

**36<sup>TH</sup> CIB W078 2019 CONFERENCE**

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**NEWCASTLE, UNITED KINGDOM, 18 – 20 SEPTEMBER 2019**

**INDUSTRY 4.0 IN CONSTRUCTION: PRACTITIONERS' PERCEPTIONS**

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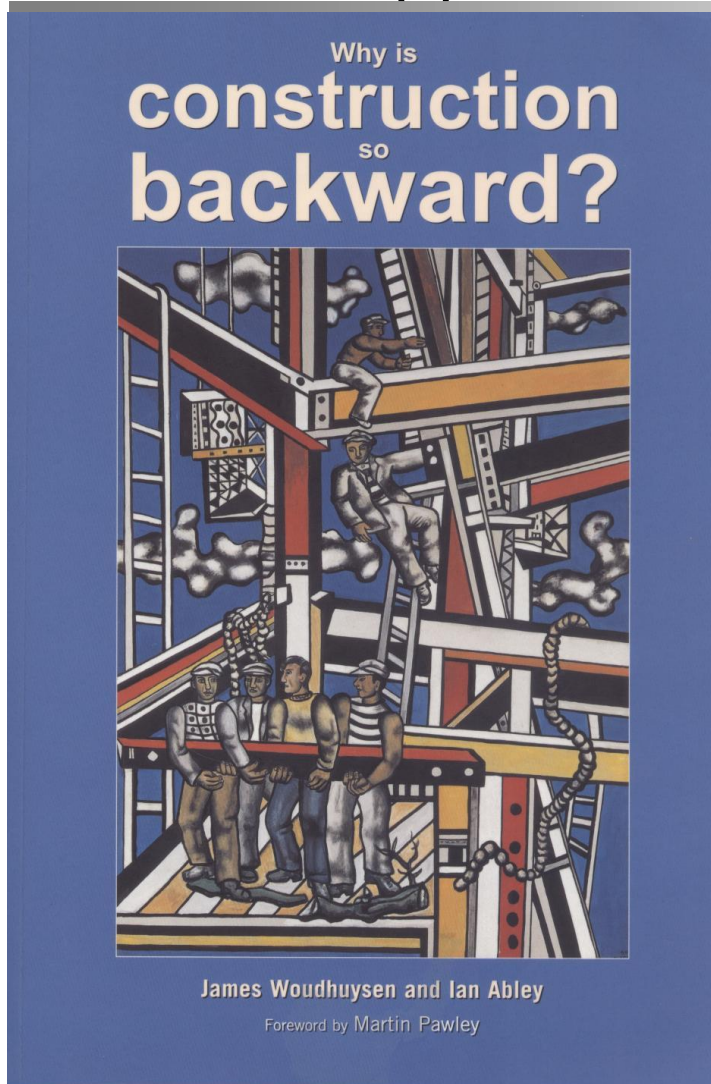
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# Introduction (1)



(Woudhuysen and Abley, 2004)

## **Introduction (2)**

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**Within the context of South Africa, the Construction Industry Development Board (cidb) (2016) highlighted a range of performance issues:**

- **Clients were neutral or dissatisfied with the performance of contractors on 18% of the projects surveyed**
- **Clients were neutral or dissatisfied with the construction schedule performance of contractors on 26% of the projects**
- **Approximately 13% of the projects surveyed had levels of defects which are regarded as inappropriate**
- **There was a noticeable increase in the levels of defects over the period 2012 to 2015**
- **Contractors were neutral or dissatisfied with the performance of clients on 18% of the projects surveyed**

## **Introduction (3)**

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- **Contractors were neutral or dissatisfied with the quality of tender documents and specifications obtained from clients on approximately 17% of the projects surveyed**
- **Contractors were neutral or dissatisfied with the management of variation orders on 24% of the projects surveyed**
- **60% of payments to contractors were delayed for longer than 30 days after invoicing**
- **The recommendations of the tender committee were overruled in the award of approximately 9% of public sector projects**
- **H&S on construction sites as well as transportation to the sites remains a concern**

## **Introduction (4)**

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- **Considering the numerous challenges experienced in construction, especially the delivery of projects, it is inevitable that Industry 4.0 is considered to overcome these**
- **According to Autodesk & CIOB (2019), digital technologies are transforming every industry, and construction is no exception - infinite computing, robotics, machine learning, drones, the IoT, augmented reality, gaming engines, and reality capture are innovating the design, build, and operation of buildings and infrastructure**
- **Given the continuing poor performance in South African construction, and the cited benefits of implementing Industry 4.0 technologies, an exploratory study was conducted to determine the:**
  - **Frequency that project parameter-related phenomena are experienced on projects**

## **Introduction (5)**

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- **Frequency that eighteen-construction resource-related phenomena are experienced on projects**
- **Extent of the need for performance improvement on projects;**
- **Respondents' self-rating of their awareness of / exposure to ten Industry 4.0 technologies**
- **Potential of Industry 4.0 technologies to reduce the occurrence of seven project parameter-related phenomena**
- **Potential of Industry 4.0 technologies to reduce the occurrence of eighteen construction resource-related phenomena**

## Drones (1)



**Using drones to help with safety inspections makes the process safer (Coutts Bros in Dodge Data & Analytics, 2017)**

## **Drones (2)**

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- **Coutts Bros., a Maine, USA-based electrical line construction and maintenance contractor**
- **To minimise the inherent risks, the company is investing in technologies that improve safety on workers' behalf, from robotics to sensory devices**
- **“Any time you can put equipment in, instead of a lineman, you always want to do that”: Jared Rossignol, Safety Director**
- **Coutts's team inspects between 6 000 and 10 000 transmission structures - typically entails a lineworker climbing the structures to examine components for signs of deterioration**
- **Drones safely extend inspections of inaccessible poles and other structures beyond what lineworkers can see from the ground**



## Drones (3)

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- **“We can take a picture from 30 feet away, and tell you how many legs are on an ant on the cross-arm.”**

## Current reality versus robots



**Tying reinforcing – bending, rapid repetitive movements etc. (Deacon, 2004)**

## Robots (1)



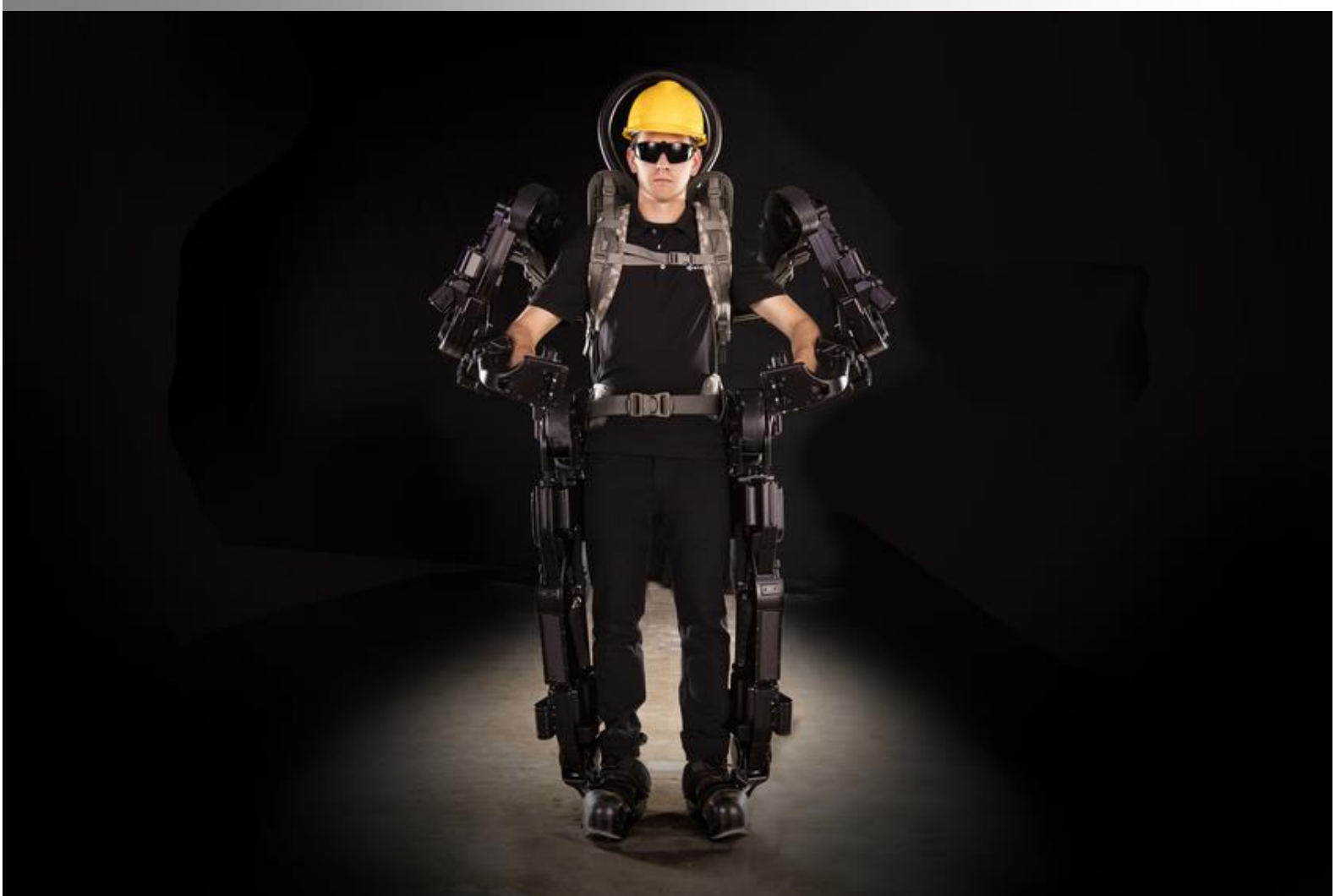
**Rebar-placing robot unveiled at Bauma (GCR Staff, 2019)**

## Robots (2)

- **An American construction robotics company unveiled its concept for an autonomous machine that can lift, carry and place rebar on bridges and other horizontal reinforced concrete applications**
- **TyBot was the brainchild of Brayman Construction owner Stephen Muck, who was concerned by the difficulties his company faced in finding enough skilled labour to deliver bridge projects**



# Exoskeletons (1)



**Worker in an exoskeleton (Sarcos in Quirke, 2018)**

## Exoskeletons (2)

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- **An electric exoskeleton that enables the wearer to lift 90kg for extended periods has been built by American**
- **The Guardian XO Max is a full-body exoskeleton that has been in development for 17 years, at an R&D cost of \$175m**
- **The batteries that power the suit last for eight hours on a single charge, and can be swapped in and out without losing power**
- **The suit requires 400W of power while walking at human speed, and it takes about a minute for operators to get in and out of it**
- **Suite of sensors integrated into the exoskeleton, allowing the operator to intuitively control the robot in a way that leverages his or her instincts and reflexes, which minimises the need for human training**

## Exoskeletons (3)

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- **The Guardian XO Max has a strength amplification of 20 to 1, making 100 lbs of weight feel like 5 lbs to the person wearing the suit**
- **The full weight of the suit and anything being carried is transferred through the suit's structure to the ground (Quirke, 2018)**

## Humanoid robot (1)

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- **A Japanese research institute has produced an android that can perform tasks on construction sites, including installing drywall panels by picking them from a stack and screwing them into position**
- **It takes human form so it can do things in a workplace designed for humans**
- **This addresses a problem with industrial robots, which is that industrial processes usually have to be designed for them, rather than the other way around**
- **The robot is the HRP-5P, the latest prototype from Humanoid Research Group (HRG) of the National Institute of Advanced Industrial Science and Technology (AIST):**
  - **It can detect objects, plan routes around obstacles and analyse its environment by, for example, measuring the sizes of things**
  - **Standard advantage of industrial robots in that it has an extra joint in its wrist**



## Humanoid robot (2)

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- HRG views the android as a platform for further collaboration between industry and academia, and sees its long-term role as replacing or supplementing human labour on construction sites, factories and shipyards and other environments
- The move to non-human labour is a priority of the Japanese government and industry:
  - The Japan Federation of Construction Contractors estimates that there will be 1.3 million fewer construction workers by 2025 compared with 2014
- <https://youtu.be/ARpd5J5gDMk?t=16> (Construction Manager, 2018)

## **Research - Method and sample strata**

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- **Sample strata:**
  - **UPE / NMMU / NMU Construction Management Alumni**
  - **Pr CHSAs**
  - **Master Builders Association (MBA) Kwazulu-Natal H&S competition award winners**
- **Questionnaire:**
  - **Self-administered questionnaire**
- **Response:**
  - **46 Responses were included in the analysis of the data**

## Research – Findings (1)

Parameter	Response (%)						MS	Rank
	Un- sure	Not.....Very						
		1	2	3	4	5		
Cost	0.0	0.0	0.0	2.4	19.0	78.6	4.76	1
Time	0.0	0.0	2.3	0.0	30.2	67.4	4.63	2
Quality	0.0	0.0	2.3	4.7	25.6	67.4	4.58	3
Health and safety	0.0	0.0	0.0	7.1	31.0	61.9	4.55	4
Productivity	0.0	0.0	2.3	4.7	32.6	60.5	4.51	5
Environment	0.0	0.0	9.3	23.3	16.3	51.2	4.09	6

**Table 1: Importance of project parameters to respondents' organisations (MS = 1.00 – 5.00).**

## Research – Findings (2)

Phenomenon	Response (%)						MS	Rank
	Unsure	Never	Rarely	Sometimes	Often	Always		
Delays	0.0	0.0	7.0	16.3	46.5	30.2	4.00	1
Poor productivity	0.0	2.3	9.3	27.9	37.2	23.3	3.70	2
Late completion	2.3	2.3	14.0	25.6	32.6	23.3	3.62	3
Quality non-conformances	0.0	0.0	9.3	39.5	34.9	16.3	3.58	4
Costs exceed value	2.3	0.0	9.3	41.9	34.9	11.6	3.50	5
Damage to the environment	0.0	4.7	41.9	34.9	9.3	9.3	2.77	6
Accidents	0.0	0.0	62.8	23.3	7.0	7.0	2.58	7

**Table 2: Frequency at which project parameter-related phenomena are experienced on projects (MS = 1.00 – 5.00).**

## Research – Findings (3)

Phenomenon	Response (%)						MS	Rank
	Unsure	Never	Rarely	Sometimes	Often	Constantly		
Late information	0.0	0.0	4.7	20.9	46.5	27.9	3.98	1
A shortage of workers with the necessary skills	4.7	2.3	7.0	23.3	34.9	27.9	3.83	2
Information anomalies / ambiguities	4.7	2.3	4.7	30.2	41.9	16.3	3.68	3
Rework occurs	2.4	0.0	9.5	45.2	33.3	9.5	3.44	4
Inadequate coordination of subcontractors	0.0	0.0	20.9	27.9	32.6	18.6	3.49	5
Similar or alike errors are repeated	2.3	0.0	11.6	41.9	30.2	14.0	3.48	6
Data / Statistics is / are not available	7.0	2.3	18.6	20.9	41.9	9.3	3.40	7
Underpricing	7.0	2.3	11.6	37.2	32.6	9.3	3.38	8
Management information is not available	7.1	0.0	19.0	31.0	33.3	9.5	3.36	9
Materials are not available when required	7.0	0.0	23.3	39.5	20.9	9.3	3.18	10
Difficulty monitoring the process and activities of construction	4.7	2.3	25.6	27.9	37.2	2.3	3.12	11
Fatigue among workers	9.3	4.7	18.6	34.9	27.9	4.7	3.10	12
Materials are lost / stolen	2.3	2.3	18.6	51.2	18.6	7.0	3.10	13
Unauthorised people fulfill functions	9.3	11.6	18.6	30.2	18.6	11.6	3.00	14
Workers are regularly absent	7.0	2.3	30.2	32.6	20.9	7.0	3.00	15
Poor plant and equipment utilisation	7.0	4.7	23.3	39.5	18.6	7.0	3.00	16
Materials are damaged	4.7	2.3	18.6	53.5	18.6	2.3	3.00	17
Sprains and strains among workers	4.7	0.0	41.9	30.2	16.3	7.0	2.88	18

**Table 3: Frequency at which eighteen resource-related phenomena are experienced on projects (MS = 1.00 – 5.00).** © 2019 : Prof JJ Smallwood & Chris Allen

# Research – Findings (4)

Need	Response (%)						MS	Rank
	Un-sure	Minor..... Major						
		1	2	3	4	5		
Improved communication	0.0	0.0	2.3	4.7	44.2	48.8	4.40	1
Workers with technical skills	2.3	0.0	0.0	11.6	34.9	51.2	4.40	2
Integration of information (construction)	0.0	0.0	0.0	16.3	39.5	44.2	4.28	3
Integration of information (design)	0.0	0.0	0.0	18.6	41.9	39.5	4.21	4
Improved planning & control of activities on site	0.0	0.0	2.3	23.3	27.9	46.5	4.19	5
Integration of information (procurement)	0.0	2.3	2.3	16.3	37.2	41.9	4.14	6
Link processes across the stages of projects	2.3	0.0	0.0	23.3	41.9	32.6	4.10	7
Reduced occurrence of H&S incidents / accidents	0.0	2.3	9.3	14.0	27.9	46.5	4.07	8
Digitalisation of information	4.7	0.0	7.0	16.3	34.9	37.2	4.07	9
Workers with technology skills	4.7	2.3	2.3	20.9	39.5	30.2	3.98	10
Deployment of technology	2.3	0.0	4.7	27.9	37.2	27.9	3.90	11
Improved security	0.0	2.4	7.1	31.0	16.7	42.9	3.90	12
Improved materials management	0.0	2.3	7.0	25.6	41.9	23.3	3.77	13
Modern plant and equipment	0.0	0.0	7.0	39.5	27.9	25.6	3.72	14
Simulation of activities	9.3	2.3	9.3	27.9	25.6	25.6	3.69	15
Automation of activities on site	7.1	2.4	7.1	26.2	40.5	16.7	3.67	16
Workers with IT skills	4.7	7.0	11.6	32.6	25.6	18.6	3.39	17

**Table 4: Extent of the need for improvements on projects (MS = 1.00 – 5.00).**

## Research – Findings (5)

Technology	Response (%)						MS	Rank
	Un- sure	Limited.....Extensive						
		1	2	3	4	5		
Internet of Things	7.1	7.1	2.4	23.8	35.7	23.8	3.72	1
Digitalisation of information	0.0	16.7	11.9	16.7	33.3	21.4	3.31	2
Drones	0.0	18.6	9.3	30.2	27.9	14.0	3.09	3
Virtual Reality	0.0	32.6	16.3	25.6	14.0	11.6	2.56	4
3-D printing	2.3	39.5	20.9	14.0	16.3	7.0	2.29	5
Blockchain	11.6	32.6	27.9	18.6	4.7	4.7	2.11	6
Augmented Reality	7.0	48.8	11.6	14.0	14.0	4.7	2.08	7
Artificial Intelligence (AI) / Machine Learning	2.3	41.9	25.6	18.6	9.3	2.3	2.02	8
Robotics / Exoskeletons	2.3	48.8	18.6	20.9	4.7	4.7	1.95	9
Nanotechnology	4.8	47.6	23.8	16.7	2.4	4.8	1.88	10

**Table 5: Respondents' self-rating of their awareness of / exposure to ten Industry 4.0 technologies (MS = 1.00 – 5.00).**

## Research – Findings (6)

Phenomenon	Response (%)						MS	Rank
	Un- sure	Minor.....Major						
		1	2	3	4	5		
Late completion	11.9	0.0	9.5	23.8	26.2	28.6	3.84	1
Quality non-conformances	11.6	0.0	7.0	23.3	37.2	20.9	3.82	2
Delays	11.6	2.3	7.0	16.3	41.9	20.9	3.82	3
Poor productivity	9.3	2.3	11.6	20.9	27.9	27.9	3.74	4
Costs exceed value	14.0	2.3	11.6	18.6	30.2	23.3	3.70	5
Damage to the environment	14.0	2.3	14.0	25.6	20.9	23.3	3.57	6
Accidents	11.9	2.4	14.3	23.8	28.6	19.0	3.54	7

**Table 6: Potential of Industry 4.0 technologies to reduce the occurrence of seven parameter-related phenomena (MS = 1.00 – 5.00).**



# Research – Findings (7)

Phenomenon	Response (%)						MS	Rank
	Un-sure	Minor.....Major						
		1	2	3	4	5		
Information anomalies / ambiguities	7.0	2.3	4.7	11.6	37.2	37.2	4.10	1
Difficulty monitoring the process and activities of construction	4.7	2.3	2.3	18.6	39.5	32.6	4.02	2
Similar or alike errors are repeated	4.8	2.4	4.8	26.2	26.2	35.7	3.93	3
Management information is not available	7.0	4.7	4.7	23.3	25.6	34.9	3.88	4
Data / Statistics is / are not available	7.0	7.0	9.3	16.3	18.6	41.9	3.85	5
Rework occurs	7.0	2.3	2.3	32.6	25.6	30.2	3.85	6
Late information	4.7	4.7	4.7	27.9	27.9	30.2	3.78	7
Inadequate coordination of subcontractors	4.7	2.3	9.3	23.3	37.2	23.3	3.73	8
Underpricing	7.0	7.0	9.3	11.6	39.5	25.6	3.73	9
Poor plant and equipment utilisation	7.0	2.3	7.0	30.2	32.6	20.9	3.68	10
Unauthorised people fulfill functions	9.3	4.7	16.3	14.0	32.6	23.3	3.59	11
Materials are not available when required	9.5	7.1	11.9	16.7	31.0	23.8	3.58	12
Materials are damaged	9.3	7.0	16.3	34.9	18.6	14.0	3.18	13
Sprains and strains among workers	7.1	11.9	16.7	23.8	23.8	16.7	3.18	14
Materials are lost / stolen	9.3	18.6	11.6	18.6	20.9	20.9	3.15	15
Fatigue among workers	4.8	9.5	19.0	28.6	26.2	11.9	3.13	16
A shortage of workers with the necessary skills	11.9	14.3	14.3	23.8	21.4	14.3	3.08	17
Workers are regularly absent	7.1	26.2	23.8	19.0	9.5	14.3	2.59	18

**Table 7: Potential of Industry 4.0 technologies to reduce the occurrence of eighteen resource-related phenomena (MS = 1.00 – 5.00).**

## **Conclusions (1)**

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- **Frequency that parameter-related phenomena, and eighteen resource-related phenomena are experienced on projects:**
  - Respondents' experience reflects the general research findings in South African construction
  - A need for improvement, potential to improve, and a need for the implementation of Industry 4.0
- **Need for improvement on projects in terms of integration, linkages, mitigation of errors, automation, digitalisation, simulation, security, and technology:**
  - Respondents' experience reflects the general research findings in South African construction
  - A need for the implementation of Industry 4.0
- **Respondents' self-rating of their awareness of / exposure to ten Industry 4.0 technologies:**

## **Conclusions (2)**

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- **A need for interventions to raise the level of awareness**
  - **Integrate such technologies into built environment / construction education and training**
  - **Continuing professional development**
- However, in a contextual manner**
- **The need for the implementation of Industry 4.0 in construction is amplified by:**
    - **Potential of Industry 4.0 technologies to reduce the occurrence of:**
      - **Seven parameter-related phenomena**
      - **Eighteen resource-related phenomena on projects**

## **Recommendations**

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- **Built environment-related tertiary education must include, or rather embed Industry 4.0 in their programmes**
- **Construction employer associations, and built environment associations and statutory councils must promote, and preferably provide Industry 4.0 continuing professional development (CPD), and evolve such guidelines and practice notes**
- **The Construction Industry Development Board (cidb) should evolve a position paper relative to Industry 4.0 in construction and deliberate the development of a related industry standard**
- **Researchers should actively conduct and document Industry 4.0 case studies to record the benefits of implementing Industry 4.0 technologies**

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