Optimizing Profits by Way of Distributed Decision Making Lot Movement w/ Trends of Engineering System Evolution Analysis

Semiconductor Industry Work in Process Management Proposal

David Conley
2008

Scientists have made recent advancements in understanding how biological swarms make intelligent decisions about their collective activities despite no decision making at the individual unit level. For example, bees and ants understand what jobs to do, and where to carry out the associated tasks, without any personal decision making. For example, when an ant colony first sends out foragers on a given morning additional foragers are not deployed until the initial ones return with food items and at the correct timing sequence. Too slow of a return sequence can indicate that either sufficient food has not been located or that there is an attacking predator close by the mound; both good reasons not to send out more foragers. Too fast of a return sequence could mean that there are ample food supplies in the immediate vicinity and that extra foragers are not required as enough ants are currently involved in the food movement process resulting in the required food return rate with the current number of foragers already deployed. The poised foragers can better serve the mound by performing other jobs such as building or protecting. In bridging the application gap between biological swarms and lot movement through a factory some distribution and transportation companies are beginning to utilize knowledge about swarm movement to help with the efficient movement of materials and goods.

Bee's rules for decision making:

1.) seek a diversity of options
2.) encourage free competition among ideas
3.) use an effective mechanism to narrow choices

In apply this theory to the movement of lots through a complex and dynamic processing environment all that is needed is to provide information about individual lot Through Put Time (TPT) by activity to the overall Automated Material Handling System (AMHS) data base and decision system. Just as with our ant friends, if lots move through a processing step with the desired drum beat then this indicates that the step is in control and following lots have a high probability of experiencing the same desirable processing time. On the other hand, if a lots moves through a particular processing step with significant variability, or too long of a drum beat, then the system would know that it is best to avoid that route or at least to dynamically balance the queues leading to the "good" and "bad" tool set – good tool gets longer queues. Further, tool by tool yield could be comprehended by performing a differential analysis of final lot yields based on the differences, and similarities, of two separate lot's routes and understanding which lot resulted in the higher yield. Assuming an accurate understanding of TPT cost and Assembly Die Inventory, our new "smart system" can make dynamic decisions about whether TPT or ISO (a measure of die Yield) is more important for a particular factory health profile and direct lots through high Yield or short TPT tool sets as most beneficial to the overall profitability of the process.

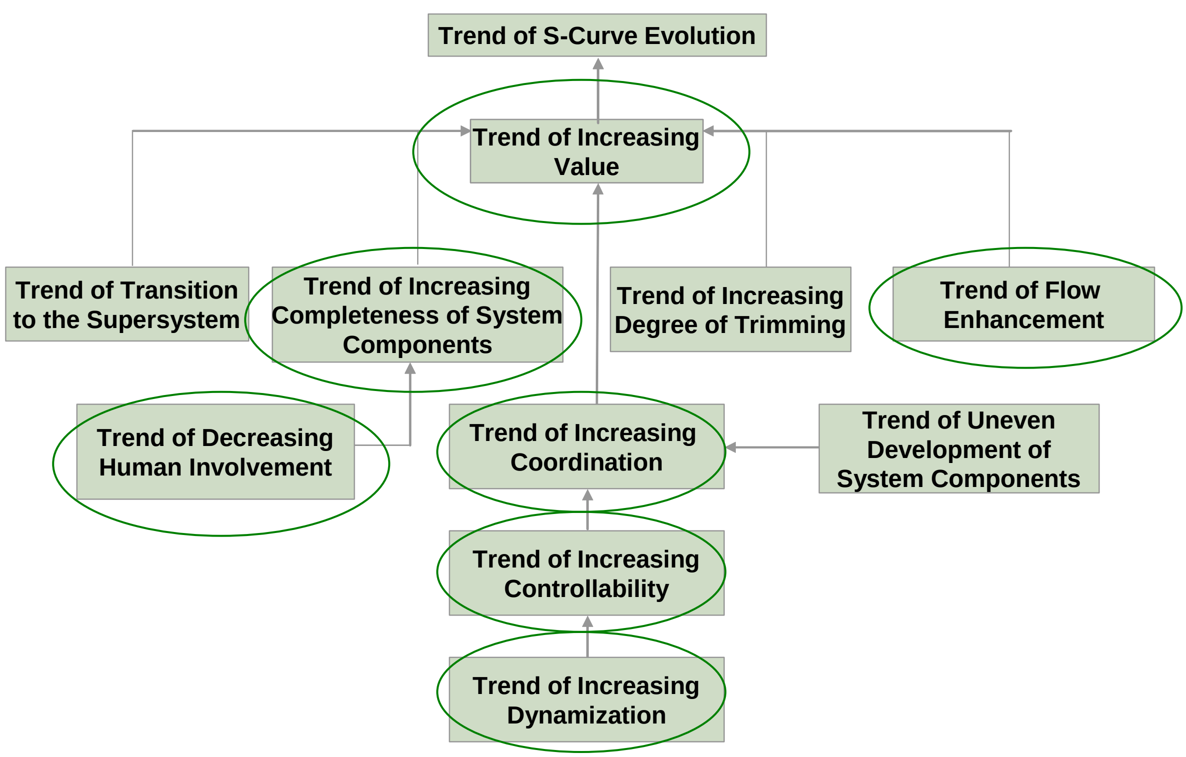
Making this concept even more attractive is that the only change to many existing systems required to implement as described above is to add, or modify, the AMHS data base and decision system required to store and comprehend the new tool by tool TPT and Yield information. All other hardware, decision support systems, and AMHS control systems already exists in the correct configuration, in most 300mm factories. More specifically a rules based decision making system, which already makes lot/tool decisions based on tool set-up and availability could be easily modified to also take into account previous lot/tool TPT performance. Further, enhancements could include dynamic AMHS path decision making. In other words, which path between tools has the minimum travel time? This would require that Material Control System (MCS) software be able to accept input from a rules based decision making system and respond correctly. Usually the MCS is hard wired as to lot paths through the AMHS system. The assumed benefit of this proposal is based on the additional assumption that the factory is in fact unstable in so far as tool set TPT and Yield is concerned. In fact, it would be more beneficial to the overall profitability of the factory system that all variability be eliminated; completely removing any benefit achieved by implementing a distributed decision making system.   While eliminating all variability in a factories is of course the goal, it is actually very difficult to achieve due to the complexity of the tool sets, their unavoidable mechanical and electrical failures, and the introduction of new processes. It is true that as a process matures Process Engineers (PEs) are effective at ever increasing the factories ISO and reducing the variability in the overall TPT. However, early in a processes life cycle the factory is indeed more unstable than at its' maturity but it is during this early "unstable" period when the factories product have the highest market value and therefore when the factory has the highest profit potential. Therefore, while the more important goal is to eliminate the same variability that makes the distributed lot movement theory valuable it is expected that the theory will indeed dynamically optimize the factory's TPT and Yield in whatever health state the factory exists. And in fact the best case optimization provided by the proposed distributed lot movement decision making system will have its biggest impact during the early highest profit potential stage of the factory. In short, it is proposed that dynamic distributed lot movement decision making will minimize a factory's TPT, and maximize its Yield, for any given process maturity, maximizing factory profits with the largest effect occurring when profit potential is at its highest. And the factory is at its' most unstable.

There are some gaps that must be closed to take this concept to fruition. First, variability based on wafer problems must be distinguished from variability based on tool problems as the former supplies the intelligent system with false warnings of tool health issues.

Secondly, a better understanding of the statistics governing the TPT and lot Yield differential analysis must be obtained to determine the validity of this theory.
Thirdly, discussions of the concept with a colleague has resulted in the realization that ISO may be irrelevant as intelligent system input because the lagging indicator associated with measuring Yield at end of line may be too late to effectively control the process.

Now, the proposal above is not actually a perfectly distributed decision making process. The lots are only generating data that is fed into the super system control computer. An analogy is that worker bees do not have some supreme decision making bee hovering above their hive to whom they feed data that in return tells the workers what to do. However, the next technical evolution of this "distributed decision making process" could indeed be a true distributed decision making model by utilization of lot e-tags (with send and receive capabilities), local Infar Red communication, and local AMHS data input and control. This 2nd generation distributed decision making system could eliminate the need for overall AMHS control systems and routing tools. The factory itself would dynamically decide what lots to route where without any centralized decision making system comprehending the big picture. Just like a bee going about its business in a highly effective and unknowing manner, resulting in the optimum decision for its hive, our lots can optimize their own movement without really having any individual concept of what they are doing or why.

Solution Concept Relation to Trends of Engineering System Evolution



Trend of Increasing Controllability:

As Engineering Systems evolve they develop more ways in which they can be controlled. Increasing Controllability is a sub-trend of the Trend of Increasing Coordination – increasing controllability causes an increase in coordination

1.) Level of control with in the Engineering System increases:

- Uncontrolled system (i.e., open intersection, rocket)
- Fixed program (all lots as a group) (i.e., timed traffic light, cruise missile)
- Fixed program w/ intervention (i.e., timed traffic light w/ detection, watch resets by user for time change)
- Externally controlled (all lots as a group) (i.e., traffic cop @ intersection, laser guided missile)
- Self controlled (all lots as a group) (i.e., detection controlled traffic light, target seeking missile)
  - Macro level (i.e., a/c with thermostat)
  - Micro level (i.e., relief valve)

2.) Number of controllable states increases (all stable except last one):

- Single state (i.e., Chinese umbrella – always open)
- Multiple states – discrete (i.e., modern umbrella, car seat w/ stops, TV)
- Multiple states – infinitely variable (i.e., speaker volume, screw drive for position)
- Multiple states – multiple resources (i.e., hybrid car with electric and gas engines)
- Dynamically stable states (i.e., bicycle, F24 raptor)
- Unstable state – non-reversible/ unstable to stable (i.e., mouse trap, air bag, land mine)

Trend of Uneven Development of System Components:

As an Engineering System evolves, development is concentrated on the operating agent first, and then on the rest of the system later. (i.e., Auto – during early development, the automobile engine was the most sophisticated component in the system. Now the engine is the least sophisticated component in the system.)

Focus shifted from processing tools to control systems

Trend of Decreasing Human Involvement:

As an Engineering System evolves the number of system functions performed by humans decreases. Before an Engineering System emerges, humans perform the functions at all levels (otherwise, the functions do not exist). This trend is an essential sub-trend of the Trend of Increasing Completeness (Section 22).

complete

Humans Stop Performing:

- Transmission
- Energy source
- Control
- Decision Making

Trend of Increasing Coordination:

As an Engineering Systems evolves, characteristics of the Components of the System become more coordinated with each other and the Supersystem.

Coordination – selection of a Parameter value with reference to the values of other Parameters.

1.) Coordination of shape (no implied sequence to 4 bullets below)
- Identical (i.e., nut and bolt threads)
- Self compatible (i.e., brick 1X2 – allows for multiple pattern combinations)
- Compatible (i.e., ergonomic tool)
- Special (i.e., bulbous bow on ship – reduces drag)

2.) Coordination of Rhythms (no implied sequence to 3 bullets below)
- Identical (i.e., advanced 3D movies – L&R blink flash alternatively along with goggles)
- Complementary (i.e., mass PC network calculation during PC dormant times – extraterrestrial search program)
- Special – (i.e., vibrating massager coordinates with mechanical properties of body)

3.) Coordination of Materials
- Identical
- Similar
- Inert
- Materials with shifted Parameters (i.e., Thermocouples)
- Materials with opposite Parameters (i.e., Si transistors – conductor and insulator)

Coordinated Materials	heart transplant	blood transfusion
Identical	cloned heart	autoreinfusion
Similar	donated heart	donated blood
Inert	artificial heart	saline solution

4.) Coordination of Action
- 0 D, 1 D, 2 D, 3 D

Evolution Direction (0D - 3D)	Resource Available	
Desired Effect	Excess	Deficit
Strong Interaction	A →	← B
Weak Interaction	← C	D →

Coordination of Action	0D	1D	2D	3D
evolution direction → A	fishing pole	long line	net	trawling basket
evolution direction → A	computer	2 linked	internet	wireless connectivity
evolution direction ← B	pick	axe	hammer	meat tenderizer hammer
evolution direction ← C	point contact pizza box	corrugated bottom pizza box	flat bottom pizza box	
evolution direction → D	DW Conley, all	rights reserved	safety net	stuntman air bag

5.) General Coordination Sub-trend

a.) Parameters coordinate in the following order (mainly informational):
- Identical Parameters (i.e., shot pattern from gun matches bird cross-section)
- Different parameters (i.e., diapers absorb liquid and transport material away from skin – absorption and material movement)
- Internal Parameters (i.e., Japanese auto parts wear rate – coordinated to be multiples of each other)
- Internal and external Parameters (i.e., Stealth design to not reflect radar, trains size coordinated with bridge and tunnel sizes)

b.) The 3 stages of coordination (more instrumental):
- Limit coordination - The Parameters of the Engineering System are coordinated with the most limited element of the system (i.e., bow is limited by strength of archer)
- Mediator coordination - The Parameters of the Engineering System are coordinated by introducing intermediate components (i.e., cross bow cocking wench coordinates human strength with string draw)
- Self coordination - The parameters of the Engineering System are coordinated by using the system's own resources (i.e., modern gun - firepower is now independent of human strength)

Trend of Flow Enhancement:

As an Engineering System evolves, flow rates of substances, energy, or data increase, and/or the flows are better utilized:

1.) Improve useful flows

a.) Increase of conductivity
- Reduce the number of flow transformations (i.e., diesel engine to fuel cell)
- Transition to a more efficient flow type (i.e., electronic modem to optical)
- Reduce the length of the flow (i.e., belt to pneumatic dentist drill)
- Eliminate "gray zones" (i.e., fish finder)
- Eliminate "bottlenecks" (i.e., filter to cyclone separator)
- Create a bypass (i.e., bypass surgery)
- Increase the conductivity of the separate parts of the flow channel (i.e., 2 to 8 lanes)
- Increase the density of the flow (i.e., compressed natural gas distribution)
- Apply the useful action of one flow to another (i.e., use flowing water to carry a log flow)

- Apply the useful action of one flow to the channel of another flow (i.e., combine liquid hydrogen and electrical cables in a single channel – hydrogen cools conductor and decreases resistivity)
- Arrange for one flow to carry another flow (i.e., register tape with indicator markings)
- Allot many flows to one channel (i.e., fiber optics)
- Modify the flow to increase conductivity (i.e., visible light to x-ray)
- Direct the flow through a Supersystem channel (i.e., radio waves through the air)

b.) Improved flow utilization

- Eliminate a stagnant zone (i.e., intersection to overpass)
- Utilize impulse action (i.e., water jet demo of concrete)
- Utilize resonance (i.e., vibrating conveyor)
- Modulate the flow (i.e., loosen snow and then remove from runway by jet blast from landing aircraft)
- Redistribute the flow (i.e., glass cutting scoring, lightening rod point)
- Combine homogeneous flows (i.e., Viking ship rowing)
- Utilize recirculation (i.e., synchrotron, generator coils)
- Combine two different flows to obtain synergy (i.e., anthrax killed by both heat and disinfectant applied at low levels – neither works alone) – this is not easy or very often achievable
- Preset the necessary substance, energy, or information (i.e., sleeping pills contain a small amount of antidote in case of overdose, landmines)

2.) Reduce negative effects of Harmful/incidental flows

a.) Reduce the conductivity of Harmful/incidental flows

- Increase the number of flow transformations (i.e., thermal insulator – conduction, convection, conduction, convection)
- Transition to a low-conductivity flow (i.e., stealth materials)
- Increase the length of the flow (i.e., labyrinth seal)
- Introduce bottlenecks (i.e., sunglasses)
- Introduce stagnant zones (i.e., respirator)
- Reduce the conductivity of part of the flow channel (i.e., wood handled frying pan)
- Utilize recirculation (i.e., vehicle muffler – bounced wave cancels noise)

b.) Reduce the impact of Harmful flows

- Introduce gray zones (i.e., camouflage)
- Reduce the density of the flow (i.e., rotate missile to lessen laser impact)
- Eliminate resonance (i.e., vehicle suspension)
- Redistribute the flow (i.e., high beam/low beam – not blind others)

- Combine a flow and an anti-flow (i.e., reactive armor, noise canceling headphones)
- Modify the flow (i.e., lithography area lighting)
- Modify the damaged object (i.e., chrome plating resist road salt damage)
- Preset the substance, energy, or data that will be required to neutralize the flow (i.e., deodorant)
- Bypass (i.e., electrical grounding)
- Transfer the flow to the Supersystem (i.e., CPU cooler – blows heat out of CPU)
- Recycle or recover incidental flows (i.e., gray water for lawns, filtered clothes dryer exhaust for room heat)

Trend of Increasing Completeness of a System:

As an Engineering System evolves, it acquires the following typical functions:

1.) Function of operating agent (part of Main Function)
2.) Function of transmission (transfer of energy)
3.) Function of energy source (energy to operate system)
4.) Function of control (system to control)

Operating agent → rock
Transmission → spear
Energy source → gun
Control → cruise missile

(↓ increasing completeness)

Trend of Increasing Degree of Trimming:

As an Engineering System evolves, system elements (components or operations) are eliminated without impairing the functionality of the system, and possibly improving it.

There are 3 Sub Trends:

1.) Trimming Subsystems
   a.) Transmission (i.e., belt driven to internally driven modern machinery)
   b.) Energy Source (i.e., arc welder to encased explosive welding)

c.) Control System (i.e., heat controlled by thermometer to use of curie point of a material to stop the heating process)
d.) Operating Agent (i.e., lawn mower to max. height grass)

2.) Trimming Operations
   a.) Operations with Corrective Functions (i.e., eliminating need for water removal in paper manufacturing)
   b.) Operations with Providing Functions (i.e., elimination of pre-painting priming step)
   c.) Operations with Productive Functions (i.e., elimination of heat treatment of metal)
3.) Trimming Components with the Lowest Value

WIP Formulas:

CT = CTq + EPT
CTq = Variable + utilization + throughput
V = $(Ca^2 + Ce^2)/2$
A=arrival
E = processing time
Coefficient of variation $C^2 = S^2/Xbar^2$

Ca^2 = biggest impact (arrival variation)