Knowledge management model for a flight test environment

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ABSTRACT

This paper investigates how Knowledge Management (KM) patterns in a Brazilian Air Force (BAF) flight test environment, can be modeled using a System Dynamics (SD) methodology. The research has been conducted initially by a literature review on the main KM and SD theories. Data for this research was collected in a previous work where a documental research regarding the flight test environment KM was done and a questionnaire was submitted identifying a low KM maturity level and the flight test core competence as the capability of performing flight test campaigns. The problem issued was the trade off between actions focused on performing flight test campaigns versus knowledge management to transfer the core competence inside organization in order to keep it in a high level. As a result of this work, it was feasible to build a system dynamics qualitative model, where fluxes and stokes were identified and the relation between them emerged by identifying systemic feedback loops that may compromise the KM and core competence transfer, enabling a holistic visualization of the problem, better understanding and possibilities of improvement.

Keywords*: systems dynamics. core competence. knowledge transfer. qualitative model.*

1. Introduction

The Flight Test (FT) activity is based on knowledge attained by experience or research, and its core competence, for the Brazilian Air Force (FAB), may be expressed as the capability of performing flight test campaigns (Follador, 2015) and should be kept and propagated inside the organization.

The Flight Test Organization (FTO), object of this work, presents in its Internal Regulation the following definition to its mission: “It is a Brazilian Air Force Organization specialized in the field of Science and Technology, and its mission is to deliver specialized technological services regarding flight test, aircraft instrumentation and data telemetry to support research, development and certification of aeronautical products, and to train specialized personal in flight test” (Brazil, 2011a, p. 7).

The FTO executes great part of the FAB activities regarding flight test and is also responsible for the courses that prepare test pilots, test engineers, instrumentation engineers and flight test technical personnel to BAF. Knowledge inside the FTO environment, mainly regarding its core competence, must be preserved and activities regarding Knowledge Management (KM) must exist, understanding the genesis, maturation, use, preservation and dissemination of this valuable knowledge.

Follador (2015) presented a documental research regarding the flight test environment and also submitted questionnaire for KM maturity level assessment, identifying a low KM maturity level inside the FTO in FAB and the flight test core competence as the capability of performing flight test campaigns. These findings, in addition to a high demanding activity in performing Flight Test Campaigns, indicated that may exist a commitment between actions focused on performing flight test campaigns versus KM activities regarding the transference of the core competence inside the organization preventing an ideal sharing of important knowledge.

The objective of this work is to understand how KM patterns, in a Brazilian Air Force FTO, can be modeled in order to apprehend the relation between performing flight test campaigns and the knowledge transferring of core competence among the organization. This problem was addressed using a system dynamics methodology, were a qualitative model was proposed to identify the main stakeholders in this system, pointing out fluxes and stocks, and the relation between them, enabling a holistic visualization of the environment, better understanding of the problem and identification of possibilities of improvement of the KM system results.

This paper is organized as follows: Section 2 presents the literature review and describes the contribution of this work. Section 3 describes the methodology used to construct the model. Section 4 presents the results and discussions about FT qualitative model, regarding performing flight test campaigns or KM to maintain the core competence in the organization. Section 5 summarizes the contribution of this work and discusses future work.

2. Literature Review

Sterman (2002) suggested that in a world of accelerating complexity and change, thoughtful leaders increasingly recognize that the tools we have been using have not only failed to solve the persistent problems we face, but may in fact be causing them. Examples o cases of policy resistance are plenty when well-intentioned efforts to solve pressing problems create unanticipated side effects.

To understand our system in this research, a literature review was performed on the topics of knowledge management, system dynamics and flight testing.

Knowledge Management

KM is an important issue that has been researched in detail in the last decades (Davenport; Prusak, 1996; Nonaka et al., 2001; Nonaka and Takeushi, 2004; Grundstein, 2008; Lloria, 2008; Albers, 2009). An organization that doesn't understand the importance of knowledge and doesn't manage or improves it, based on the environment demands in which it is inserted, may be faded to a condition of capabilities loss or stagnation.

Nonaka and Takeuchi (2004) explored the concepts of explicit and tacit knowledge and proposed four modes of knowledge conversion in a process called The Spiral of Knowledge. These modes are: 1) Socialization; 2) Externalization; 3) Internalization; and 4) Combination.

The organizational environment must provide conditions and means for allowing knowledge to flow. Bock (1998) says that it is important to consider KM in terms of four integrated dimensions: content, culture, processes and infrastructure. Content is related to the following question: what kind of knowledge is important to my organization? Prahalad and Hamel (2006) state that some knowledge, known as core competence, is the source for organizations technological success.

Culture sets both the limits (constraints) and the direction of movement of behavior within the organization: culture dictates the acceptance off all organization change (Mcnabb, 2007), therefore, the organization cultural dimension is a main factor to KM success, so people and their beliefs may be responsible for the cycle of knowledge acceptance inside one organization.

Albers (2009) proposed a practical approach to implementing knowledge management, based upon five basics steps:

1. Select knowledge management team;
2. Establish knowledge management strategy and business case;
3. Perform knowledge assessment and audit;
4. Perform information technology (IT) assessment;
5. Develop project plan and measurement systems.

Fonseca (2011), in a study about KM in an aeronautical sector industry, pointed out that the KM system in that environment has a low effectiveness. This finding is confirmed by institutional characteristics like lack of cultural organization and low adherence to KM initiatives. This kind of finding may be present also inside of a FT organization, where the high work load of FT workers may contribute to reinforce the tendency of low KM effectiveness.

Flight Test KM

Kimberley (2003) states that the FT activity is dependent on a good KM as it references human psychology and skills that are not often found in curriculums.

The Brazilian Air Force Basic Doctrine Manual (DCA 1-1) defines the flight test activity as "the action that consists in use air force resources to identify the flying qualities and the performance of aircrafts and systems" (Brazil, 2012, p. 57). This statement indicates the dynamic characteristic of the flight test activity, because it deals with new systems that accompanies the airspace technology continuous evolution. The correct evaluation, via flight test, of these new systems guarantees their proper work and ensures flight safety.

Dealing with the state-of-the-art technologies available, a FT organization must have a KM concern in order to keep its operational capabilities and to be able to process the market technology push.

There are examples of FT research like Gray (2004) that proposed a mathematical model to investigate and understand boundary tracking in order to propose new FT techniques to identify the causes of dangerous conditions known as Pilot Induced Oscillation (PIO). Follador (2009) studied new FT methods to evaluate aeroelastic structural vibrations using Operational Modal Analysis (OMA).

An example of knowledge management applied to flight test techniques are the aeronautical certification manuals, such as the Advisory Circulars (AC), from Federal Aviation Administration (FAA). They suggest a great number of techniques that are recognized as a guide to conduct flight test activities. The AC 25-7 - Flight Test Guide for Certification of Transport Category Airplanes (United States, 2012) – indicates its purpose as:

"This AC provides updated guidance for the flight test evaluation of transport category airplanes. These guidelines provide an acceptable means of demonstrating compliance with the pertinent regulations […]" (United States, 2012, p.1).

In the AC-25-7, it is possible to notice that flight test knowledge is always in evolution, according to the new technologies capabilities and in order to provide compliance to regulations. These acceptable flight test techniques evolution demand constant training of human resources in order to be able to understand and apply those suggested techniques.

Another source for FT knowledge is the reports produced after each flight test campaign. It is possible to understand from them the issues regarding the whole campaign, from motivation, resources applied, and flight test techniques to results.

Although there is a huge amount of written material regarding flight test, a great part of the knowledge attained during flight test campaigns is related to tacit knowledge, acquired during on the job learning and must be shared with the organization in processes of externalization (Nonaka and Takeuchi, 2004). This kind of knowledge is part of the FTO core competence, identified as the capability of performing flight test campaigns (Follador, 2015).

Another important issue regarding FT reports is related to its main part, the *7 part paragraph*. There are key features likely to be required in a complete flight test report: conditions, results, analysis, role relation, conclusions, recommendations, and standards compliance (Gratton, 2014)

In the judgment of the researcher, the core part of the seven part paragraph is the *role relation* or *Mission Impact*. This part deals with the impact of the tested system characteristics on the mission it is supposed to perform. The test team must joint the operational knowledge with the FT information obtained and predict if the mission is still possible to be accomplished or how it will affected by the issues revealed by the flight testing. A lack on this operational knowledge may lead to a misinterpretation and a false FT result that may produce serious problems in the future system flight testing or even in the aircraft operational performance.

Follador (2015) proceeded a documental research and submitted a questionnaire regarding the flight test environment KM, identifying a low KM maturity level and the flight test core competence as the capability of performing flight test campaigns. That work also identified the following characteristics in the KM environment analyzed in his work:

1- Lack of infrastructure dedicated to KM ;

2- Lack of KM expert;

3- High turnover of trained staff;

4- Flying Test Course (CEV) and library are the main stocks of registered knowledge;

5- Flying Test Course (CEV) and library not linked;

6- High work load to flight test teams, causing to lack of time to conduct knowledge sharing; and

7- Frequent occurrence of rework.

These findings, especially number 6, emphasize that the operational knowledge may be lost because of FTO high work load on performing flight test campaigns, with little or no time to maintain the flight test pilots actualized with the evolution of operational missions.

Systems dynamics (SD)

Systems dynamics (SD) is a methodology largely used for analyzing systemic behavior in organizational or social systems, by means of representing causal relations between its elements and by studying its evolution in time (Forrester, 1961, 1971, 1994; Sterman, 2002; Villela, 2007; Morecroft, 2007; Figueiredo, 2009; Ford, 2009; Amaral, 2012). The main objective of SD is to understand the behavior of complex and dynamic systems, based on interactions of its parts using existing patterns of relationship.

The interest for SD is growing because of its unique capacity to representing the real world. It accepts complexity, non-linearity and feedback structures, inherent to social and physical systems. It is a methodology that allows better learning of complex systems evolution (Forrester, 1994; Sterman, 2002; Meadows, 2009).

Generally, in SD the systems, response is represented by particular behaviors and patterns like exponential growth and oscillations, and by its direct relation to feedback loops characterized as reinforced, balanced, delayed balanced, and their combination (Ford, 1999; Gonçalves, 2009).

Sterman (2002) proposes that the SD modeling process is iterative. Results of any step can yield insights that lead to revisions in any earlier step, as presented in Figure 1. The first step is to understand, characterizing an articulating the problem (Ford, 1999; Sterman, 2002; Morecroft, 2007).

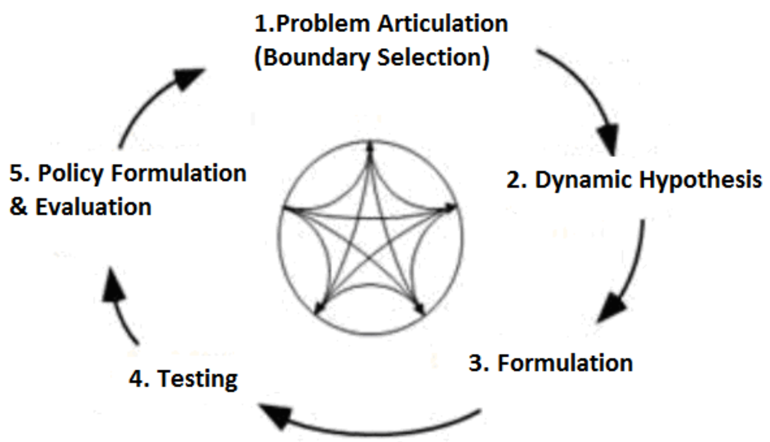

Figure 1 - Iterative SD modeling process (Sterman, 2002).

Ford (1999) proposes eight steps four system dynamics modeling, namely:

Step 1. Get acquainted with the system;

Step 2. Be specific about the dynamic problem;

Step 3. Construct the stock and flow diagram;

Step 4. Draw the Causal Loop Diagram (CLD);

Step 5. Estimate the parameters values;

Step 6. Run the model to get the reference mode;

Step 7. Conduct Sensitivity analysis;

Step 8. Test the impact of policies.

Several authors studied the relation between qualitative and quantitative approaches to SD modeling (Ford, 1999; Wolstenholme, 1999; Coyle, 2000). These two approaches are complementary as seen in the eight step method proposed by Ford (1999): the first four can be classified as a qualitative system dynamic modeling, and the following three steps belong to quantitative approach.

The eighth step - to test the impact of policies - may be applied both in qualitative and quantitative SD modeling (Coyle, 1996). This may be translated into new policies applied to the model in order to achieve improvements in performance and to minimize the problem addressed (Morecroft, 2007).

Meadows (2009) identifies twelve Leverage Points, as places to intervene in a system with new policies, in order to change the structure of systems to produce more of what is needed and less of that which is undesirable. Among the proposed leverage points are:

- Numbers — constants and parameters such as subsidies, taxes, standards;
- Buffers — the sizes of stabilizing stocks relative to their flows;
- Delays — the lengths of time relative to the rates of system changes.

In the literature are found are several works using as a tool for modeling subjects like: technology innovation (Swinerd and Mcnaught, 2014), improvement of anemia control (Mccarthy et al, 2014), adult obesity trends (Fallah-Fini, et al, 2014), infection screening among young women (Teng et al, 2015), projects: Information sharing, psychological safety, and performance effects (Bendoly, 2014), and diffusion of technological innovation (Swinerd, and Mcnaught, 2014).

Regarding specifically studies of KM, the following subjects my be listed: knowledge management performance (Chen and Fong, 2015), knowledge management process in airlines (Zaim et al. 2013), organizational IT investment strategy and market performance (Liao et al, 2015), analysis of technology districts' evolution in a knowledge-based perspective (Dangelico et al, 2010), and capacity planning (Špicar, 2014).

Nakamura and Chaim (2014) applied SD methodology in order to identify, understand and model the factors involved in the causes and impacts of the loss of organizational knowledge in a Project Management Office in FAB. In that work, key variables were identified using MICMAC methodology (Godet, 2000).

Gonçalves (2011) studied the balancing between the provision of relief and recovery with capacity building in humanitarian operations, modeling the performance of two polar resources allocation strategies: one focusing in relief and recovery efforts, and another focusing on capacity building, reporting a counterintuitive behavior from relief/ recovery and capacity tradeoff.

A similar condition to the reported by Gonçalves (2011) was visualized in the KM system for the FT environment addressed in the present work considering that Follador (2015) also reports the high work load as an obstacle to the knowledge sharing between flight test teams.

These papers show the increased relevance of SD in the modeling of complex systems, but, none of them addresses specifically the KM particular to a FT environment. Thus the contribution of this study deals to identify a counterintuitive relation between the dedication of performing flight test campaigns and the risk of loosing the organization core competence using a SD modeling methodology.

3. Model Description

The modeling method applied in this work aimed to answer the research objective, which is to understand how KM patterns, in a Brazilian Air Force FT environment, can be simulated in order to visualize the relation between performing flight test campaigns and the need of knowledge transferring among the organization.

The SD modeling method used was based on that proposed by Sterman (2002) and Morecroft (2007). It prescribes the following: identify a sectors map of the organization, represent the main parts to the system as culture/ people, technology/ infrastructure and process and verify locally the causal loop diagrams, fluxes and stocks. Then these sectors were integrated to achieve a global diagram of fluxes and stocks.

The KM dynamic response was preliminary identified based on interpretations regarding the findings of Follador (2015) and Fonseca (2011) about KM systems, where it was understood that a KM system may have a good initial adhesion by the workers that use that knowledge, but it tends to stabilize at a lower level during temporal evolution. This assumption of dynamic response is presented in Fig. 3. This curve corresponds to one of the fundamental modes of dynamic behavior and it corresponds to a reinforced loop followed by a balanced loop plus another reinforced loop (Sterman, 2002). It traduces the behavior of a crescent adhesion in the initial moments of a KM system (reinforced positive loop) and the temporal progression when this adhesion reaches a maximum (balanced loop) and tends to a lower level (reinforced negative loop) due to systemic issues in the organization.

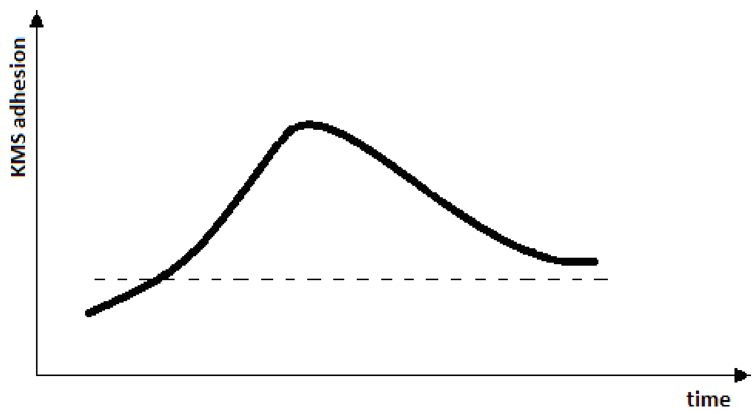

Figure 3 – Dynamic response to workers adhesion to a KM system.

After stated the dynamic response of the KM system, it was identified the causal loop diagram – CLD - of each identified sector. The CLD of KM process sector is presented in Figure 4.

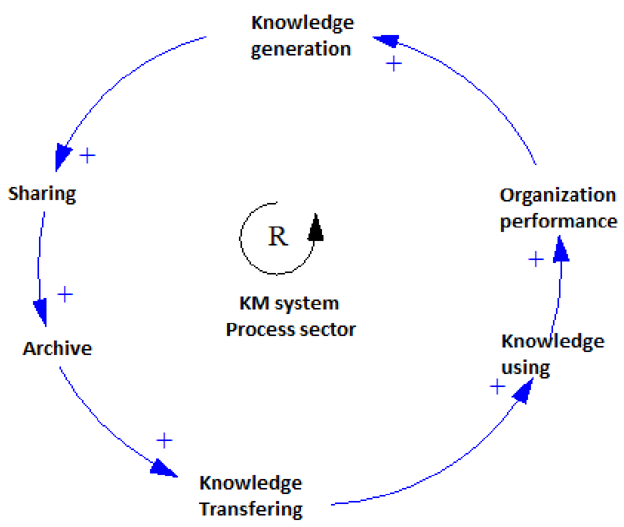

Figure 4 - CLD of KM Process sector.

Once the KM sectors CLD were grouped, it was possible to construct the proposed stock and flow diagram for the KM System model, depicted in Fig. 5. The model was created using Vensim® PLE Version 6.3.

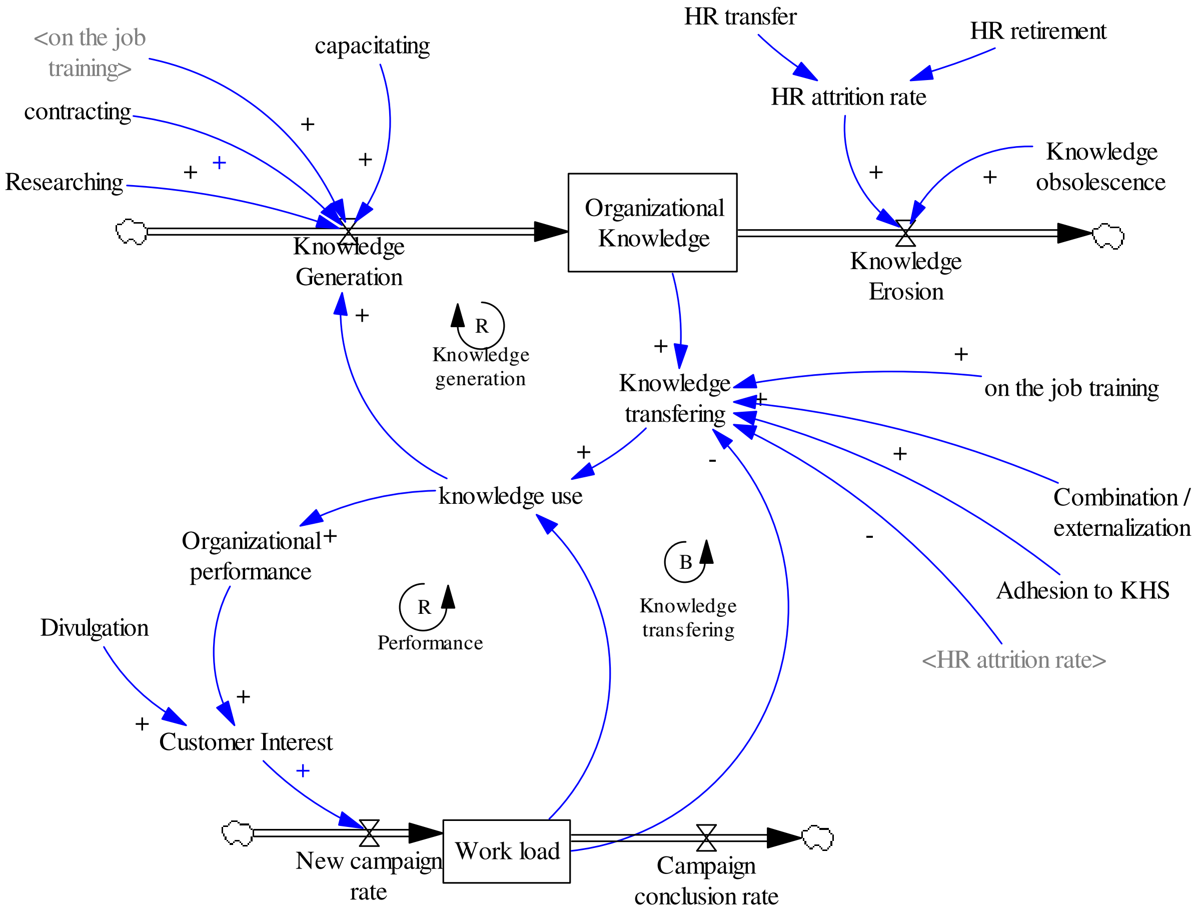

Figure 5 - Proposed stock and flow diagram for the KM system model.

4. Results and Discussion

Based on the research it was possible to construct the SD model to represent a KM system inside a FT environment, providing means for observing the existing feedback loops in the KM system. In Figure 5, the stock {*Organizational Knowledge*} participates in one loop involving: [*Knowledge transferring*], *[Knowledge use*] and [*Knowledge generation*]. This loop deals with the knowledge generation effort of the organization. Several variables are relevant in this loop, such as <*researching, contracting*>, <*capacitating*> and <*on the job training*>. In terms of flight test, the variable, <*on the job training*> bears singular importance, as its carries the experience exchanged during execution of flight test campaigns or flight tests. Even the operational knowledge, as basis to understand the Mission Impact, is transferred from pilot to pilot during flights or participating in operational campaigns.

Another important variable in the model is <*knowledge use*>. It participates in three feedback loops, namely, Knowledge generation (reinforced loop), Performance (reinforced loop) and Knowledge transferring (balanced loop) as can be observed in Fig. 3.

These three loops interact among themselves and are influenced by a high HR attrition rate, denoting two conflicting concerns to the FTO: 1) Performing FT campaigns; and 2) Transferring knowledge among the teams involved in flight test campaigns execution. This shows that with a low number of flight test teams in this organization, and the stress to perform flight test campaigns, continually proposed by the main customer (Brazilian Air Force), that are time sensitive and may occur simultaneously, the KM activity is jeopardized.

This finding may represent a counterintuitive observation that, the greater is the effort to maintain the FT organization totally focused in perform flight test campaigns, the greater is the risk of loosing its core competence and the ability to continue fulfilling the customer needs in the future. Despite the effort to generate and transfer knowledge by the FTO, the additional work load influences the system and it may be prevalent over the other activities and, in a medium to long term, may threaten the knowledge transferring in order to keep the flight test teams dedicated to flight test campaigns and to fulfill the customer needs and expectative, being this characteristic a threat to the organization itself.

5. Conclusion

Based on the research it was possible to construct the SD model to represent a KM system inside a FT environment, providing means for observing the existing feedback loops in this KM system.

The model provided means to understand a counterintuitive observation that, efforts to maintain the FT organization totally focused in perform flight test campaigns, may offer a risk of loosing its core competence and the ability to continue fulfilling the customer needs in the future. This finding is not specific to the organization in study, and may be applied in different organizations, where the dynamic of knowledge management is similar to the environment of FT in FAB.

Further works will address in applying methodology to identify key variables using a methodology as applied by Nakamura and Chaim (2014). Also a quantitative part of the model will be studied, where data from the actual FTO will be used to estimate the parameters values. These parameters will be adjusted in order to conduct sensitivity analysis and to test the impact of policies to change the system into a more appropriate behavior of knowledge transferring, where KM must be able to ensure the maintenance of the organization core competence without affecting its ultimate goals and the customer needs and expectative.

The new policies to be applied to the model will take in account lean initiatives to Systems Engineering as the proposition of Lean Enablers for Systems Engineering (LEfSE) by Oppenheim, Murman and Secor (2009), linking System Dynamics to Lean Management.

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