Problem Solving and Process Improvement in context of the Fourth Industrial Revolution

with reference to Root Cause Analysis, Lean Six Sigma, Managerial Problem Solving and Decision Making

J Adriaan du Plessis
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Disruptive Change

The advent of Industry 4.0 and the subsequent impact of the Fourth Industrial Revolution is disruptive to manufacturing and service businesses alike. Irrespective of technology choices product, service and business processes are forcefully catapulted to a new paradigm.

The disruptive change is so powerful that businesses do not have a choice but to adapt and adapt fast. It is probably said best by the Yoda character in Star Wars - "*Do or do not. There is no try*."

There is no option for halfhearted adaptation to the 4^{th} Industrial Revolution, the only outcome of such an approach, will be lack of competitiveness and eventually, the demise of the business.

The Client, Employee, Product, Service and Business Process Impact

Clients are increasingly interconnected with businesses and its stakeholders, in many instances, due to the presence of *Cyber Physical Systems*. The use of integrated networked technology is no longer optional, it has become the life blood of business, and its impact is accelerating at an exponential pace.

Products and Services are also drastically changing, it is no longer good enough to provide required product and service features defect free, clients shifted and often link their purchase to 'an experience' or entry to 'a community'. A demand that product and service should increase the pleasure of the personal life of a customer, is fast on its way to be the "new normal".

Business Process have become heavily technology infused and digitized. As a result, the complexity and operational speed of business processes are increasing dramatically. Increasing management and problem-solving complexity occurs as a result of automation, augmented reality, digital (software) platform integration, and more "open" business models.

Employees are significantly impacted and need to adapt since repetitive and manual tasks are easily automated. Reskilling to remain gainfully employed is not optional. Jobs that require complex human thinking such as conducting a recruitment interview are, however, likely to remain unchanged.

The Internet of Things (IoT)

The large number of interconnected devices and cyber physical systems, generate and record vast amounts of data in business processes, as well as the behavioral data of customers and employees.

The IoT creates an abundance of data, both qualitative and quantitative data is recorded everywhere. The business world is now data rich, and the information derived from data enables "*data driven decision making*" in business, like never before.

The Internet of Service (IoS)

The IoS is a lessor discussed, yet not less important component, of the 4th Industrial revolution. In large part the increase in complexity in business processes is described by the IoS, since it describes the "invisible" digital functionality that enables the IoT, as well as the collaboration of people and cyber physical systems.

The IoS is best described as the abstract functionality of the digital architecture, inside and outside of the business. These systems and digital platforms are no longer a "functional tool" in the business process, in many cases it is the business process, or a significant part of it.

A New Competitiveness Driver

Data converted to information is a valuable business knowledge creator and a major input to competitive advantage. The market for customer data is growing at a rapid pace and is expected to be worth $229 billion by 2025.

The use of data by business, created a significant revenue stream for the Information Technology Industry and the continued growth in demand for data, fuels innovation and the expansion of the 4th industrial revolution.

A further consequence of the 4th Industrial Revolution, due to ever increasing computing power, machine learning, automation and robotics of various kinds, is that a business can now produce the same products and services as before, but in a more efficient manner. Increasingly this causes a reduction in the labor required per product/service output unit. The impact will depend on the nature of each industry and will be different. The jobs most affected (these will reduce in number and may disappear), are routine and repetitive occupations in the middle of the employment hierarchy.

Is Problem Solving, Lean and Six Sigma Obsolete?

Problem Solving and Process Improvement

In the fourth industrial revolution, business systems remain a collaboration between People, Processes and Technology. The main difference is that technology, specifically information technology, rose to a dominant position in business systems. Processes in business systems were traditionally improved with problem solving methodologies such as ***Lean Thinking*** and ***Six Sigma*** (or the combination thereof, i.e. Lean Six Sigma). In addition, these projects are supported with a plethora of problem solving and root cause analysis tools.

Data Science is a recent information technology centric methodology and occupation that is a core component of the 4th industrial revolution. Technically, data science requires higher-level knowledge and skill and spans several fields of study. It depends significantly on coding skills (scripting language) and the domain knowledge of a specific industry, for successful use. Data Science practitioners are well educated and highly skilled individuals who are able to work at high levels of complexity.

Data Science typically aims to address a business problem by creating insight for decision making, through the use of

- data acquisition
- data cleanup
- data analysis and visualization
- modelling of the data (and)
- deploying model(s) for use by business.

An important consideration is that Lean Thinking, Six Sigma and Data Science are all multidisciplinary methodologies, it integrates knowledge and skill components in an improvement methodology. The methodologies can at a high level be summarized as:

- Lean Thinking
  - *Current State – Analysis – Future State*
    - *Improvement method 1: Event Based Improvement (Kaizen Team Event)*
    - *Improvement method 2: Value Stream Mapping, Analysis and Improvement*
    - *Problem Solving Heuristics with various problem-solving tools*
- Six Sigma
  - *Define – Measure – Analyze - Improve – Control*
    - *Improvement method: DMAIC Process Improvement Project*
  - *Define – Measure – Analyze – Design – Verify*
    - *Improvement method: DMADV Project for product and process innovation*
- Data Science
  - *Business Problem - Data Acquisition & Preparation - Data Exploration, Model & Data Visualization - Deploy and Maintain Model*
    - *Improvement method: Data driven specialist project.*

Is Lean Six Sigma Obsolete?

Lean Six Sigma practitioners should recognize that since the 4th industrial revolution is changing business; it will bring change to process improvement methodology. The question is whether current process improvement methodologies are redundant or alternatively, are in need of adaptation. For the purpose of review, Lean and Six Sigma will be separated and compared to Data Science.

Lean Thinking focusses on increasing value to the customer by [1] removing waste (non-value adds), [2] reduce problems (distance, time, flow constraints, technical problems, negative events and bottlenecks) and [3] operations management issues such as the capacity of a process, the load placed on the process, as well as the number people working in the process.

Lean is generally touted as an improvement methodology [a] based on observation of the business process, [b] involves employees at all organizational levels, and [c] aims to make many small changes, that will be beneficial to the customer and the efficiency of the business process. Lean analysis therefore focusses attention on

- the interfaces between physical process infrastructure and people
- process components and the interfaces between the physical components of the process
- the interface between people and digital infrastructure
- the interfaces between people, internally as well as externally with customers and suppliers.

As a result of the 4th industrial revolution, business processes are increasingly automated and software robotics added. Augmented reality is becoming commonplace, i.e. “chatbots”. A natural consequence of automation and robotics is that the time and distance measurements traditionally used by Lean, now have very small values. Digital process functionality can generally not be observed physically, except for observation of process outputs and a review of the software program code.

When Lean is compared to Data Science, the following can be deduced:

- the overlap of Lean and Data Science can be found in the operations management component of lean, such as logistics, workflow, capacity planning, process load and resource allocation. Data science can create models based on process data to optimize the operations management items included in Lean.
- Lean Thinking remains unique in its ability to identify waste, and to create high level understanding of the flow of business, from the customer to delivery of value to the customer (Value Stream Mapping). Value Stream Mapping is a critical tool for business domain understanding and is therefore integral to management education.

A significant volume of business process will, however, retain its 3rd Industrial Revolution characteristics for time to come, and Lean Thinking will continue to play a key role in these businesses. Whether waste is physical, intangible or digital, waste remains and can be identified, especially where humans interacts with systems. In addition, in such interactions, flow of work and many traditional Lean concepts remain useful.

Operational problem solving and root cause analysis for ***events, incidents and accidents***, are generally categorized as a component of Lean Thinking. Whilst the methods would largely remain the same, it is expected that problems will increase in complexity, however, data and information for problem solving will be more readily available.

To ensure effective operational problem solving, domain knowledge therefore need to be enriched with suitable problem-solving heuristics and be adjusted to analyze increasingly complex problems. Some lower-level problem solving, i.e., checklist style troubleshooting, could potentially be automated as part of process control systems, and software robots could make a significant contribution in a highly digitized process, especially in respect of data gathering.

Six Sigma as a methodology engages in data driven analysis to address product and service deficiencies. The main focus is on defects associated with customer quality requirements. Six Sigma is a predominantly data driven methodology with 4 major foci for analysis

- Customer requirements
- Process analysis
- Data analysis { Y = f(x) } – *Input – Process - Output*
- Future control of critical variables.

Six Sigma is based on [a] collection of data, [b] uses a multidisciplinary project team, and [c] work towards breakthrough change/s, that will improve customer satisfaction and experience. Six Sigma analysis focus on

- using valid data (valid sampling and measurement system analysis)
- graphical and statistical analysis of data
- performance benchmarking: moving processes to target values and reducing variation around the target value
- predictive models such as regression and design of experiments (DOE) at higher levels
- data analysis to validate that proposed solutions work
- quantification of financial benefits resulting from process improvement.

It can be theorized that Six Sigma is probably better “future” aligned than Lean Thinking, due to its data driven approach. When Six Sigma is compared to Data Science, the following can be viewed as common characteristics:

- six sigma and data science both uses data acquisition, analysis and model creation
- statistics and data visualization are used in both approaches
- projects implement a “research style” project to achieve goals

- both approaches require the skills and knowledge of individuals who are able to function at higher levels of complexity and decision making.

A Basis for Future Problem Solving in Business

Future Problem Solving and Process Improvement

The World Economic Forum in its research concluded that the top 4 skills required within the workforce in 2020 would be (in descending order):

- Cognitive Abilities ("*critical thinking*")
- Systems Skills ("*information technology*")
- Complex Problem Solving
- Content Skills ("*business domain knowledge*").

The 4th Industrial Revolution seem very dependent on critical thinking skills and logic. A suitable approach to the future use of problem solving and process improvement methodologies, would be to [a] review the complexity of the problems that the business need to solve, [b] consider who in the organizational hierarchy would need to employ critical thinking skills to solve these problems, [c], determine the core problem solving tools, heuristics and appropriate methodology to use, and [d] build an organizational learning model for problem solving. It is extremely insightful that specific business domain knowledge (i.e. related to a specific business) and skill, is very important in the 4th Industrial Revolution.

The types of problems generally recognized by problem solvers and process improvement specialists are in 4 categories, namely:

- Abnormal Events
- Performance Deviation (from a standard)
- Target Condition (to achieve)
- Innovation.

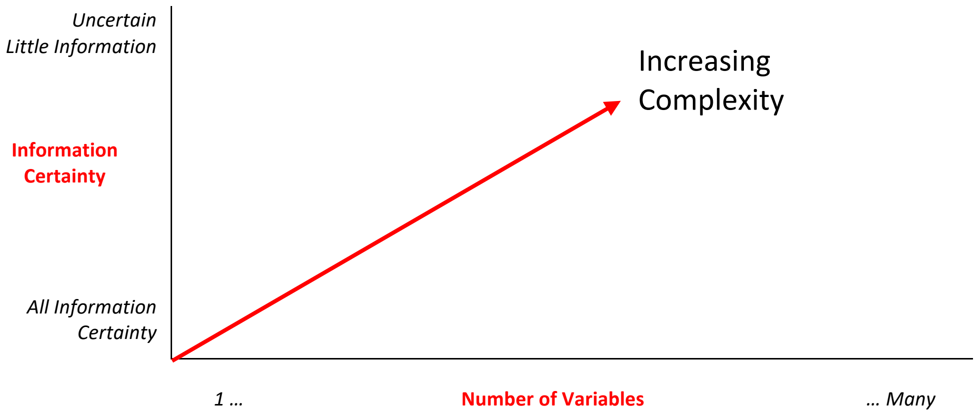
It follows logically that the thinking skills, tools, heuristics and methodology needed to solve the various types of problem, will overlap, but will differ for the problem types.

Complexity – People – Problem Solving – Process Improvement

Cognitive ability is the ability of an individual to process complex scenarios and make appropriate decisions. When considering problem solving and process improvement methodology for the future, the following are therefore relevant considerations:

- the complexity of the problem in hand, (and)
- matching the problem with a person who can function at that level of complexity
- use of the appropriate problem-solving tool/s and methodology for the problem.

A problem can be regarded as complex if it has many components (variables) that are linked and in many cases interacting with each other, resulting in a higher-level scenario which is a problem to the stakeholders in the specific scenario. Lack of information about the problem variables, will complicate the problem scenario and increase the scope of problem-solving activity. Simplified, the complexity of problems can be illustrated as follow.



Business problems, can in terms of Increasing complexity, be categorized as follow (using the terms originally coined by Stacey).

- Simple
- Complicated
- Complex
- Chaotic.

The ability of a person to cognitively deal with complexity (a problem), is directly related to the ability of the individual to organize and analyze the variables associated with the problem (problem analysis). The cognitive ability of individuals to manage complexity, differs, and consequently problems need to be allocated to individuals who has the appropriate cognitive profile. The modes of thinking an individual will employ for problem solving are:

- Divergent Thinking: *Expands outwards by generating multiple ideas, or, breaking a problem down in its various components.*
- Convergent Analytical Thinking: *Narrows down multiple ideas to a solution.*
- Systemic Thinking: *The understanding of how the different parts of a system influence one another within a whole.*

It is hypothesized, to solve a problem, that one of the thinking modes will be dominant at the start of the problem-solving process, this initial dominant thinking mode and other modes of thinking, will thereafter be used as needed in the problem-solving process.

The complexity of problems is listed below (based on information certainty and number of variables):

- Simple Problem: *Information is certain and only a limited number of variables need to be considered. The problem that can be solved with rational thinking, based on domain knowledge, using a checklist style troubleshooting tool.*
- Complicated U: *The problem is complicated due to significant information uncertainty and problem solving need to include increasing information certainty.*
- Complicated D: *The problem is complicated due to the presence of a large number of related variables. Problem solving will include the filtering of variables to determine significant variables.*
- Complex UD: *This kind of problem is complex since it has significant information uncertainty and a large number of relevant variables.*
- Complex U: *Problem complexity is due to extreme information uncertainty.*
- Complex D: *Complexity of the problem is a result of a large number of variables.*
- Chaos: *This problem type is information uncertain but lots of variables are potentially available, that may be relevant.*

The current status of problem complexity, people, problem solving and process improvement in business, can be summarized as follow:

<table>
<tr><td>Uncertain Little Information</td><td colspan="2"><u>Complex U</u>
• Thinking: Systemic …
• Method: Value Stream Mapping
• Method: Lean Six Sigma</td><td><u>Chaos Problem</u>
• Thinking: Systemic …
• Method: Competitiveness, Strategy & Risk
• Method: Business Model & Architecture</td></tr>
<tr><td>Information Certainty</td><td><u>Complicated U</u>
• Thinking: Divergent …
• Method: Root Cause Analysis
• Method: Lean Kaizen Event</td><td><u>Complex UD</u>
• Thinking: Systemic …
• Method: Root Cause Analysis
• Method: Lean Six Sigma
• Method: Value Stream Mapping</td><td rowspan="2"><u>Complex D</u>
• Thinking: Systemic …
• Method: Root Cause Analysis
• Method: Lean Six Sigma
• Method: Design for Six Sigma</td></tr>
<tr><td>Information Certainty</td><td><u>Simple Problem</u>
• Thinking: Convergent Analytical…
• Method: Trouble Shooting & Troubleshooting Heuristics
• Method: Lean – Low Level Kaizen Event</td><td><u>Complicated D</u>
• Thinking: Convergent Analytical…
• Method: Root Cause Analysis
• Method: Lean Six Sigma</td></tr>
<tr><td></td><td>1 . . .</td><td>Number of Variables</td><td>. . . Many</td></tr>
</table>

Problem solving tools and methodology, like humans, need to be matched to the complexity of the problem in hand. A straightforward " Laser Printer – Not Printing", does not need statistics for problem solving, it requires a simple checklist-based fault-finding technique. The core consideration is therefore to match problem complexity, to the correct tool or methodology, then to a person or team.

The 4th Industrial Revolution will also spawn the automation of some problem solving and the employment of software robots in problem solving.

Problem-solving and methodologies will probably be affected as follow

- Troubleshooting and Root Cause Analysis
  - **4IR Impact:** *Automation of problem solving for Simple Problems and partial automation for complicated and complex problems. It is expected that the divergent thinking tasks (i.e. information gathering and ideas) will be automated with relative ease.*
  - **Solution:** *Provide for root cause analysis in information technology and digital environments. Adjust the methods to function at various levels of complexity and build software robots for information gathering.*

- Lean Six Sigma DMAIC (Yellow Belt), Lean Basics and Kaizen Event
  - **4IR Impact:** *Data science can more effectively deal with process flow and logistics in a mathematical model and therefore these components will likely disappear from Lean implementation.*
  - **Solution:** *Refocus the curriculum for Lean Six Sigma Yellow Belt on Customer Value and Waste removal where people and digital systems interact. Include mathematical literacy as well as more refined and powerful troubleshooting skills for simple (though potentially quite technical) problems.*

- Lean Six Sigma DMAIC Green and Black Belt
  - **4IR Impact:** *The abundance of data generated by the IoT will push Six Sigma back to its previous higher levels of graphical and statistical analysis. It is at present (especially at Green Belt level) often presented in a "dumb down" state in order to appeal to a larger audience.*
  - **Solution:** *Lean Six Sigma Green Belt to revert back to a data driven curriculum and must include basic probability and parametric statistics. Lean Six Sigma Black Belt to be enriched with*
    - *Big Data and Management of Big Data*
    - *Data extraction from Big Data*
    - *Big Data as a Source of Projects*
    - *Evaluating the validity or Data*
    - *Evaluating the validity of analysis*
    - *Supervised machine learning (Regression and Design for Six Sigma components)*
    - *More modelling tools to the Analyze and Improve phases, specifically for categorical data in relation to the customer space.*

- Value Stream Mapping
  - **4IR Impact:** Value Stream Maps will be inadequate for decision making since it often ignores software platforms, processes and inadequately deals with Cyber Physical Systems, in its flow diagram. The value stream diagram could also be "automated" to be a management information system and will in its digital form

become a key building block of the business architecture, and the capture of domain knowledge.

- **Solution:** Substantially upgrade the Value Stream map method to place significant emphasis on the digitized components of the business. Automate Value Stream measurements and design it to be a managerial information system. It should be included as a key component in managerial and executive education.

It is postulated that problem solving and problem-solving methodology in its adjusted form, will be employed as follow in business, for the various problem types with specific levels of complexity. Data Science is also included in this diagram.

<table>
<tr><td>Uncertain
Little
Information</td><td colspan="2">Complex U
• Abnormal Event
○ Research
• Performance Deviation
○ Lean Six Sigma Black Belt
• Target Condition
○ Value Stream Design
• Innovation
○ Data Science</td><td>Chaos Problem
• Abnormal Event
○ Strategy & Risk Decisions
• Performance Deviation
○ Competitiveness & COPQ
• Target Condition
○ Business Model & Architecture
• Innovation
○ Product Innovation
○ Data Science</td></tr>
<tr><td>Information
Certainty</td><td>Complicated U
• Abnormal Events
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<tr><td>All
Information
Certainty</td><td>Simple Problem
• Abnormal Events
○ Trouble Shooting Heuristic
• Performance Deviation
○ Trouble Shooting Heuristic
• Target Condition
○ Lean – Low Level Kaizen
• Innovation
○ Ideas & Decisions Heuristic</td><td>Complicated D
• Abnormal Events
○ Root Cause Analysis Heuristic
• Performance Deviation
○ Lean Six Sigma Green Belt
• Target Condition
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<tr><td></td><td>1 . . .</td><td>Number of Variables</td><td>. . . Many</td></tr>
</table>

Conclusions - Future Curricula

Various curricula currently exist for the above tools and methodologies. The existing curricula should be significantly adapted for more effective use within the context of the 4th Industrial Revolution. The following are general guidelines that should be considered when curricula are designed.

- Business process will in future all be ‘Cyber Physical Systems’
- Understanding of the IoT and Big Data is vital
- Thorough understanding of correct and appropriate data extraction from ‘Big Data’
- A basic understanding of ‘*scripting language*’ and ‘*data science tools*’ to acquire and analyze data

- Legal and Ethical use of “Big Data” outside the business and data generated inside the business
- Increased numerical literacy is required in relation to data analysis: graphical, statistical and modelling
- An understanding of Software Robotics and Machine Learning.

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