SIMULATING A CONSTRUCTION SUPPLY CHAIN– PRELIMINARY CASE STUDY OF PRE-CAST ELEMENTS

Patricia Stella Pucharelli Fontanini [1], Flávio Augusto Picchi [2], Sérgio Adriano Loureiro[3], Orlando Fontes Lima Júnior[4] and Alex Tort Folch [5]

ABSTRACT

This paper presents a preliminary case study of simulation in a construction supply chain, adopting as focus company a pre-cast elements producer. The framework for relationships analysis was provided by a value stream macro mapping (VSMM), taking steel as the specific case. Data collection was carried out gathering information from the company's information system and from interviews with representatives of involved agents. This data was compiled in a first simulation of current state, using *iThink* software, generating output of selected parameters for analysis. A future state is drafted, suggesting modelling strategies for a second simulation using lean tools, in further studies. The paper concludes with recommendations and considerations about the potential of this kind of simulation to study complex construction supply chains behaviour.

KEY WORDS

lean simulation, supply chain, lean thinking

INTRODUCTION

In order to study a lean simulation of a supply chain in the construction industry, we considered the complex systems theory, which basically analyzes auto-organizational and emergency phenomena, properties of the dynamic systems theory. An emergency phenomenon is a mostly non-intentional process that results from interactions between relevant agents within a system. Agents' individual actions (at least in social systems) may be considered as rational, since they are directed by self-preservation interest (EHRLICH, 2005). Despite this, such theory showed applicability to understand the behavior of agents in a supply chain, since decisions taken by the agents tend to propagate throughout the whole supply chain. Many systems show detail or combinational complexity an intricate web of relationships between the components, which makes it hard

1 PHD Candidate of the Architecture and Civil Engineering Department, DAC-FEC-UNICAMP/ GTE, stella@fec.unicamp.br

2 Professor of the Architecture and Civil Engineering Department, DAC-FEC-UNICAMP/ GTE; fpicchi@fec.unicamp.br

3 Master Student of the Architecture and Civil Engineering Department, DGT-FEC-UNICAMP/ LALT, saloureiro@gmail.com

4 Professor of the Architecture and Civil Engineering Department, DGT-FEC-UNICAMP/ LALT, oflimaj@fec.unicamp.br

5 Executive Director of MUNTE Construction, atf@munte.com.br

the help of detailed models built on specific knowledge.

According to Wash *et al.* (2004), supply chain management is more mature in manufacturing than in construction, as indicated by many differences in the modeling and analysis approaches between these industry sectors, including the widespread use of simulation tools to optimize supply chains relationships in manufacturing.

This paper will present the first stage of preparation and simulation of the proposed supply chain, namely the drafting of simulation in the software *iThink* and its initial results.

MANAGING THE SUPPLY CHAIN IN CONSTRUCTION

The study of supply chain management has a key role in achieving the common objectives of the companies and in generating wealth for them. Many authors have discussed the issue by presenting approaches for the analysis of lean concepts application already successfully implemented in other supply chains (TOMMELEIN, 1997; AZAMBUJA, 2002; ISATTO, 2005; VRIJHOEF; KOSKELA, 2000; FONTANINI; PICCHI, 2004).

However, it is difficult to reach these goals due to the complexity of supply chains, the conflicting interests of its participants and the interactions between chain participants through information flow (TOMMELEIN, 1998; ALVES, 2005; ALVES; TOMMELEIN, 2007). The mentioned authors developed an interesting study of simulation with four scenarios, simulating them and analyzing the impact and changes both in the duration of the activities of the supply chain and in the definition of large lots in the project lead time.

In Alves and Tommelein's study (2007), the authors considered during the simulation delays in information sharing, uncertainty and distortions in real demand and analyzed fluctuations that are triggered by all levels of the studied chain. When studying the fluctuations and their impact on purchase orders and on the levels of production of all participants of the chain, they concluded that the chain took months to return to the original demand and regular production levels. Walsh et al. (2004) also present a simulation of discrete events aiming to analyze construction supply chains.

Czarnecki and Loyd (2002) consider that the analysis of the lean simulation would be more practical and cost saving if used before taking the decision to effectively implement improvements that interfere with the layout of factory. Thus, they encourage studies to research this theoretical level.

RESEARCH METHOD

The research strategy is an exploratory case study, taking the steel supply chain for a pre-cast elements producer as the case for simulating selected parameters behavior.. For developing the first scenario we used data collected from semi-structured interviews and relationships depicted in a Macro Value Stream Map. The limitations are inconsistencies in the information of the quantity of steel in stock, observed both in situ and in the system (SAP/R3). For this initial analysis, we considered the in situ quantities of the two main agents of the studied chain: the manufacturer of pre-cut steel bars and the pre-cast elements producer.

To draft of the first diagram, a model was proposed, based on the relationships identified from conducted interviews, although the model requires periodic reviews to identify possible variations of the agents' relationships. Subsequently, this has been studied through the software *iThink* with the support of LALT - (Learning Laboratory of Logistics and Transports - FEC/ UNICAMP). This software is a tool based on System Engineering, widely used for simulation in industrial logistics. A draft for a further future state scenario is proposed, as preparation for further simulation of lean tools application an its impacts analysis.

CASE STUDY

DESCRIBING THE AGENTS IN THE CASE STUDY

For the development of the first exploratory study, a supply chain for pre-cast concrete elements was used, in which the main focus was the supply of bended steel bars this supply chain is composed of following agents: the producer of pre-cast elements, structural designers, pre-cast elements manufacturer, client, and construction site. A second layer supplier is the steel mill. This supply chain has some specific characteristics, since the bended steel bars are made in the factory and delivered on demand.

After the client contracted the building, the demand of pre-cast elements producer the designers' shop drawings to be sent to the bended steel bars manufacturer. then, the bended steel bars manufacturer produces the bended steel bars and sends them to the pre-cast elements factory so they can be used to produce structural elements.

Thus, the pre-cast elements producer is dependent on two agents of the system: the bended steel bars manufacturer and the structural designers. he depends on the information flow (receiving the structural projects) and the material flow (specifically, in this case, the bended steel bars to be used in structural parts in the factory). The main agent to be analyzed (the pre-cast elements producer) controls two important stocks: the executive project stocks (information) and the steel bended steel bars stocks (material). Main relationships, lead times, inventories, and other data are presented in Figure 1.

CASE STUDY CONSIDERATIONS

Data used to initial modeling the influence chart was obtained through semi-structured interviews held with the pre-cast producer and its agents. Value stream charts of the administrative and productive processes were designed using information extracted from the same interviews. These rounds of interviews were carried out with the leaders and managers of the involved areas. The times and rates were established, based on available data. The initial model is an attempt to broadly represent the functionality of the chain and to demonstrate the influence of lack of rhythm coordination between agents in the amplification of excessive stock throughout the supply chain. The visualization of the amplified oscillations in the demand will be later shown along the research. The suggested lean policy will consider the application of some lean tools to define the relationships among agents.

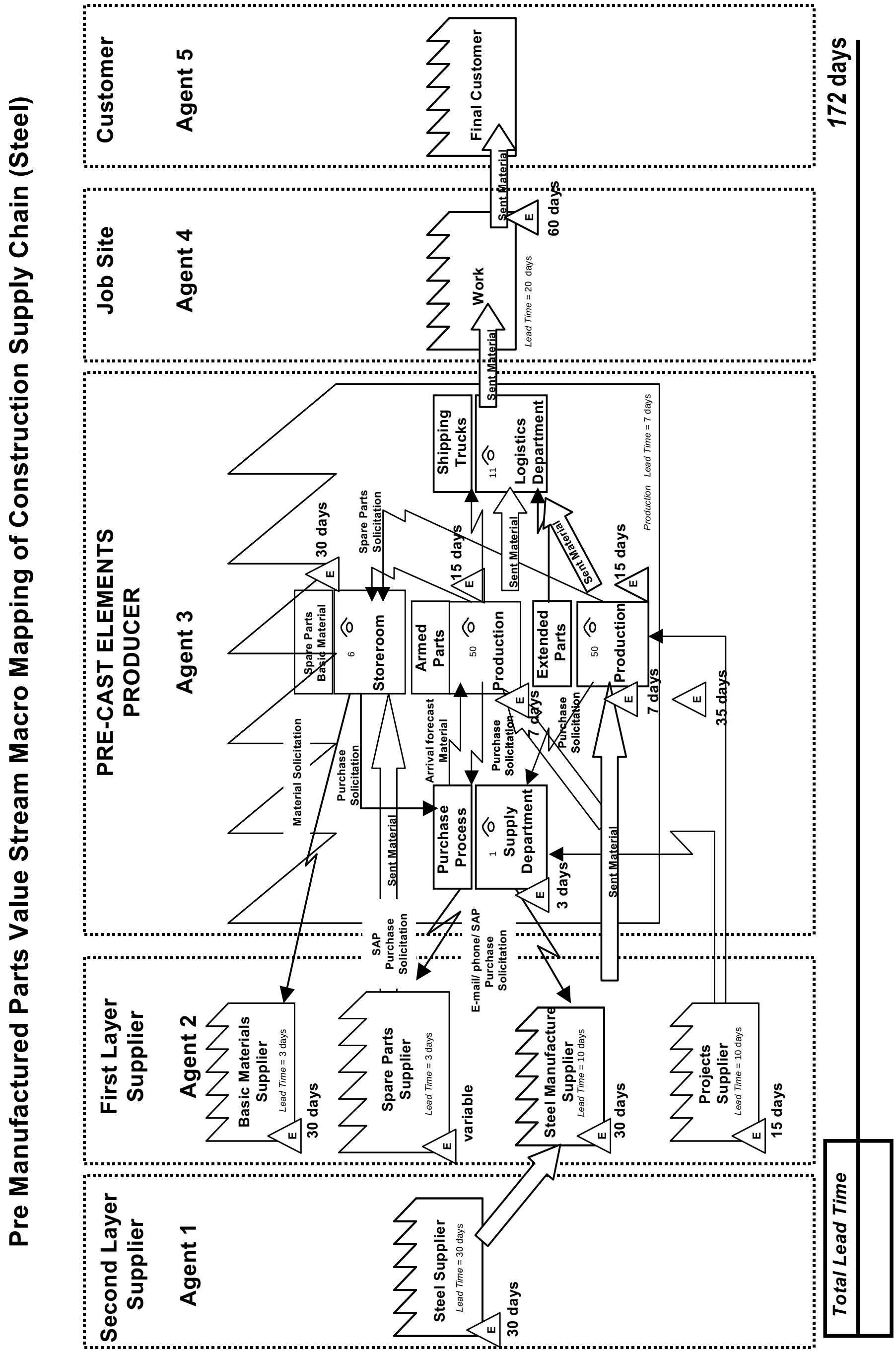


Figure 01 – Value Stream Macro Mapping of the current state of the supply chain

MODELING THE COMPLEX SUPPLY CHAIN SYSTEM OF PRE-CAST ELEMENTS PRODUCER

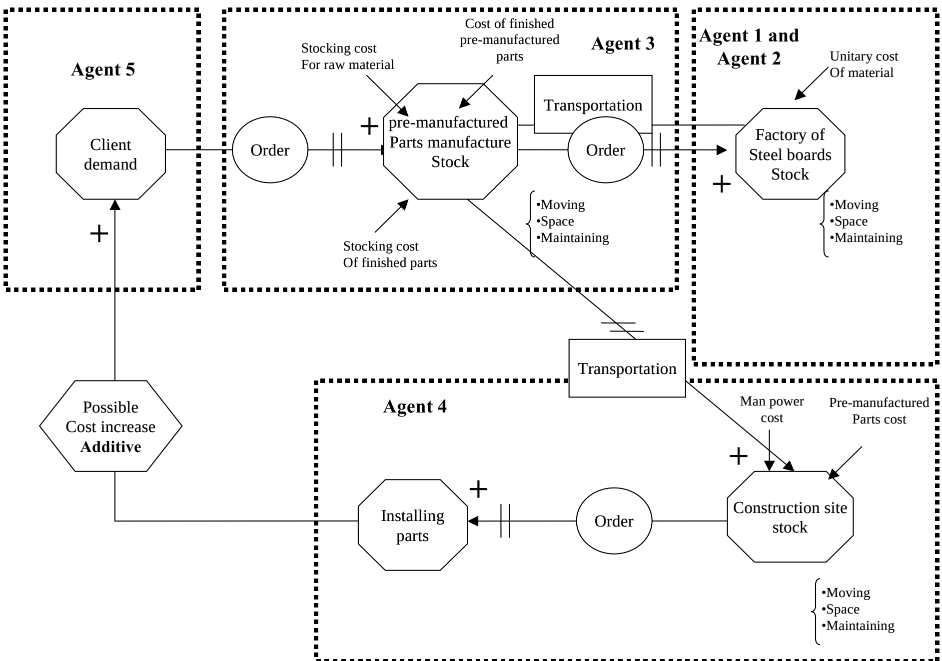
From the VSMM, the system for simulation is defined identifying several relationships among agents. The graphical convention that will be adopted for the model is the following: the polarity of the arrow (+ or -) indicates a direct relationship between the variables and the double-marks represent a temporal delay that is consequence of cause and effect.

Scenario #1 Description

Scenario #1 (Figure 02), current state of the supply chain, assumes an increasing demand of buildings for pre-cast elements producer and a raising steel price, resulting in an increasing price for bended bars (third agent).

The increasing cost of steel bars motivates the bended bars manufacturer (agent 2) and the pre-cast producer (agent 3) to increase their stocks of raw materials (steel bars for agent 2 and bended bars for agent 3). In this scenario, pre-cast producer (agent 3) planning strategy is a pushed production, producing the maximum capacity of structural elements, regardless job site demand, resulting in high stock levels both in factory (agent 3) and job site (agent 4).

Figure 02 – Influence Diagram of the supply chain as used for computational modeling - current state



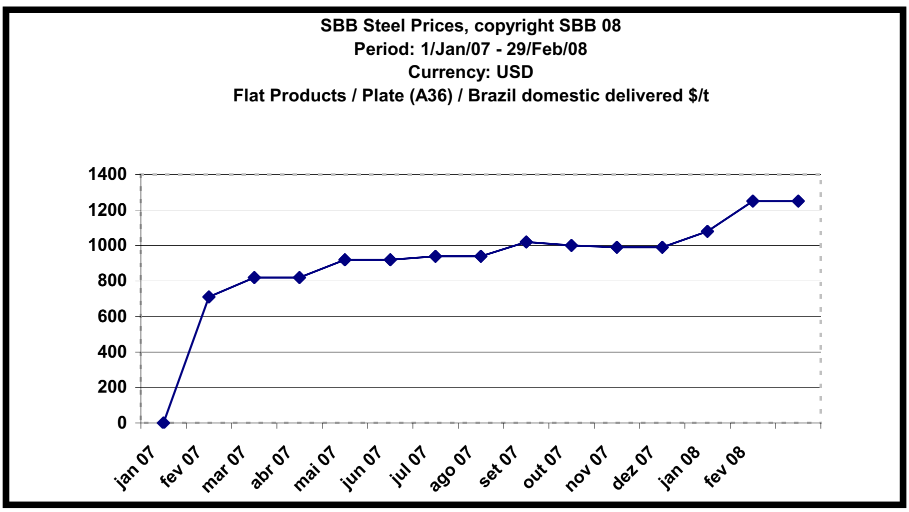
Scenario #1 Simulation

The first simulation was run using VSMM data. The first simulation considered just five agents. During data collection and interviews we found high stocks (measured in days of demand coverage) in the two first agents (Agent 1 and Agent 2), comparing to the last agents (3 Agent and Agent 4). During the first round of simulation, client demand was adjusted taking into account historical data (Graph 3). A total of 3 rounds were run, for a window of time of 2 years (See Figure 03).

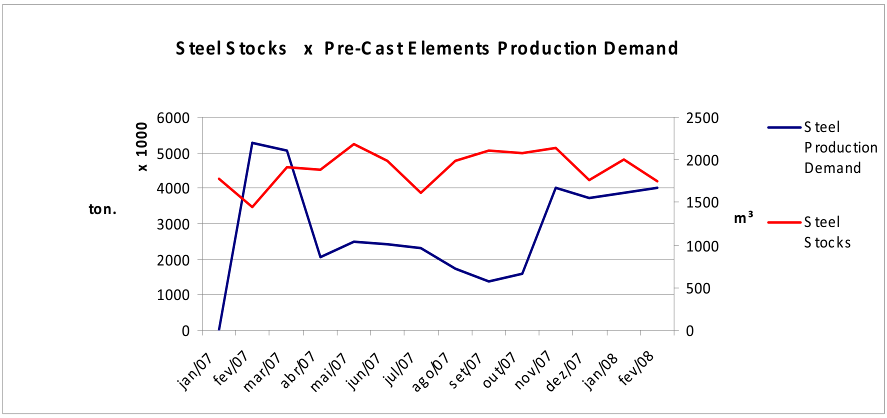
In Graph 02, we can observe recent steel price evolution (Jan/2007 – Feb/2008), used for simulation of steel price.

In Graph 03, we can observe the steel stock and production demand recent variation, illustrating the disconnection between demand and production, reflecting a pushed system. This data was used for modeling desired production rate and inventory coverage.

Graph 02 - SBB Steel Prices, copyright SBB 08

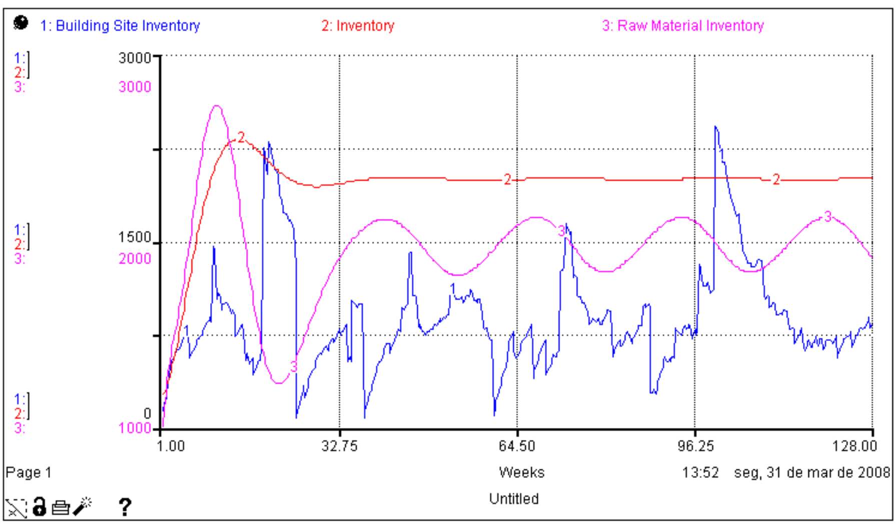


Graph 03 - Steel Stocks x Pre-Cast Elements Producer Production Demand



The stock curve (Graph 01) considers workforce plan, work forecast, contracting delay when an increase is needed, and other parameters, according to data collected in interviews. The simulation used the software *iThink* and the stock results can be observed (Agent 3) in the Graph 01.

Graph 01 – Building Site Inventory/ Inventory/ Raw Material Inventory x Time (weeks)



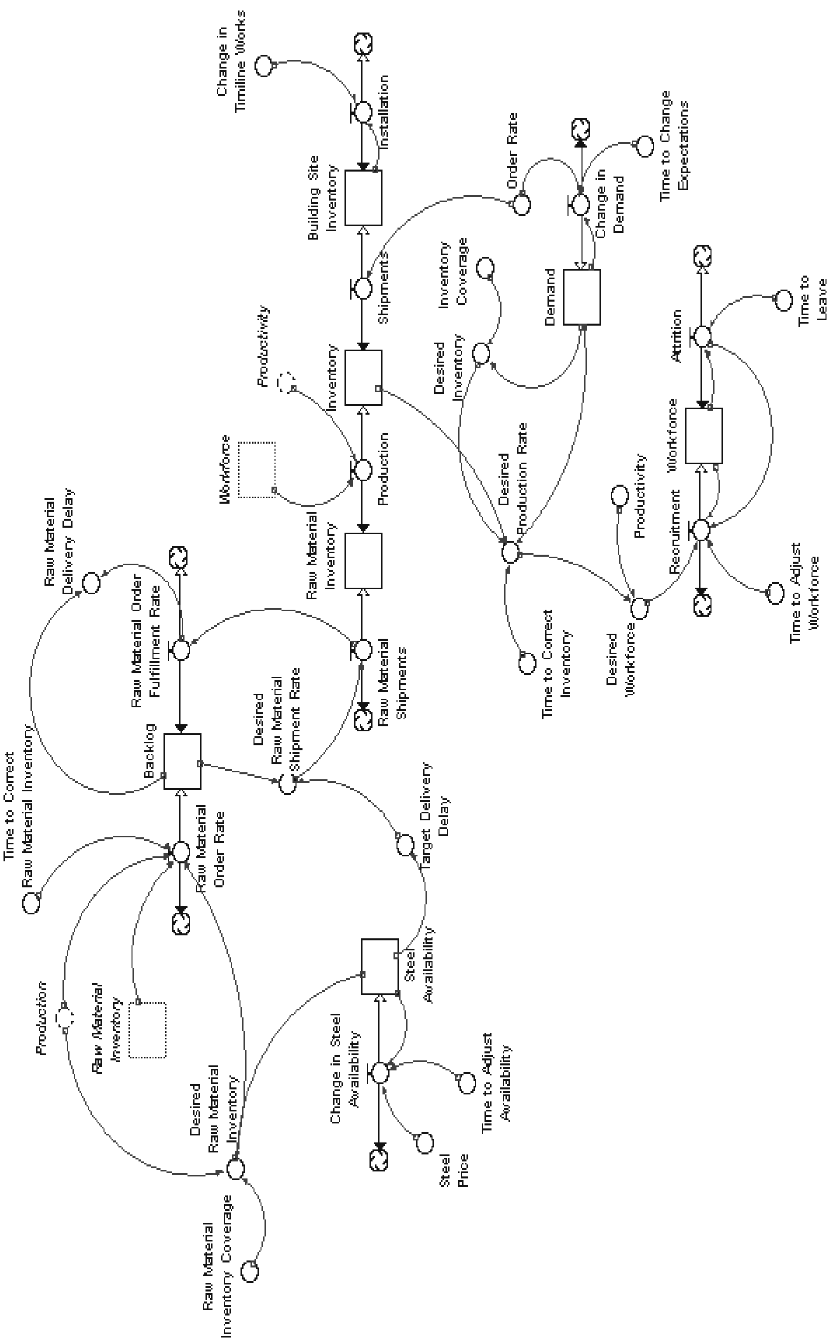


Figure 03 – First Modeling of Pre-Cast Elements Supply Chain

SCENARIO #2 PLANNING

A second scenario will be proposed, considering the application of lean tools. Table 1 presents some fundamental lean tools planned to be applied in scenario #2 seeking better adherence demand – stock. This second simulation will be part of further studies.

When detailing scenario #2 there is the necessity to take delays between one order and the other into account (represented by the arrows with two dashes), and also to consider the impact of the delays in the electronic arrival of the orders among agents. Using the simulator, we intend to analyze the impact of these delays, in days, for the system as a whole.

Table 1 –Proposed *Lean* Tools for scenario #2 simulation

Lean tools	Description	Application in the Supply Chain
Supermarkets	Tools used when there are obstacles between processes, which are bottlenecks in the system. Supermakets are applicable in regularizing both raw material and finished product stocks, enabling the implementation of a *just-in-time* mechanism.	Supermarkets are used for stocking products and raw material in an orderly and dimensioned manner, according to the needs of client process.
Kanban	Tool used coupled to the supermarket system to speed up production. Its main function is controlling the replacement of parts and maintaining a continuous flow.	*Kanban* responsible for speeding up production and signaling the need for replacement, carrying all information about the product that can be necessary for production.
Continuous flow	Concept that lets the work unit flow between the process stages without halting and, thus, without the need for stocks and transportation. The main goal of combining the aforementioned tools is to achieve a continuous flow.	This tool suggested to be used within each agent, but the challenge is implementing it among the agents, considering transportation time and demand fluctuations inherent in the analyzed system.
Macro value stream charting (MVSC)	A diagram with all the agents involved in the analyzed productive process, with representations of stocks, transportation, warehouse and information flow, from order to delivery.	MVSC helps defining and planning the policy to be adopted throughout the supply chain. The systematic data capture is necessary to reduce costs through elimination of waste material and the creation of a smooth production (material) and information flow (WOMACK; JONES, 2002)

CONCLUSIONS

This study is preliminary and considered the variation of a limited supply chain for steel in pre-cast elements producer. The output for inventories is adherent with real observed behavior in the case study supply chain. The impact of lean tools application will be simulated in a second scenario simulation, considering selected fundamental lean tools such as pulled system among agents. The real potential of this simulation application for lean strategies evaluation needs the development of next steps planned for this research.

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