

The Development and Use of the Production Learning Environment Simulation at Ford Motor Company

Shelia Covert-Weiss, Ford Motor Company - 313-594-3571 - scovertw@ford.com

Gregory J. Clark, Ford Motor Company - 313-594-3634 - gclark@ford.com

Phil Odenice, High Performance Systems, Inc. - 603-643-9637 x 107 - podence@hps-inc.com

PURPOSE FOR THE PRODUCTION LEARNING ENVIRONMENT

The Production Learning Environment (PLE) provides a high level view of a generic Ford plant in the pursuit of operating their business in a new way. The PLE is designed to give teams a practice field to experiment with systemic thinking, make assumptions explicit, gain shared understanding, and learn how to take effective action. The PLE is not a deterministic model, it is not a "how to implement lean manufacturing in your plant" tool, and it does not provide technical information about the concept. Rather, it's intent is to foster honest and open conversation between the players of the simulation and help them to understand the interrelationship of the variables within the concept of lean manufacturing.

This paper tells the story of the development and use of the Production Learning Environment.

HOW AND WHY DID THIS EFFORT START?

Some leaders at Ford felt that the concepts of Organisational Learning (OL) could assist in the implementation of Ford's major reengineering initiatives. Lean manufacturing is one of the key reengineering projects and is known at Ford as the Ford Production System (FPS). The development and roll out of FPS is following a fairly standard "large company" process. Mix subject-matter-experts with a few outside consultants at World Headquarters and design the process and create the infrastructure to implement. Train the "doers" in the process and concepts, enforce the use of the process and concepts, and measure the results. With well over 100 plants worldwide destined to implement FPS these leaders interested in the methods of OL felt it would be prudent to see what OL could do to help FPS. On such a large scale how much "damage" could OL do if it failed? Combining OL concepts with FPS may be the right thing to do conceptually but what would the mechanics look like? A small team of experimenters started working on how to combine OL and FPS. Systems Thinking seemed like more than a natural concept to apply and soon the idea of creating causal loops to describe the interactions of the elements of FPS grew into the idea of creating a computerized system dynamics model of those interactions.

THE DEVELOPMENT STORY

The OL team contacted High Performance Systems, Incorporated (HPS) and met with Phil Odenice on October 29, 1996. The purpose of the meeting was to discuss the possibility of forming a partnership between HPS and Ford to develop a computer based simulation. After a full day reviewing the possibilities the OL team and Phil agreed to co-create an interactive multi-media simulation/learning environment based on FPS. The simulation was to take the perspective of a senior plant management team (Plant Operating Committee) and the primary users of the system would be plant personnel. The beta version would be completed within 4 months, outside consultant costs of less than \$100,000, and about 88 person-days of Ford personnel time. In addition to working with HPS on the development of the FPS model and leaning environment by being subject matter experts in FPS and the Ford environment, the Ford personnel were to begin gaining experience in the world of modeling and System Dynamics. There would be opportunities for HPS to teach courses on Systems Thinking and the Ithink tool as well.

By the end of November, two champions and funding were secured for the project. The FPS Reengineering Team agreed in theory to support the simulation. Greg Clark, the leader of the project from the Ford side, set out a plan that would meet the timing, cost and quality of the project in partnership with HPS. The timing, cost, and quality targets were neither arbitrary nor dictated from upper management but were derived with the idea of demonstrating what could be done "fast enough" and "good enough" to be seen as being able to capture an opportunity at a cost understandable at Ford. This project was just as much about experimenting with System Dynamics in the Ford environment as it was about simulating lean manufacturing.

One of the first tasks on the plan was to create two teams. One team, the "small team", was to develop the models and the Learning Environment to be used in the simulation. They were the Ford subject matter experts and had access to other Ford subject matter experts. They would also be responsible for ensuring the quality of the project through testing and using the product. The small team would work in the closest partnership with HPS. These people would get the most experience in System Dynamics, modeling, and creating Learning Environments - hopefully with an eye towards applying that experience on subsequent projects. The authors of this paper were members of the small team. A second team, the "large team", was also formed. Their purpose was to be a sounding board, initial users of the system, and a "sanity check" for the direction of the effort.

Not being terribly clever the small team was so named because it consisted of four Ford members which contrasted with the large team's ten members, including the small team. HPS contributed two people to the small team making the team sizes six and twelve in total.

The Ford members of the small team held positions Information Technology, Organisational Learning, Business Process Reengineering Integration, and Ford Automotive Component Manufacturing. The backgrounds of the Ford people on the large team were much more diverse with leaders as well as workers from all areas: the FPS Reengineering Office, Human Resources, Computer Aided Engineering, Process Improvement, and Organisational Learning. The experiences of these people ranged from Vehicle Simulations to System Dynamics studies to Organisational Development to Lean Manufacturing.

Implementation formally began on the 9th of December in 1996 with an introduction to Systems Thinking class for the members of both these teams. A team building model, the Group Development Model¹, was followed in the formation of these teams. The simulation was off and building!

Towards the end of January, 1997, the small team had enough of a "working" simulation to present it to users for feedback. The simulation was presented to a group of twenty people from a component manufacturing plant outside of Detroit. These twenty people held a variety of positions in the plant including maintenance, information technology, FPS implementation, and came from both the hourly and salary ranks. Though there was smoke and mirrors and none of the twenty people were allowed to actually play the simulation the feedback was positive. In particular the direction as well as the concept of using "flight simulator" was well received. The translation between this specific plant and the generic plant in the simulation was viewed as the biggest problem.

The encouraging news from the plant personnel was welcome as the large team assembled as overseers were not as happy. Various members of the large team were all looking for different things. It was very clear quickly that there was no shared vision for the simulation. Questions loomed around the underlying model and the supporting data. The "fiction" of the environment was dismissed as not matching FPS exactly. The purpose of the simulation was discussed for many hours in search of that shared vision. It was very difficult for the large team to understand, much less agree with, that the purpose of the simulation was to provoke new conversations. The large team, in the view of the small team, was looking for deterministic results and exact adherence to FPS detail. Such a view is not at all surprising in retrospect given the Ford environment. After all, "computer simulation" has a definition all its own in a large automotive design and manufacturing company and this project was not adhering to

that definition. The two teams parted company at this point, though not officially. Through the rest of the development period "doing something with the large team" remained on the task list but the simulation was never presented to the large team as a group again.

The small team continued its almost daily meeting schedule. This team also had its struggles, misunderstandings, and doubts about the possibility of success for the project. Central to the struggle was the audience of the simulation. The "perspective of plant management" as the focus was clear enough but what did that mean about who would be sitting in front of the computer using the simulation? The level of detail to be included was another source of frustration. Automobile manufacturing and assembly can grow into a pretty complicated process very quickly. The dichotomy of the reactions of the large team and the potential users at the component manufacturing plant led to yet another set of discussions.

All this sounds pretty bleak. And at times it felt pretty bleak. Development started to come to a standstill while these issues and disagreements took the forefront. Finally the small team returned to a list of "will's and will not's" for the simulation that had been generated in December. This list of about 30 things provided a way to include or exclude items from the simulation and/or the discussion. It is important to note that there was not necessarily agreement in these resolutions. It was all fairly heavy handed. It was clear that more time should have been spent in December developing a better understanding of the purpose of the simulation, why the project was being done, and the in scope and out of scope parameters with all the people involved in the project. But to meet timing, development forged ahead with the feeling it was better to complete the experiment as designed rather than "do the right thing" and achieve the shared vision and consensus

Of course, now the project was behind. What else to do? Add some people!

Towards the middle of February, 1997, two new members from Ford were added to the small team and the team continued with model validation and making the "this is in and this is out" decisions around the model. With the model very solid at 85% complete by the beginning of March, 1997, the small team now turned to the surrounding learning environment which was no better than 50% complete. The team had agreed long ago not to worry about the environment deeming the model more important. It was time to take the "beta" version back out to the plants in early March and the self-contained environment envisioned in first meeting in October of 1996 was not there. The small team took the "beta" PLE simulation to five additional Ford manufacturing plants on three continents with a manually created environment or facilitated session, complete with paper manuals and all. Good old-fashioned people were used to set the context of the simulation and facilitate the running of the PLE. Though not having the complete learning environment would limit the ability to take the PLE to a large number of plants, getting real live use experience was deemed more important. Feedback from these "beta" sessions could be incorporated into the final learning environment.

The "beta" PLE was received with overwhelmingly positive feedback. Almost no requests for changes to the model were received. Demand for the PLE in the plants was starting to form.

The small team also took the "beta" PLE to senior Ford management in this March, 1997, timeframe. And here the team received feedback of different nature. Though most were enthusiastic and excited about the simulation most had specific suggestions on ways to change the model. They all had particular biases about lean manufacturing that they wanted to "teach" through the PLE. Some of these suggestions were actually in direct conflict with the goals of the PLE. Some, interestingly enough, were already contained in the model! Only one change to the model was implemented which, while satisfying the senior Ford manager, had the desired side-effect of making the simulation easier to "win" or play.

It was now April, 1997. The model in the PLE was essentially complete and was usable, timing had been met. The learning environment was not computerized and was rough. The external budget was met.

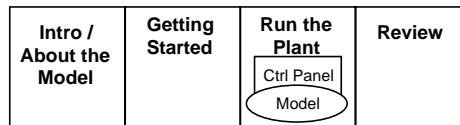
The internal budget (88 person-days) was never directly tallied. The development teams never jelled. Large-scale transfer of System Dynamics skills to Ford people did not happen. Was the project a success? The two de facto owners of the product, with the development teams disbanded, were too busy handling requests for demonstrations to tell.

OVERVIEW OF PRODUCTION LEARNING ENVIRONMENT

The paper, to this point, has focused on the story of the development of the PLE simulation. Now, attention will be placed on exactly what the PLE is.

At the beginning, the small team intended that the PLE would not be simply a model, but rather would be enhanced with a user interface and substantial content (a scaled-down version of what HPS calls a “Learning Environment”). This was critical for a variety of reasons, the most important of which was to ensure the portability of the simulation. That is, we wished to minimize the experience required to facilitate the training sessions that included the model.

The overall structure of the Production Learning Environment is as follows:



Teams of users step their way through the sections. They are lead into their fictional role as the Plant Operating Committee through the introduction and model review. In *Getting Started* and *Run the Plant* users are “in the fiction.” In other words, they are presented information as if they *are* the Plant Operating Committee. The *Review* recaps the learnings.

This overview focuses primarily on model and its associated control panel.

Note that because the PLE is designed to be consumed by teams or groups, when the description below references the *user*, that is meant to refer collectively to the team of users.

The Model / Control Panel / User System

For the PLE (as with other Learning Environments and Flight Simulators) it is difficult to divorce a discussion of the model from that of the Control Panel and the user because:

- The Control Panel is the manifestation of the perspective of the model. What the user sees and is able to control is dictated by the fictional role the user takes on.
- Much of the feedback in the PLE is not inherent in the model per se, but rather passes through the user’s brain via the Control Panel.



For that reason this description looks at the Model / Control Panel / User System (“the system”).

System Perspective

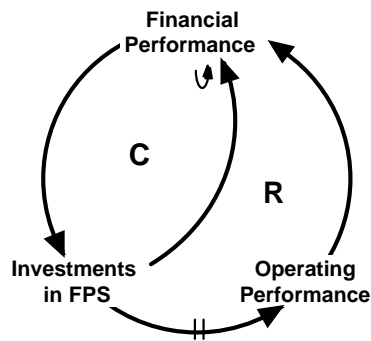
The system takes the perspective of the plant operating committee. Further, this perspective is a strategic one, looking at the issues that the committee faces as a team in their monthly strategy meetings, as opposed to all of collective day-to-day decisions the individual team members make. As such, it is not necessary for the committee members to take on particular roles.

Even within this realm, there are a variety of decisions on which the team might focus. The system specifically deals with the strategic issues faced by a plant implementing FPS, such issues as:

- How fast to implement the new process.
- How much time and effort to invest.
- How to change other operating aspects of the business, in light of the new process.

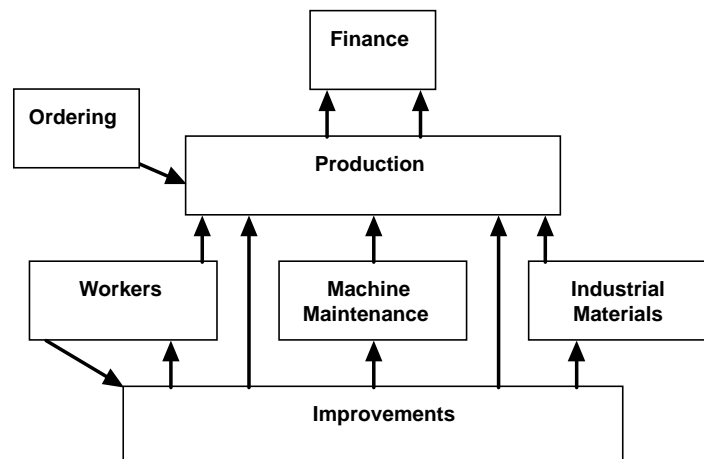
Structure

Underlying the system is one fundamental feedback structure within which the user is perched. In order to be successful users need to invest in putting the new process in place and supporting it. With some delay, that yields better operating performance and therefore better financial performance. The difficulty is that in the short term the investment (like all investments) adversely impacts performance.



Clearly these feedback relationships could be captured in a very simple model structure. However, making the system “feel” like a plant and enabling users to better understand what was involved in rolling out FPS required more detail.

Below is a high level map of the structure by sector and some of the key connections between elements of the sectors. This more or less reflects the FPS view of a plant at a very high level. Remember, the purpose here is not to describe the technical detail of FPS but to give a believable "fiction".

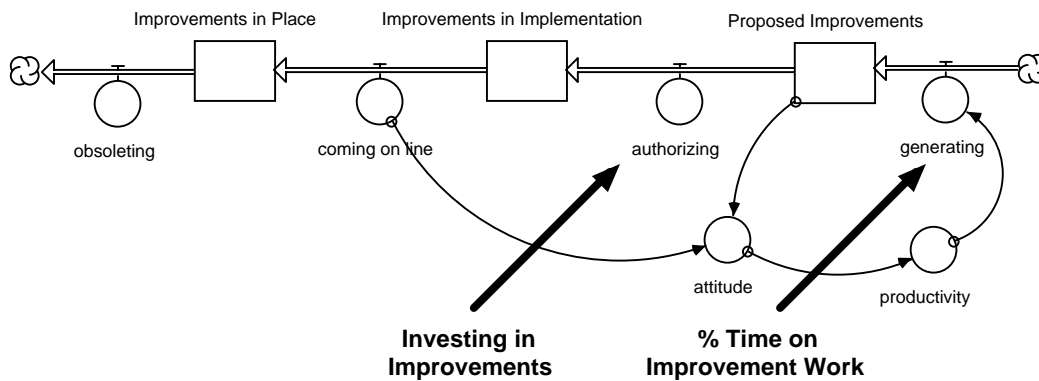


Fundamental to the system (and the FPS approach) is the concept of improvements. At the aggregate level, the heart of FPS is allowing workers to view improvement work as part of their job. With more experience in improvement work, workers are more able to generate improvements. Those improvements manifest in better performance across the plant.

Improvements Sector

Plant improvements are aggregated in the model (vs. being disaggregated by each area of improvement). Improvements move through a process chain, first being proposed, then being authorized and finally accumulating in a stock of “Improvements in Place” which actually feeds back to various places in the model to impact performance.

The simplified diagram below depicts the basic structure. There is some feedback in the model capturing an important effect that has been observed in past process change efforts. If people believed their contributions stood a good chance of being implemented they were more productive in generating new ideas, and the converse was true as well. That is captured in the attitude feedback. (In the actual model the structure is a bit more complex, and attitude is represented as a stock.) A big backlog of proposed but unimplemented improvements drives attitude down. New improvements being implemented boosts attitude.



Once there are people in the plant trained in FPS, the user can manage the process by making investments in improvement as well as by adjusting how much of workers time should be spent on improvement work. (see Workers Sector). More time means more ideas being generated, all else equal. (Actually, in addition to the attitude feedback, there is a learning curve effect as well: More experience in generating ideas improves workers productivity in doing so.)

Workers Sector:

This sector tracks the number workers that are trained in and using FPS. Workers move through a chain of state beginning with not being trained, moving into a training (or launch) period, and then finally moving into a stock of Workers using FPS. Experience is tracked here using a classic co-flow structure. Finally this is where time allocation is worked out.

The user manages this sector by setting targets for the percentage of the plant to “turn on” to FPS, and the percentage of time workers should ideally allocate to FPS. Workers move through the chain based on how much of the plant is turned on. Their actual time allocation is slightly complex. Production work is given priority. If there’s not enough time left for improvement work it can get made up for with overtime, but only up to a point, at which the targeted amount of improvement work will not get done.

Machine Maintenance Sector:

This sector tracks stocks of machines that are on preventative maintenance (PM) and machines that are not. Further it looks at machines that are broken and are not. Machines on PM fail less frequently, but are unavailable at times for maintenance.

Improvements increase the effectiveness of PM. Before workers are trained in FPS and have put the processes (improvements) in place to understand what kind of maintenance is required, PM is relatively less effective.

The user sets the policy as to what percent of machines should be on PM and over time the number is adjusted to the target.

Industrial Materials Sector:

This very simple sector tracks the inventory of ancillary materials (like cleaning fluids, lubricants, clothing, etc.) which support the production process. Improvements both reduce the consumption of these materials, and reduce the inventory requirements (to reflect the impact of better planning).

Ordering Sector

This sector represents orders for business coming into the plant. Those orders, which arrive somewhat randomly, go into a backlog and get filled as the plant produces product. The concept of product mix is captured in the percentage of the order backlog that can be shipped.

Improvements reduce mix problems which allows the order backlog to be flushed more completely and lower product inventories to be maintained.

The user may specify the desire to take on more business. This reflects one of the anticipated payoffs of FPS. However, taking on too much new business prior to improving plant performance can clog up production and drive down performance.

Production Sector:

At the heart of this sector is a classic, aggregated production mainchain with stocks of Raw Materials, Work in Process and Finished Goods. The throughput of the process is determined by machine performance (how fast can they produce assuming their operating as they should) , availability (how much of the time are they operating) and quality (what fraction of what is produced is good).

Improvements boost quality and performance. They also have impacts on availability. Improvements reduce the loss of availability due to changeover and tooling and due to blockage and starvation. Broken machines also reduce availability, so improvements in the Machine Maintenance Sector help availability as well.

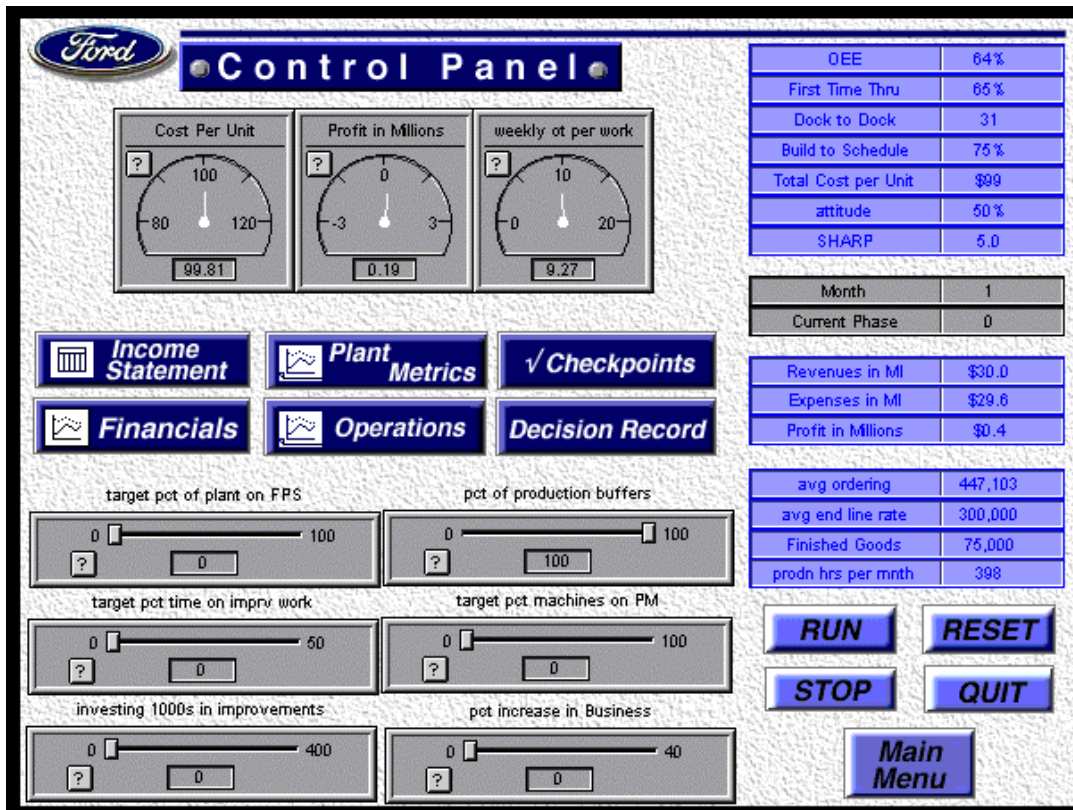
Users can free up cash by directing reductions in Work In Process (Production Buffers). However if improvements are not in place reductions could lead to blockage and starvation.

Finance Sector:

This sector is a straight-forward roll-up of expenses and revenues. Revenues are based on an internal transfer price. Expenses are based on the activities and condition of the plant.

Inputs and Outputs

The Control Panel enables users to adjust six decision levers each month.



It is also set up to provide the Plant Operating Committee with the type of information that it would expect to have access to in a real plant. Prominent in the outputs are a defined set of FPS metrics which focus on the process. As well the Control Panel provides easy access to high level operating and financial measures.

A series of buttons give the user access to more detailed information and cumulative data in the form of tables and graphs. The user can also access information about past decisions. The last button enables the user to understand the criterion used to reach different phases in the FPS process.

Another form of output for users is a series of conditionally triggered “in the fiction” messages from the model. To help cue users as to conditions in the system they might wish to explore, the model, sensing a designated condition, issues a graphic or audio message. Movies would have also been used but were thrifted as the time to develop the movies was used on model development instead. For example, users get a fax from their FPS Coach (an actual role in the FPS program) when they complete a Phase in the process. Or they get a call from Frank on the floor (complete with clanking in the background), who gives his opinion on why putting machines on preventative maintenance doesn’t seem to be helping. The messages serve both to support the realism and to provide learning nudges for the users.

USE AND FEEDBACK

As one model for implementing OL at Ford is to have teams learn OL tools and methods and practice them in a "laboratory setting", the idea of incorporating the PLE into a larger "Learning Lab" is considered the ideal use of the PLE. (Remember, this project was undertaken by an OL team at Ford.) Although the PLE is encased in a minimal Learning Environment and can be used by a single user, the maximum potential is to use the tool as a practice field to learn how to make decisions *explicitly* within a team. And to practice the explicit decision making skills around real issues, in this case, the implementation of FPS. A typical agenda for using the PLE in a facilitated session follows and ideally at least four hours is required for an initial session. This basic agenda has been used as part of a larger "Learning Lab" as well as for "stand alone" sessions:

Agenda

- *Desired Outcomes and Welcome*
- *Introductions - Facilitators and Coaches*
- *The Control Panel*
 - Overview of Screen*
 - Overview of Material*
 - Congratulations You are on the Plant Operating Committee!*
 - Follow along with the decisions and DRIVE your own plant along with us*
 - Scenario 1 - "Crash the Plant" (remember - this is practice field!)*
 - Scenario 2 - Achieve FPS Checkpoint A*
- *Now you play!*
 - ***** Rules of the Game ******
 - 1. Treat one another as colleagues*
 - 2. Assume positive Intent*
 - 3. Rotate the driver position*
 - 4. Ask Questions*
 - 5. Make collaborative decisions*
 - 6. If you do not laugh and have fun your simulated plant will be closed*
- *Debrief of Exercise in Small Groups DIALOGUE*
 - You will capture the key points and report out to the larger group*
 - What did you learn?*
- *Larger Group Debrief*
 - Call Out*

Time is spent during the sessions learning how to ask questions of inquiry that would provide opportunities for individuals to share their learnings during the simulation session and afterwards - keeping a safe place for conversations to occur. Lists of possible next steps and associated readings and techniques that groups could use after using the simulation were also created and shared.

At every use of the PLE users were asked for written feedback. This feedback was used to help develop a better tool and processes to help people adapt to change. The feedback had a large impact on shaping the agenda above and in the tuning around the model.

In January, 1997, the first session with a manufacturing plant was held with the PLE about 25% completed. Representative feedback included: "The Flight Simulator Concept is great", "I thought this would just show us what to do but you want us to find out what to do by experimenting", and "I like it, good first step".

Through February and March, 1997, with the PLE model approaching 85% completion the focus of the feedback changed to the process and mechanics of introducing and using the PLE. The participants at one of the sessions at an Assembly Plant had 12 people who were already trained in the principles of FPS. They were in the initial stages of implementation. Overall, the group responded very positively. 100% said the tool was useful. On a scale of 5 the average score was 4.5 on if the PLE was usable in their environment. Typical comments included: "This simulation is great! I can try it here before I have to do it on the floor. What a savings!", "This simulation is so similar to the real world we can take chances here without risk to the plant", and "Oh my, I did this same thing two days ago on my line, now I see why it turned out the way it did."

Another session was with one person, the HR manager of a component plant. The facilitation team became her plant operating committee so she would not have to play alone. The result? "I'd never want to be the Plant Manager. Merit <salary increases> planning has a whole new meaning to me." Perhaps the PLE had a larger audience than originally anticipated.

Perhaps the most difficult use of the PLE during this time was with over 90 participants at a components plant. The entire plant and Union management made up the base of users. The size of the group was staggering, the PLE was in the setting of a Learning Lab being conducted by others (one morning out of a three day agenda), and only two of the six facilitators had facilitated prior to this session.

Of the 55 responses received 50 strongly agreed that the PLE was useful to them. The Assistant Plant manager told everyone "I personally found out more about the consequences of my actions clearly for the first time. Before I could only guess, but now I can see". Others said "Useful tool, I never realized how important teamwork was to solving crisis", "I will solve this right if it is the last thing I do", "It allows trials without the fear of failure", "This tool demonstrates cause and effect in a way I can understand", "Understanding interrelationships is the key ingredient to running the plant", "Sometimes the initial reaction to problems may not be the right answer".

Of the 275 people exposed to the tool from February to July of 1997, 95% said they felt the PLE simulation was a good tool, something they would be able to use in their work environment.

RESULTS

Overall, one explicit measure of success for the PLE project was to create a tool that was developed "fast enough" to be seen as being able to capture an opportunity at a cost understandable at Ford. It is difficult to assess whether the PLE development was "fast enough". The project was completed, however, before the object being simulated "went away", was no longer of interest to Ford, had not changed so much as to render the simulation irrelevant, and still required significant learning on the part of the Ford implementation teams.

Another explicit measure of success was that the simulation was "good enough". By one account approximately 25 person-days was spent developing the model and a very small amount of time was spent "tweaking" the model. Since the purpose of the PLE was to stimulate different conversations in one respect it would make little difference if the model was completely wrong. If it stimulated explicit conversation and practice in decision making the model was "correct". Realistically, to achieve such conversations the model needed to be accurate enough for people to believe that the results they were seeing in the PLE were results they *could* see on the plant floor, but not so accurate as to be results they would *expect* to see on *their* plant floor. Line organisations had very little difficulty accepting the premises presented in the model. However, staff personnel questioned the validity of the models.

A different cut on "good enough" concerns the Learning Environment fiction, multi-media, and overall user interface. A great deal more time and energy could have been spent on the Learning Environment within the simulation or in screen enhancements. The more that the user interface was tweaked (or suggestions made to tweak), - "bells and whistles" - the more that was lost of the intent of the project. The main screens and overall performance of the package, like the models, changed very little from the time it was determined the multi-media part of the package had to be dropped or deferred. By remaining focused on the end result of encouraging explicit conversations the PLE was able to provide a learning experience for users to discover the interrelationships of the elements of lean manufacturing. Unquestionably, however, completing the fiction of the Learning Environment would make delivery of the PLE across a wider range of participants much more consistent. Which comes first, good models or good fiction? One should NOT conclude that a good fiction is not necessary just because a complete Learning Environment was not initially constructed for the PLE.

Overall the initial assumptions made in the model and the simulation fiction stood the test of time. The model was essentially tuned during the "tweaking" time period. The initial structure held. And the continuous improvements in the presentation and flow of the facilitated sessions followed the original Learning Environment fiction created at the start of the project. It was just never "automated".

¹ "How Teams Develop" by Art Learner, research paper 1987.