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“Autonomation: Symbiosis of Machines and Humans”

Track: Operations, Logistics, Supply Chain
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Introducing Autonomation

- Dominant issue in production and logistics is the dynamic balance of humans and machines in these operations
- Human role is changing:
  - Skills required increasing; more autonomy required
  - Human share of workload decreasing; trending to zero(?)
  - Research must determine the future of work: what role, job requirements
  - Seek the Optimal Balance; at the present and in the longer term
- For now, let's examine a possible balance - autonomation

Observing the Extent of Technology

- For many years, the author has applied a measure for the balance of humans and machines throughout an operation
- This measure, Technology Utilization Index (TUI), observes the extent of automation and information technology across all workstations of any production process
- The methodology is detailed in the next slides:
  - Defined with measurement
  - Meaning for design, improvement of performance
  - Examples of application in production and logistics operations

Observing Technology Utilization: Measure the extent of AUTO and INFO TECH

- 0 - indicates no technology present, dominate human motion and paper records
- 1/2- indicates both a human and machine present, human action in proximity but using a terminal or portable device to cause motion and read/record data electronically
- 1 - machine conducts operations automatically and senses all information

Technology Scoring Examples

- 0 – human carrying material, forklift operation, paper directives and paper recording
- ½ - Machine operated by button/switch or terminal entry by humans, handheld electronic devices, continuous worker monitoring
- 1 – Bar code reader, PLC or computer direct operations, infrequent human observation

Technology Utilization Index (TUI)

- A utilization index is determined by summing two scores at each station, for all operations and transit activities, divided by the total number of scores possible:
- Example:

$$TUI = \frac{(0+1/2)_1 + (1/2+1)_2 + (1+1)_3}{3(2)}$$

$$TUI = 4/6 = 67\%$$

Observing this Balance

- Price's Technology Utilization Index (TUI) field tests:
  - Scored many warehouses, TUI range up to 92%, but most measure 20-40%.
  - What TUI is optimal, desirable for any warehouse operation?
- A contract product service company – FLEX. Their production systems were observed at 60-70%; with these factors affecting TUI:
  - Product/production with no automation design available
  - Designer prefers workers present at some share of Workstations
  - Productivity demands are achieved by a higher TUI
  - Prepared production workers/engineers not available, TUI must rise
    - FLEX – At Milpitas facility, now 90 staff members short

Autonomy Builds on TUI

- An elaboration of a machine – human continuum:

  Autonomous Machine - Automation – Autonomation - Autonomous Human

- Autonomous machines with AI/ML create higher productivity and flexibility, decrease need to involve humans in work tasks
- Yet autonomation or autonomous humans are necessary when machines are incapable, confused or make errors (weak learning/programming)
- Humans provide redundancy, a backup to seek correct/rational action
- Humans skills still valuable:

  Design adaption/adoption, flexibility/cooperation, empathy/interpersonal skill

Autonomation, Similar Terminology

- Autonomation has been defined as "Automation with a Human Touch"
- The Japanese theory of Jidoka/Poka-Yoke means error proofing
  - Humans observing machine behavior, intervening when needed to ensure acceptable outcomes.
- Another: Co-botics, a collaboration between a person and a robot
- In general, a "symbiosis of machine and human"
  - Not in the "cyborg" sense of mechanical components in biological systems, but sharing thinking/acting in conduct of operations

A General Theory of Autonomation

- Machines are assigned certain tasks, avoiding human fatigue/safety
- Humans perform tasks when their knowledge/adaptability are needed
- If a machine is confused, acts erroneously or breaks down, human intervention is necessary
- The machine may know it must stop, ask for help (Andon Red Light or e-signal), production time is being lost
- Human responds autonomously, never wait for a decision or direction

General Theory (continued)

- Human capability may be weaker, depend on machine intelligence to comprehend, act quickly and correctly
- Machine intelligence can be denied by weak design of e-instructions, prompting well prepared human knowledge to take control
- Yet, at any workstation for any task, weak performance of either machines or humans suggests a redundancy (autonomation)
- Combining these two resources intends to optimize production outcomes – minimize error, breakdown, delay and system failure, while minimizing total cost of design/operations and failure response

What does Optimization Require?

- Smarter Machines – physical design and software sophistication
  - Software coding fails too often, must be called weak “engineering”
- Smarter humans – necessary preparation, certified/licensed capability
  - As humans act more autonomously, skills/expertise must be found
- Enhanced ability by both most likely to be needed, must be achieved
- The balance at each workstation may vary:
  - Sometimes increased human involvement is preferred
  - Sometimes machine improvement will evolve and be chosen

Learning by Case Studies

- Autopilot and Aer Lingus from Shannon to JFK – June 2000:
  - Returning from a vacation in Ireland, delayed and managed to get “bumped” to first class
  - Airbus 330, with 10 seats forward of the cockpit door and open to those first-class passengers (before September 11, 2001)
  - Able to sit with the pilots and observe their involvement with an Autopilot system they had invoked
  - Pilots started takeoff themselves, let the autopilot control rotation/liftoff
  - Never touched controls across the Atlantic, just watching for other traffic
  - As they approached landing, final steps were handled by a pilot
    (My Navy experience with carrier landings, pilots always took control – lack of trust)

Case Study Two

- Asiana Flight 214, descending to SFO – July 2013:
  - Boeing 777 - autopilot handling approach to runway 28L
  - Plane autopilot slips below guide path, does not correct itself
  - Real pilots notice plane too low, wait for autopilot to correct or to sound a signal for humans to correct. Tower backup response is down!
  - Pilots try to take control, apply power to “go-around”, but it is too late
  - Plane hits runway embankment in SF Bay, bounces onto runway and breaks apart. Only 3 deaths on the ground during fire fight.
  - Autonomation failures: Autopilot design incorrect, failed to adapt
Crew had no timely intervention as expected

Learning from Terrible, Repetitive Autonomation Failures

- Boeing 737 Max, disasters with Lion 610 and Ethiopian 302 – two very similar accidents within six months – October 2018 and March 2019:
  - Just unacceptable toll: 189 + 149 lives lost, passengers and crews
- Both flights were taking off with MCAS – Maneuvering Characteristics Augmentation System or autopilot function operating
- Faulty sensor information or poor interaction with the pilots during takeoff, caused both planes to sense stall and to turn the plane down to gain speed and recover from a stall; was a stall actually occurring?

737 Max Disasters Case (continues)

- Human Pilots unable to comprehend their correct recover action, while at low altitude, autopilot keeps turning plane down, pilots unable to determine action to turn off autopilot and fully recover
- Both aircraft crash shortly after takeoff with too little time for pilots to identify the correct action
- Maybe impossible to survive at low elevation without a new design:
  - Was it MCAS's fault by acting erroneously, with bad data or wrong coding?
  - Was the crew unprepared to find a solution, given weak training/practice or due to slow and inadequate thinking?

Autonomation Failure

- Neither actor could overcome the other's failure – opposite of the intention of an autonomation design
- While redundancy is expected to avoid failure, in these repetitive, similar stories of autonomation, both actors failed at the same time
- Even redundancy has a potential/risk of disaster, if at least one partner will not act correctly in 100% of all situations
- The aircraft and autopilot designs both failed to provide a system, in this event, where the probability of an aircraft crash was near zero
- Who are guilty/at fault, what should have been done to avoid disaster?

Acting to Avoid Failure/Disaster

- Fault is everywhere:
  - Blame starts with Boeing and the FAA, but extends to airlines and pilots (Glanz, et al, "Behind the Lion Air Crash", New York Times, Feb. 3, 2019)
- Beyond aircraft designer and operator, must we depend on others:
  - Stakeholders: airline employees, passengers/travel professionals and government regulators, even educators
- An Academic Reader is coming, by this author, to serve a variety of disciplines with continuing case studies, entitled "Learning to Avoid Disruption/Disaster"; inquire at wprice@pacific.edu

Depending on Other Actors

- Beyond aircraft designer and operator, must we depend on others:
  - Additional actors to have demanded avoidance in the first place or, reluctantly, act now to learn and improve from this case
- Stakeholders:
  - Airline employees:
    - Managers, engineers, maintainers and crews can all demand, imagine and act
  - Passengers/travel professionals
    - Do passengers know the risk, would they resist flying if risk too high
  - Government regulators, in this case FAA of USDOT:
    - Politically, the FAA often has a cozy relationship with the airline industry, letting self-regulation govern and failing to imagine aircraft operation with businesses in-charge
    - Purpose of regulation, no matter by whom, is to protect the flying public, crews, others

Further References

- Autonomation:
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- Boeing 737 Max Cases:
  - U. S. FAA, "Boeing 737 MAX Flight Control System: Observations, Findings and Recommendations", Joint Authorities Technical Review, Oct. 11, 2019
  - Beech and Suhartono, "Spend the Minimum: After Crash, Lion's Air's Safety Record Back in Spotlight", New York Times, Nov. 22, 2018
  - Robert Wall, "Airbus Foresees More Regulatory Scrutiny after Boeing's 737 MAX Crashes", The Wall Street Journal, May 21, 2019