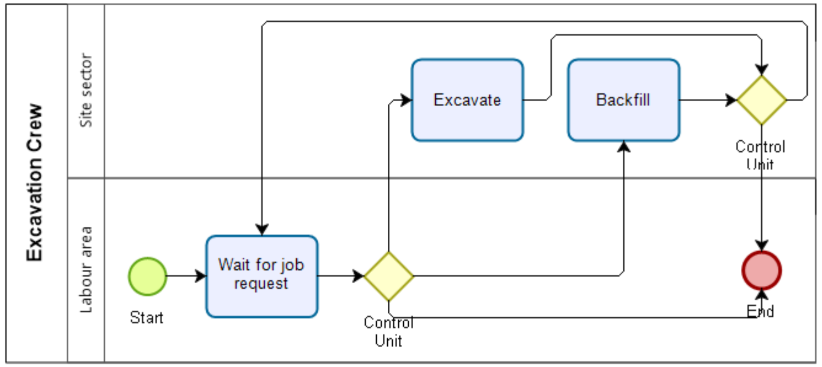
CASE STUDY

- Following the integrated LPS/CM framework, **a complete conceptual model** was built only based on the LPS documentation.



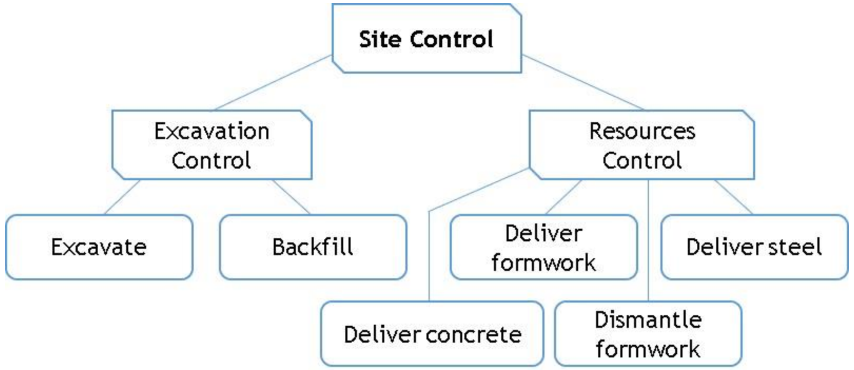
Individual behaviour of Excavation crew

Activity list

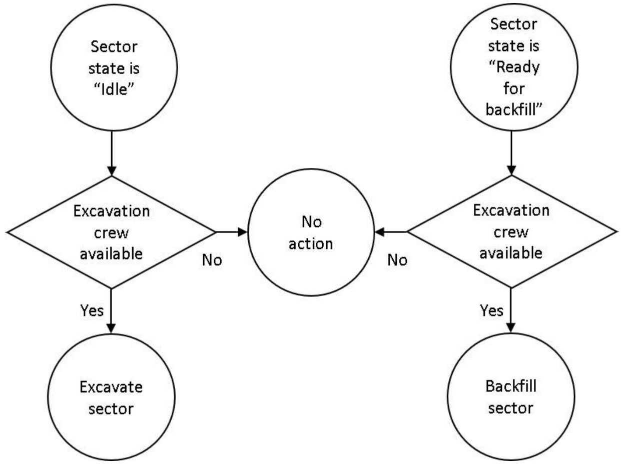
No.	Activity	Entities	Start Type	End Type	Control Unit
1	Excavate sector	Excavation crew Site sectors	Requested	Scheduled	Excavation control
2	Deliver formwork to sector	Storage area Site sectors	Requested	Scheduled	Resources control
3	Formwork erection	Formwork crew Site sectors	Sequential	Scheduled	*N.A.*
4	Deliver steel to sector	Storage area Site sectors	Requested	Scheduled	Resources control
5	Rebaring	Rebaring crew Site sectors	Sequential	Scheduled	*N.A.*
6	Deliver concrete to sector	Storage area Site sectors	Requested	Scheduled	Resources control
7	Concrete pour	Concrete, Formwork & Rebaring crew Site sectors	Sequential	Scheduled	*N.A.*
8	Dismantle formwork	Concrete crew Site sectors	Requested	Scheduled	Resources control
9	Send formwork back to storage	Storage area Site sectors	Sequential	Scheduled	*N.A.*
10	Backfill sector	Excavation crew Site sectors	Requested	Scheduled	Excavation control

Entity list

Entity	Type	Attributes
Crews (Excavation, Rebaring, Formwork, Concrete)	Active	Number, Productivity
Materials (Reinforcement Steel, Formwork, Concrete)	Active	Quantity for each sector, Arrival rate
Site sectors	Passive	Area, Location
Storage area	Passive	Location, Capacity
Labour area	Passive	Location, Capacity



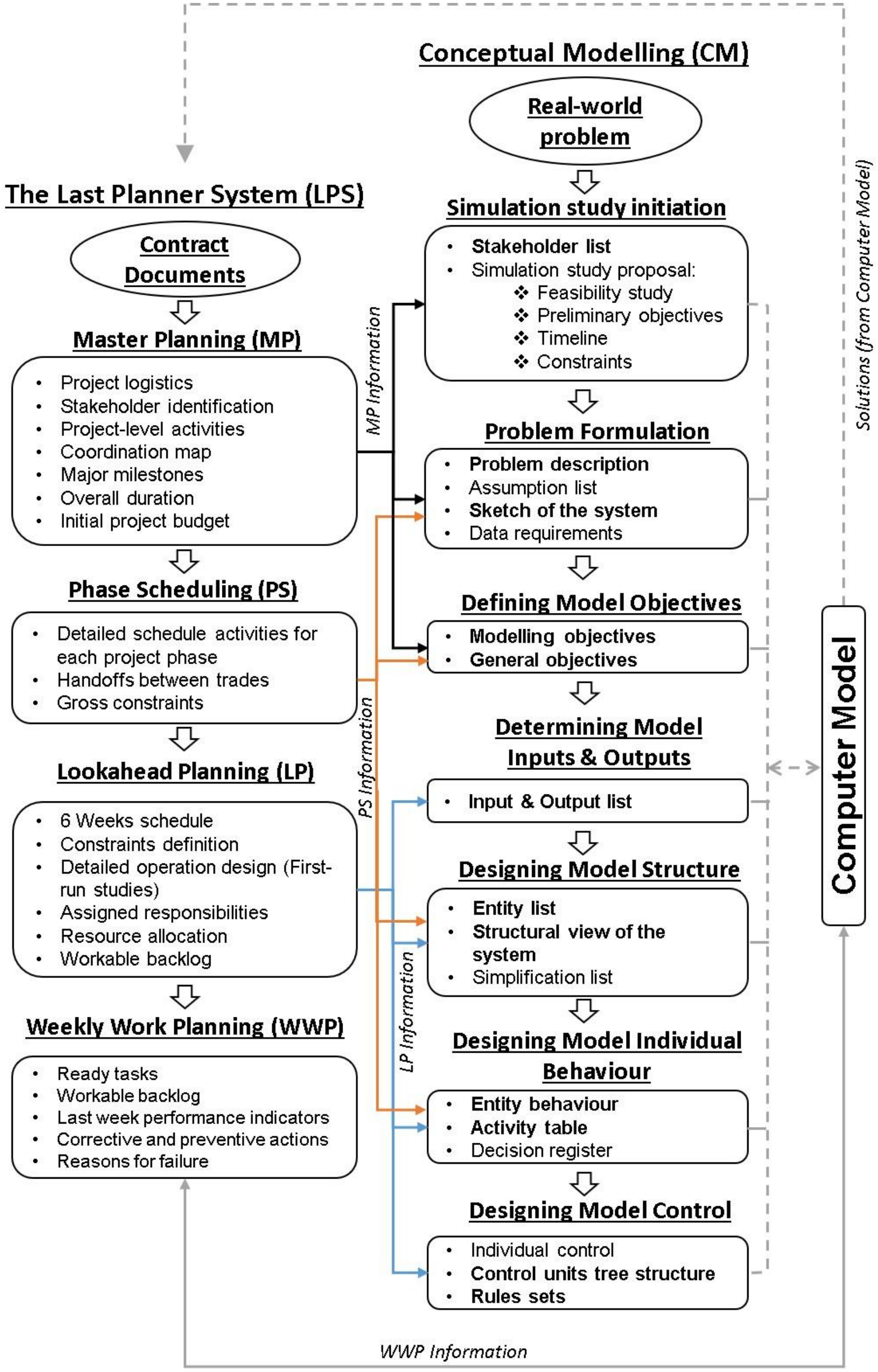
Hierarchy of Control units



Control policies
(Governing Rules of control units)

Main findings from the case study

- **Most of the information** needed to build a conceptual model **was available in** the documentation of **the LPS**.
- The **master plan** was most useful for the **first three steps of the CM** framework.
- The **phase schedule and lookahead plan** provided technical information for the **later advanced CM** steps.
- **Weekly work plans** can provide information to **update and validate the computer model** based on live data from the site.



Conclusion

- This paper examines the applicability of an integrated framework to **link the LPS and simulation modelling** by a real-life case study.
- The integrated framework **utilises the synergy between the LPS and a simulation CM framework**.
- This paper contributes to LPS research by providing an integrated framework that can **improve the LPS performance and adherence by assisting in building virtual decision-support tools through simulation modelling.**
- By **avoiding effort duplication**, the integrated framework contributes to construction simulation research by **providing a means to enable rapid building of simulation models**.
- Future work should investigate the ability to **extend the applicability** of the integrated framework to conduct a **complete simulation study side by side while the LPS is being implemented**.