The autonomous system cycle approach in off-road industrial applications – a holistic view

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ABSTRACT: The fundamental need in *'Off-road industrial applications'*, e.g., mining, tunnelling, construction sites etc. are – safety, reliability, operational / economic viability, and sustainability. Available 'automation and autonomous technologies' has numerous benefits in off-road industrial applications. In the last 15 to 20 years 'the automation and autonomous technologies' has gained popularity in off-road industrial applications and addresses many of its above-mentioned fundamental needs. Although with all its operational and long-term economic benefits, still spread of automation and autonomous technologies are limited to few geographies and certain applications only. In this paper, we are presenting '*the autonomous system cycle approach in off-road industrial applications*', and its potential benefits. We will also briefly review the available autonomous technologies, its status, and applications e.g., in mineral exploration, rock breaking, material haulage, rock processing etc. Through *'the autonomous system cycle approach'*, goal of this paper is to present a step-by-step guideline for integration and implementation of the new technologies in off-road industries.

Keywords: Automation, Mining, Construction, Civil, Digitalization, Tunneling.

1 INTRODUCTION

As we know, the fundamental needs of customers in any industry (including off-road industry) remains the same but the way we address those needs in different times, in different applications, at different geographical locations – differs and changes. The available technology level, it's accessibility and adaptability vary a lot from one region to another and from one country to another.

The scope of this paper is limited to the activities and machines used in 'off-road industrial applications. The products, machines used in on-road, agricultural applications and related activities are excluded from the scope of the paper.

Defining and differentiating between applications –

- *On-road industrial applications*: Referring to applications, activities primarily used for moving or transporting passengers and goods using commercial vehicles running on roads e.g., road trucks, buses, passenger cars and vehicles etc.

- *Off-road industrial applications*: Referring to applications, activities primarily carried out in mining, tunnelling, quarries, and construction sites etc. using heavy earth moving machines.

We are using the automation / autonomous maturity level definition from 'Global Mining Guideline Groups (GMG)' [1]. Figure 1 below taken form the GMG's 'Guideline for the implementation of Autonomous System in Mining', version 1, published in 2019.

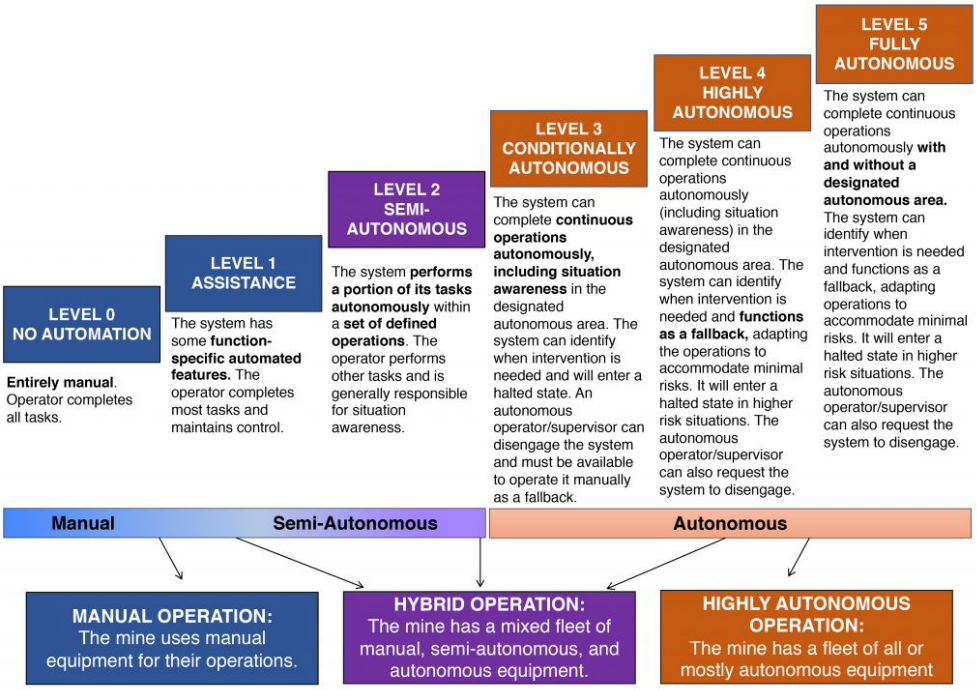

Figure 1. Defining automation level, GMG's Mining Automation Maturity Model.

As per the information from GMG's webpage - *https://gmggroup.org/*[1], this document is currently shown as under review at the time of writing this paper.

1.1 Current approach to implement automation in off-road industrial application.

In authors view of this paper, the current approach of implementing and integrating automation technology in off-road industry i.e., mining, tunneling, quarries, and construction sites etc. is mainly driven by original equipment manufacturers (OEMs), suppliers of equipment, developers of autonomous systems and associated products.

The current approach to implement a new technology e.g., automation, did not address the *end-users* needs in the whole. Due to lack of knowledge and application skills about automation, autonomous technology at end-users' side and lack of proper application knowledge and understanding about off-road industrial applications at OEMs end, makes it more challenging to implement and integrate it.

In ‘off-road industrial applications’ few activities are common across the industry e.g.

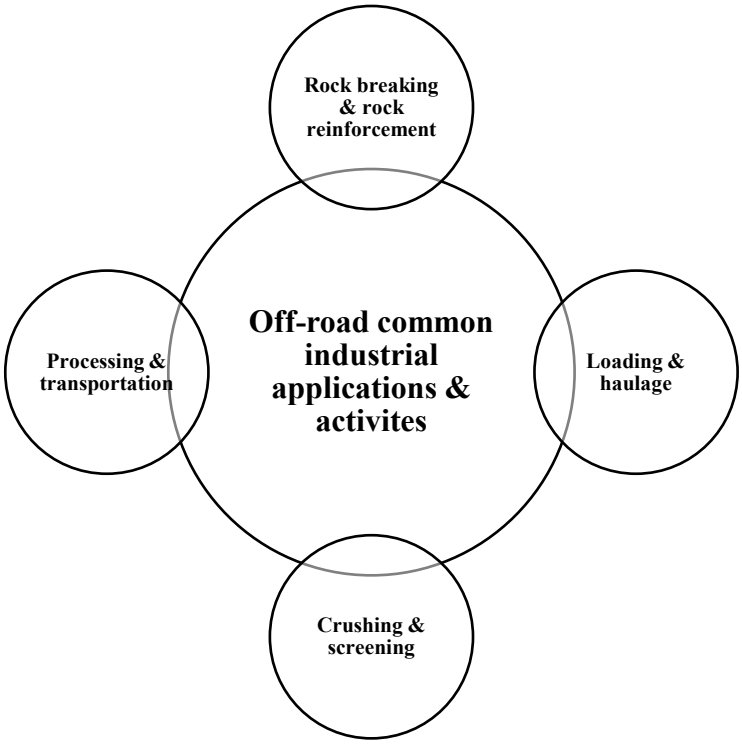

Figure 2. Off-road common industrial applications and activities.

Applications and activities shown in Figure 2 above remains mostly similar e.g., activities in a mine, tunnel, or quarry, construction sites etc.

Figure 3 below represents an overview of current approach of implementing automation technology. The approach is to automate one process or activity from the whole operational cycle based on the availability of equipment and technology from OEM (original equipment manufacturer).

The status and level of automation according to *‘GMG’s Automation Maturity Model’*, based on Figure 1.

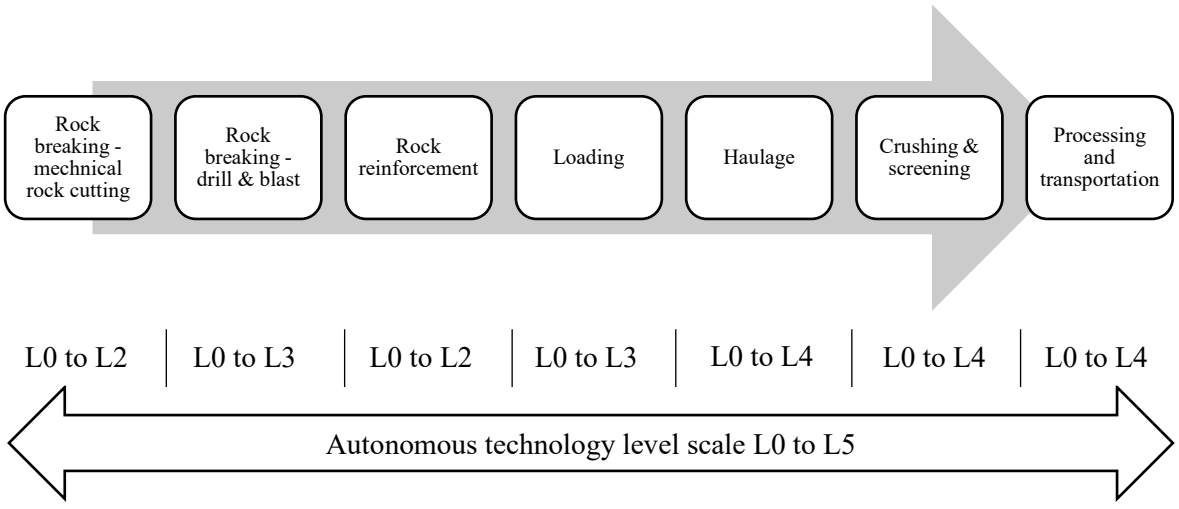

Figure 3. Status of automation level and current approach of implementation in off-road industry.

2 CHALLENGES WITH EXISTING APPRAOCH TO IMPLEMENT AUTOMATION IN OFF-ROAD INDUSTRY

The success and failure of any technological upgrade depends on, how much quantifiable benefits it brings to its end users. By looking at Figure 3, we can question – is the existing way of implementing automation, autonomous technology in off-road industry giving the desired results OR technology is getting utilized to its full benefits?

- In most cases long term objectives with technology planning, preparation and implementation is missing.
- The current approach is product dependent i.e., drill automation, truck automation etc. and it is mainly driven by OEMs.
- Integrating an automation function OR autonomous operation with existing manual operation is a big challenge. It creates confusion and doubts about the possible benefits which technology could provide.

In authors view of this paper, the existing way of implementing autonomous technologies are giving partial benefits. Whether the technology is providing benefits at the whole system level and helping end users from project life cycle perspective, it is difficult to quantify.

3 INTRODUCING THE AUTONOMOUS SYSTEM CYCEL APPROACH IN OFF-ROAD INDUSTRIAL APPLICATION

Off-road industry e.g., mining, tunneling, quarries, and construction sites etc. is a *system of interdependent end to end processes*, each end of an activity or activities, leads to start of another activity or activities. So, we need to have *system thinking* to work with *off-road industrial applications*. We can not just adopt a production factory or process plant concept and way of working to off-road industry.

The autonomous system cycle approach is based on the principal of '*working from whole to part'* [2]. *The autonomous system cycle approach* starts with following key points –

- It takes the whole project lifecycle and its different stages of technology upgrades, project milestones into account.
- The end-users' needs, challenges and expectations from the proposed technology.
  The leadership's i.e., of mine, site, project etc. desired level of performance and productivity gains expected from the proposed technology.

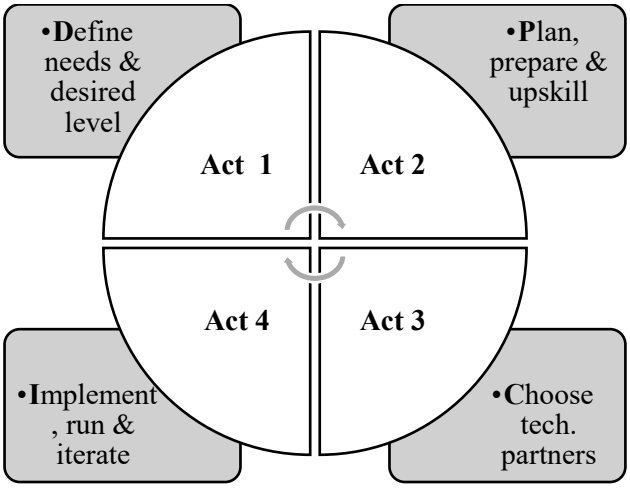

Figure 4. The autonomous system cycle approach for off-road industrial application.

Description of *the autonomous system cycle approach* presented above in Figure 4 is a four-stage process of implementing technology in off-road industry.

- **Act 1** – Defining needs of all stockholders involved and desired level expected from the technology.
- **Act 2** – Plan, prepare, upskill, reskill the organization and teams accordingly.
- **Act 3** – Choose technology provider build partnership and collaborate in developing technology according to your application needs.
- **Act 4** – Implement the whole system, run it, and iterate it with outcome of each measurement point.

Further in the paper we will use the short name **DPCI*** (**D**-defining, **P**- plan & prepare, **C**- choose partners, **I**- implementation) to describe the four-stage process for technology implementation, integration in off-road industry.

4 GENERAL GUIDELINES FOR IMPLEMENTATION OF AUTONOMOUS TECHNOLOGES IN OFF-ROAD INDUSTRIAL APPLICATIONS

Referring to challenges mentioned in 'section 2' above with current approach of implementing technology, we propose following guidelines.

1. It is recommended to apply the whole *system thinking* approach and consider *project life cycle* in the scope for benefits estimation.
2. Suggest using **DPCI*** four-stage process describe in 'section 3' of this paper for technology implementation in off-road industry.
3. Define the needs and desired level of expectations from the technology. Also, define the baseline for performance measurements.
4. Involve all stakeholders at every level in the organization and explain *the change* in a way it reaches across the whole organizations.
5. Plan and prepare ahead in advance. Start upskilling program in the organization to cope with the technology change.
6. Choose the technology partners and collaborate in development of technology.
7. Take the learnings from different industry e.g., ports, harbors, on-road or other industries autonomous where system thinking approach has been implemented.

An example of autonomous system implementation in harbors, ports application is presented in 'section 5' below for reference to suggested guidelines in 'section 4'.

5 EXAMPLE AND LEARNINGS FROM AN AUTONOMOUS OPERATIONS APPROACH IN PORT AND HARBOUR APPLICATION

The vehicles and applications e.g., terminal truck, container handler etc. are like some of these off-highway equipment but the approach for autonomous operations is very different compared to off-road industry. For example, if we look at harbors and ports, we find that the *automation process solutions* are not offered by an OEM or equipment manufacturer but by local companies providing *process control system solutions* for automated container terminals, as an example.

Even though most of these OEM´s can develop, support and could run autonomous vehicles and container management solutions but none of them can offer full autonomous processes managing several OEM vehicles, machines and 3rd party local solutions required.

As the OEM´s in this specific segment focus more on their core products integration layers are implemented to enable a full transparent autonomous process enabling vehicle control, data, and

safety beyond the isolated machine. The local process control system provider can also customize the solution towards specific terminal which maximize the productivity and performance and, in the end. Also it will be easier to optimize the energy required to run the whole operation.

Today about 40 semi or fully autonomous container terminals are in operation around the world and about as many are expected to be implemented within the next five years.

Whether we will we see a similar process automation approach in mines in the future, where OEM's designs automation ready machines to be automated on sites? Only the time and the nature of process improvement will provide the answer.

6 CONCLUSION

The existing approach of implementing automation technology in off-road industry is driven by product manufacturers or OEMs. It has improved the productivity and working conditions in certain applications in off-road industry. With the current approach and with its rate of implementation, it will take long time to realize the full potential of automation and autonomous technologies.

The proposed *autonomous system cycle approach* considers the life cycle of the project in scope and provide a *system thinking* to work in off-road industry. Considering the improvements, development in autonomous technology in last 15 to 20 years and general awareness about its technological benefits in the off-road industry, it is recommended to try this approach of implementing technology. As this autonomous system cycle approach recommends for involvement of stakeholders on larger scale and for preparation in advance, it could be that decision making process about the projects could take longer time. Once the decision is made, the system thinking approach present lots of benefits over to existing way of implementation of technology in off-road industry.

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