Digitalization Implementation
Decision Support Tool

Canada Research Chair
in Fuzzy Hybrid Decision Support Systems for Construction

Cenovus Energy

Construction Owners Association of Alberta
Workshop Outline

• Welcome and safety+productivity moment
• Digitalization defined
• Digitalization implementation in action – Mark Sombach/Cenovus Energy
• Decision support tool – Larry Staples/ COAA
• Fuzzy logic decision support tools for digitalization implementation – Mohammad Raoufi/UofA
• Community of Practice
• Workshop participation
Augmented Fitness (AF) is the augmentation of human fitness by machines, especially computer systems. These processes include auto-correction (fat fingers), interpolation (lethargic late afternoon keystrokes) and auto-generation of creative ideas (glazed-over screen stare).
Safety+Productivity Moment

**Bene-Fit (to humans)**
- Improved concentration
- Sharper memory
- Faster learning
- Mental stamina
- Enhanced creativity
- Lower stress
- Wellness
- Longevity


**Desk Fit**
- Standing desk
- Exercise ball seat
- 4 in 40
  - 150 m stroll
  - Shoulder roll
  - Arms-up stretch
  - Torso flex (four directions)
  - Leg flex

**Life Fit**

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Digitalization
International Energy Agency

“the increasing convergence between the digital and the physical worlds”

The digital world has three foundational elements:

• **Data**: digital data
• **Analytics**: use of data to create useful information and insights
• **Connectivity**: the exchange of data and information between humans, devices and machines (including machine-to-machine), through digital communications networks
Digitalization
COAA

People + Processes + Technology

Better information ... better decisions ... better productivity

Another pathway to improving heavy industrial construction productivity
Digitalization Context

REINVENTING CONSTRUCTION: A ROUTE TO HIGHER PRODUCTIVITY

McKinsey & Company
2017

Briefing by Jason Green
COAA Strategy Offsite, June 2017
Technology - lower digitization in construction relative to other industries has contributed to the productivity decline

1 Based on a set of metrics to assess digitization of assets (eight metrics), usage (11 metrics), and labor (eight metrics).

SOURCE: BEA; BLS; US Census; IDC; Gartner; McKinsey social technology survey; McKinsey Payments Map; LiveChat customer satisfaction report; Appbrain; US contact center decision-makers guide; eMarketer; Bluewolf; Computer Economics; industry expert interviews; McKinsey Global Institute analysis
Technology - infuse digital technology, new materials and advanced automation to achieve significant productivity improvements

Universally shape the basics...

- Invest in a chief digital/tech/innovation office and team
- Make 3D BIM universal
- Introduce drones and UAVs for scanning, monitoring, and mapping
- Use digital collaboration and mobility tools on portable devices

... and then push for advanced solutions

- Mobilize 5D BIM across the project lifecycle, with augmented/mixed reality interfaces
- Leverage the Internet of Things enabled fully connected sites (NFC, sensors, wearables)
- Implement advanced analytics on project and firm wide data
- Develop alternative and innovative materials
- Implement automation equipment on sites

Example: BIM has four main benefits¹

- 80% less analysis time
- 80% fewer change orders
- 20% shorter project lifespan
- 20% lower material costs

¹ According to a survey of 2,228 construction professionals working on multiple sites and academic research

SOURCE: McGraw Hill Construction Survey, Stanford University, MakMax
Construction can catch up with total economy productivity by taking action in seven areas:

Potential global productivity improvement\(^1\) from implementation of best practice

\(\%\) impact on productivity\(^2\)

<table>
<thead>
<tr>
<th>Enabler</th>
<th>48 - 60%</th>
<th>50%</th>
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<tbody>
<tr>
<td>Regulation</td>
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<tr>
<td>Collaboration &amp; Contracting</td>
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<td>Design &amp; Engineering</td>
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<td>Supply Chain Management</td>
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<td>Onsite execution</td>
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<td>Technology</td>
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<tr>
<td>Capability building</td>
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<tr>
<td>Cumulative impact</td>
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</table>

\(\text{Gap to Total Economy Productivity}\)\(^3\)

<table>
<thead>
<tr>
<th>Enabler</th>
<th>6 – 7%</th>
<th>27 - 38%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost savings</td>
<td></td>
<td>Octal point factors</td>
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<tr>
<td>Industry dynamics</td>
<td>7 – 10%</td>
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<tr>
<td>Firm-level operational factors</td>
<td>3 – 5%</td>
<td>4 – 5%</td>
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<tr>
<td></td>
<td>4 – 6%</td>
<td>3 – 5%</td>
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</table>

\(^1\) The impact numbers have been scaled down from a best case project number to reflect current levels of adoption and applicability across projects, based on respondents to the McKinsey & Co Global Construction Industry Productivity survey who responded agree or strongly agree to the questions around implementation of the solutions.

\(^2\) Range reflects expected difference in impact between emerging and developed markets.

\(^3\) Source: McKinsey Global Institute.

Cost savings

\(6 – 7\%\)

\(7 – 10\%\)

\(3 – 5\%\)

\(4 – 5\%\)

\(4 – 6\%\)

\(3 – 5\%\)

\(27 - 38\%\)
Technology - lack of internal processes is the largest barrier to digital technology

Most important barriers to adoption by technology type (n=141)
Frequency of ranking in three most important barriers

<table>
<thead>
<tr>
<th></th>
<th>No internal process to quantify or communicate business case and benefits</th>
<th>No clear industry standard yet, sub-contractors and customers need to adopt</th>
<th>Management not interested, no budget at project level</th>
<th>Frontline workers insufficiently trained or unwilling to use</th>
<th>Lower-cost options available</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Digital</strong></td>
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<tr>
<td>Real-time collaboration</td>
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<td>✓</td>
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<tr>
<td>Collaborative mobility solutions</td>
<td></td>
<td>✓</td>
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<td>Digitized project workflows</td>
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<td>Real-time workforce production tools</td>
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<tr>
<td>Sensor and NFC(^1) technology</td>
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<tr>
<td>Pattern-/trend-based advanced analytics</td>
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<tr>
<td>Surveying and inspection tools</td>
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<tr>
<td><strong>Materials</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Modular construction</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Durable and lightweight materials</td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Automation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Advanced automation</td>
<td></td>
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<td></td>
<td>✓</td>
</tr>
</tbody>
</table>

\(^1\) Near-field communication.

Beyond Best Practices

COAA strategies
• Grand vision – Twice as Safe, Twice as Productive by 2020
• Best Practices – e.g. Advanced Work Packaging, Collaborative Contracting (more emphasis on improving culture, less on improving processes)
• Increase rate of technology adoption – specifically digitalization

Meanwhile ...
• Cenovus (and others) are “just doing it”
COAA
Digital Innovation at Cenovus
And
PTAC Digital Innovation Consortium
Overview of our Digital Innovation department

4th Industrial Revolution (AI)

Digital Innovation Research Projects
Cenovus

PTAC Digital Innovation Consortium
Digital Innovation at Cenovus

Digital Innovation Life Cycle

**Sources of ideas:**

1. Vendor
2. Academia
3. Business Groups
4. Industry Peers
5. Other Industries
6. Industry Events (Conferences, seminars, luncheons etc.)

**Four criteria to verify in the research stage, is the digital technology:**

1. Simple
2. Acceptable
3. Cost – Effective
4. Potential 10X

**Questions to answer at the experiment stage, is the digital technology:**

1. Field tested, if required
2. Capacity tested, if required
3. Reliability of technology (uptime)
4. Intrinsically Safe, if required

**Expand digital technology to other functions and assets:**

1. EIS Plan Engaged
2. Hand off knowledge to SBA
3. Digital Innovation Group consults
Agile SCRUM (Kan-Ban)
Evolution

Industrial Revolution

Year 1900: One Motor Vehicle  Year 1913: One Horse & Carriage
Asset Tracking

Where is everything?

Over a dozen laydown yards and Billions ($) in assets!
Experiment Sites

La Corey Laydown Yard

Christina Lake Tool Crib and Rigmats
Cabinets: LaCorey001, LaCorey002
Direction: out
Start Time: October 16, 2018, 1:41 p.m.
Duration: 0:00:20

Name: Pipe Spools 2
Cenovus ID: PipeSpools-2
Group label: Pipe Spools

Image:

Tags:

<table>
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<th>Tag ID</th>
<th>Cabinet</th>
<th>Scanned</th>
<th>Latitude</th>
<th>Longitude</th>
</tr>
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<td>LaCorey001</td>
<td>October 16, 2018, 1:41 p.m.</td>
<td>54.441872</td>
<td>-110.768419</td>
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<td>54.441872</td>
<td>-110.768419</td>
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<th>Longitude</th>
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<td>PrfidEvent</td>
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<tr>
<td>AB99CC48</td>
<td>PrfidEvent</td>
<td>54.43866685</td>
<td>-110.77386815</td>
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</tbody>
</table>
Augment tracking with Facial Recognition
As-built laser scan augmented on 3D CAD Model
Digital Twin and Augmented Reality

https://www.youtube.com/watch?v=eqZCSD8m_7g&feature=youtu.be
Avatar
Robotic Data Capture

Update on robotic data collection
Connected Worker
Tracking devices
Heat Maps created from data captured by the Devices

Reports
- Events
- Events map
- Alerts report
- Incident report
- Usage and compliance
- Bump tests and calibrations
- Location beacons
- Devices and cartridges
- Docks
- Device logs

Events map
Use this report to explore the locations of your data events. Multiple occurrences of the same type of event might indicate a recurring issue that may require investigation.

Event map report
Last updated: 10/31/2018 7:00:14 AM MDT

Data status: 🟦
All data available

Total events: 20

Date:
7/10/2018 6/3/2018

Organization:
- Ad

Group:
- Ad

User:
- Ad

Event type:
- High Gas Alert
Connected Worker
Thermal (FLIR Cameras)
IIoT Initiatives
Organizational Structure

Consortium for Digital Innovation and Transformation (CDIT)

- Digital Forum
- Blockchain
  - Digital Twin
  - Robotics
  - IIoT
  - Drones
  - Connected Worker
  - Image Recognition
  - Augmented Reality
  - Private LTE
  - Confined
  - Biometrics
  - LP WAN
  - BVLOS
  - WAMS
### Current Members

<table>
<thead>
<tr>
<th>Company</th>
<th>Representative</th>
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</thead>
<tbody>
<tr>
<td>Cenovus</td>
<td>ATCO Gas</td>
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<tr>
<td>Suncor</td>
<td>Chevron</td>
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<td>CNRL</td>
<td>Imperial</td>
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<td>Husky</td>
<td>Encana</td>
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<td>Enbridge</td>
<td>COSIA Rep</td>
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<tr>
<td>TCPL</td>
<td>CRIN rep</td>
</tr>
</tbody>
</table>
Drones (Beyond Visual Line of Sight) - BVLOS
Question and Answer

Mark Sombach
Digitalization Opportunities

- Evaluate, Highgrade, Implement
- Just Do It!
- Opportunistic Implementation
- Not worth it
- ... but long shots
- Tempting

Size of Benefit vs. Possibility of Successful Implementation
Identifying the Best Opportunities

- Leverage paybacks
- Mitigate risks

Possibility of Successful Implementation
Size of Benefit
Possibilities >>> Practical Plans

Technology
• State of the art possibilities
• Industry trends
• Customer/partner trends
• Practical options ... likely benefits

People + Processes
• Leadership / vision
• Culture / adaptability
• Technology infrastructure
• Practical implementation plans
Information Integration to Improve Capital Project Performance

2009 CII Annual Conference
Reno, Nevada

Decision Support Tool

History

RT 258 … the first structured process to help companies assess current efforts and plan a path forward.
Assessment and Selection Process

Assess organization status with Maturity Model

Gap Analysis: Identify areas for improvement within Maturity Model

Portfolio of Integration Opportunities

Conduct IOP assessment with Integration Opportunity Tool

Select specific IOPs for further analysis

Refine IOP value assessment with hindrances and benefits

Go?

Create deployment plan and implement
### Integration Opportunity Assessment Tool

#### Part I: Benefit Drivers

<table>
<thead>
<tr>
<th>Benefit Drivers</th>
<th>Yes</th>
<th>No</th>
<th>N/A/NA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Would the IO enable entry to new market?</td>
<td>X</td>
<td></td>
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<tr>
<td>2. Would the IO facilitate or enhance regulatory compliance?</td>
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</tbody>
</table>

#### Part II: Organizational & Process Benefit Drivers

<table>
<thead>
<tr>
<th>Benefit Drivers</th>
<th>High</th>
<th>Med. High</th>
<th>Med. Low</th>
<th>Low</th>
<th>N/A/NA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Release characteristics the general extent of benefits likely to result from the IO:</td>
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<tr>
<td>a. Enhanced Quality</td>
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<td>b. Enhanced Reliability</td>
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<td>c. Enhanced Functionality</td>
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<td>d. Enhanced Adaptability/Flexibility/Robustness in responding to varying conditions</td>
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<td>e. Enhanced Productivity</td>
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<td>f. Enhanced Speed to market</td>
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<td>g. Enhanced Project Schedule performance</td>
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<td>h. Enhanced Cost reduction</td>
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<tr>
<td>i. Enhanced Predictability of cost, schedule, performance, etc.</td>
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<tr>
<td>j. Enhanced Customer Focus and/or Satisfaction</td>
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<td>k. Enhanced Security of data</td>
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<td>l. Enhanced Access to information</td>
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<td>m. Enhanced Management of human resources</td>
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<td>n. Enhanced Management of physical resources</td>
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<td>o. Frequency of IO applications to projects</td>
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<td>p. For what portion of projects is this IO applicable?</td>
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</table>

### Integration Opportunity Assessment Summary

- **Benefit Driver Score**: 67.7 %
- **Hindrance Score**: 56.1 %

### Integration Opportunity

- Benefit Driver Score (%): 67.7
- Hindrance Score (%): 56.1

---

*Leadership for the Next Generation*

*The Knowledge Leader for Project Success*

*Owners + Contractors + Academics*
Fuzzy Logic Tools - Advantages

• **Structured process** to consider potential benefits and risks
• Uses natural language (**user friendly**)
• Enables **multi-user inputs** online by stakeholders and experts across the company (eliminates difficult-to-schedule meetings to gather inputs)
• Flexibility to **customize** lists of benefits and risks, customize linguistic terms
• Can **identify opportunities** to leverage high-impact benefits; manage and mitigate high-impact impediments
• **Easily-communicated, defensible recommendations** and ranking of digitalization opportunities
Fuzzy Logic Tools – COAA Advantage

Dr. Aminah & Students / Post Docs

Assisting companies to think through benefits and risks ...
Decision Support Tool

Community of Practice

- Master List of Digitalization Opportunities

Tool Development

- Identification of Company-Specific Opportunities
- Multi-Stakeholder Inputs (aggregated judgements)

Piloting & Tweaking

- Company Customization
- Potential Benefits (each opportunity)
- Possibility of Success (each opportunity)

Marketing & Championing

- Company Road Map (ranked portfolio of opportunities)

- Possibility of Success
- Potential Benefits
- Multi-Stakeholder Inputs
- Company Customization
- Identification of Company-Specific Opportunities
- Master List of Digitalization Opportunities
## Project Plan

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<tbody>
<tr>
<td>Winter</td>
<td>Spring</td>
<td>Summer</td>
<td>Fall</td>
<td>Winter</td>
<td>Spring</td>
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<tr>
<td>Establish CoP &amp; web page</td>
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<td>BP2019</td>
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<td>Project Workshop II</td>
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<tr>
<td>Refine question sets</td>
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<tr>
<td>Spreadsheet mockup of tool</td>
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<tr>
<td>Alpha version of tool</td>
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<tr>
<td>Project Workshop III</td>
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<tr>
<td>Tool demo at BP2020</td>
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<td>BP2019</td>
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<tr>
<td>Beta version of tool</td>
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<td>Project Workshop IV</td>
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</table>
# Project Steering Committee

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adamantia Fatsea</td>
<td>Director, Engineering &amp; Construction</td>
<td>Alberta EDT&amp;T</td>
</tr>
<tr>
<td>Chris Desaulniers</td>
<td>Project Sponsor</td>
<td>Ledcor</td>
</tr>
<tr>
<td>Chris Squires</td>
<td>Project Engineer</td>
<td>Imperial Oil</td>
</tr>
<tr>
<td>Jason Collins</td>
<td>Chair</td>
<td>Alberta Steel Manufacturers</td>
</tr>
<tr>
<td>Jennifer Collins</td>
<td>Project Manager, Core Projects</td>
<td>Enbridge Pipelines</td>
</tr>
<tr>
<td>Mangesh Kumthekar</td>
<td>Project Manager, Digital Projects</td>
<td>Suncor Energy</td>
</tr>
<tr>
<td>Matt MacMaster</td>
<td>Group Lead, Construction Project Services</td>
<td>Cenovus Energy</td>
</tr>
<tr>
<td>Richard Boodoo</td>
<td>Project Manager, Core Projects, Mainline</td>
<td>Enbridge Pipelines</td>
</tr>
</tbody>
</table>
Community of Practice

• Contribute digitalization opportunities to web portal; learn from submissions of others (one-page template)
  • Potential opportunities (interesting technologies)
  • Case studies: opportunities implemented – successes and lessons learned
• Updates on project progress, invitations to join project workshops
Fuzzy Logic Decision Support Tool for Digitalization Implementation
Digitalization in Assessing Risk and Contingency

Traditional risk analysis approaches fail to capture subjective uncertainties and expert knowledge and rely on historical data. Opportunities are often not captured.

Deterministic risk analysis

Probabilistic risk analysis (Monte Carlo simulation)
Digitalization in Assessing Risk and Contingency

Multi-level risk/opportunity event breakdown structure can be created for each project category or for individual projects.
Experts assess the probability and impact of each risk and opportunity event using natural language. Methods have been developed to take into account their levels of expertise when combining their opinions in order to calculate project contingency.
Digitalization in Assessing Risk and Contingency: Fuzzy Risk Analyzer© (FRA©)

Database-driven software tool for determining construction project contingency:

- **Ease of use**
  - Efficient and consistent group inputs

- **Robust methodology & reliable results**
  - Linguistic factors calibrated

- **Proven useful**
  - Staff efficiencies and corporate benefits
Digitalization in Productivity Tracking And Analysis

Artificial Intelligence (AI) tools and a database to help construction organizations record, measure, track, and improve construction productivity.
Fuzzy Logic in Decision Support Tool
Preliminary Conceptual Model

- Community of Practice
  - Master List of Digitalization Opportunities
  - Multi-Stakeholder Inputs (aggregated judgements)
- Tool Development
  - Identification of Company-Specific Opportunities
  - Multi-Stakeholder Inputs (aggregated judgements)
- Piloting & Tweaking
  - Identification of Company-Specific Opportunities
  - Potential Prize (each opportunity)
  - Possibility of Success (each opportunity)
- Marketing & Championing
  - Company Road Map (ranked portfolio of opportunities)
  - Success
  - Benefit

- Fuzzy aggregation
- Fuzzy clustering
- Fuzzy expert systems
- Fuzzy machine learning
Workshop Participation
Sli-do “voting buttons”

1. Join WiFi: Freeman >>> Prepaid Access  Password: BP2019

2. Go to www.slido.com  Code: COAA19

3. Select room: CPC-8  Digitalization Support Tool ...
Workshop Participation
Sli-do “voting buttons”

Q1: Do you want that your identity and contact information revealed to others in the Community of Practice?

Q2: How do you prefer to provide your input for the Community of Practice?

1. Online Web Form (online form completed by you)
2. Survey Monkey (online survey emailed to you)
3. Questionnaire (Hard copy delivered to you)
4. Interview (Face-to face interview)
# Potential Benefits of implementing digitalization

To what extent do you consider each of the following as a significant benefit of implementing digitalization in a construction organization?

<table>
<thead>
<tr>
<th>Impact Level</th>
<th>Benefit Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low or localized impact on safety, productivity, effectiveness</td>
<td>significant division-wide impact on safety, productivity, effectiveness, customer service</td>
</tr>
<tr>
<td>Significant division-wide impact on safety, productivity, effectiveness</td>
<td></td>
</tr>
<tr>
<td>Alberta-wide impact on safety, effectiveness, customer relationships, strategic prospects</td>
<td></td>
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</tbody>
</table>
Potential Benefits of implementing digitalization

Q3: To what extent do you consider each of the following items as a significant benefit of implementing digitalization in a construction organization?

1. Enhanced quality, reliability, and functionality
2. Enhanced productivity and cost reduction
3. Enhanced understanding and predictability of work process
4. Enhanced customer focus and/or satisfaction
5. Enhanced security of data and access to information
6. Enhanced adaptability/flexibility/robustness in responding to varying conditions
7. Enhanced product speed-to-market and project schedule performance
8. Enhanced management of human and physical resources
9. High utilization time and applicability to majority of projects in the company
10. Enhanced strategic and tactical decision-making
Potential Benefits of implementing digitalization

Q3 Cont’d: To what extent do you consider each of the following items as a significant benefit of implementing digitalization in a construction organization?

11. Enhanced inter-company/intra-company efficiency
12. Enhanced concurrent use of data, quality of data, and subsequent leveraging of data
13. Enhanced work sharing
14. Resolving data versioning problems among different users
15. Consolidating and elimination of existing software applications
16. Utilizing/leveraging established and industry-wide data standards
17. Utilizing existing commercially proven applications
18. Enhanced ease of application and training
19. Enhanced employee morale and the work environment
20. Enhanced or encouraged positive behavioural change (e.g., collaboration)
### Success Factors for implementing digitalization

**To what extent do you consider that each of the following significantly affects the possibility of success of implementing digitalization in a construction organization?**

<table>
<thead>
<tr>
<th>weak effect (positive or negative) on successful implementation</th>
<th>possible enabler or possible barrier re: successful implementation</th>
<th>strong enabler or strong barrier re: successful implementation</th>
</tr>
</thead>
<tbody>
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</tbody>
</table>
Success Factors for implementing digitalization

Q4: To what extent do you consider that each of the following significantly affects the possibility of success of implementing digitalization in a construction organization?

1. Security and holder-of-data requirements
2. Intellectual property demands and legal ownership of data
3. Contractual agreements and labour agreements
4. Possibility of misuse and mishandling of data
5. International/local law restrictions
6. Internal/external organization culture
7. Business procedures/process
8. Internal/external parties
9. Data availability (timing)
10. Quality of data (i.e., data structure, formats, data sources)
Success Factors
for implementing digitalization

Q4 Cont’d: To what extent do you consider that each of the following significantly affects the possibility of success of implementing digitalization in a construction organization?

11. Upper management support
12. Financial support
13. Geographic dispersion of users
14. Company expertise
15. Basic capabilities of user community
16. Training requirements
17. Sustained support resources (e.g., on-call support)
18. Champions at the user/manager levels
19. Technology ownership
20. Commitment of data providers (to comply data standards/procedures)
Digitalization Resources


• Torroba, Andrea  Digitalization in Oil and Gas Projects  September 2018 (MBA capstone paper)  ... contact Larry Staples
Digitalization Resources

Digitalization Resources

Thank You
for participating today

• Sign up to join the **Community of Practice** to identify promising new technologies and share implementation experiences:
  
e-mail coaa.admin@coaa.ab.ca  Subject: Digitalization Implementation

• Stay in touch via project web page [www.coaa.ab.ca/tbd](http://www.coaa.ab.ca/tbd)

• Larry Staples  [larry@coaa.ab.ca](mailto:larry@coaa.ab.ca)