













Table 1: Practices of Lean and Agile SC strategies

| SC Strategy           | Code  | Practices / Principles  | Literature Sources  |
|-----------------------|-------|---|---|
| <b>LEAN STRATEGY</b>  | LP 1  | Just – in – Time delivery: Delivery of items just at the time of need.  | Anand & Kodali, 2008; Azevedo et al., 2012; Sanders et al., 2016; Tortorella and Fettermann, 2017; Lotfi and Saghiri, 2017. |
|                       | LP 2  | Supplier feedback and relationship  | Anand & Kodali, 2008; Sanders et al., 2016; Tortorella and Fettermann, 2017.  |
|                       | LP 3  | Customers Involvement in operational decisions  | Anand & Kodali, 2008; Sanders et al., 2016; Tortorella and Fettermann, 2017.  |
|                       | LP 4  | Pull flow / production  | Shah and Ward, 2003; Anand & Kodali, 2008; Sanders et al., 2016; Wagner et al. et al, 2017.                                 |
|                       | LP 5  | Inventory (Material, in-process and finished goods) minimization  | Carvalho et al., 2011.  |
|                       | LP 6  | Total productive/preventive maintenance   | Sanders et al., 2016; Tortorella and Fettermann, 2017; Lotfi and Saghiri, 2017.   |
|                       | LP 7  | Setup time reduction  | Sanders et al., 2016; Tortorella and Fettermann, 2017   |
|                       | LP 8  | Lead time / Takt time reduction   | Carvalho et al., 2011; Wagner et al., 2017.   |
|                       | LP 9  | Employee involvement / People and team work   | Sanders et al., 2016; Wagner et al, 2017; Tortorella and Fettermann, 2017;  |
|                       | LP 10 | Statistical Process Control / Total Quality Management (TQM)  | Shah & Ward, 2003; Sanders et al., 2016; Lotfi and Saghiri, 2017.   |
|                       | LP 11 | Standardisation of work procedures  | Anand & Kodali, 2008; Wagner et al., 2017;  |
| <b>AGILE STRATEGY</b> | AP 1  | Centralized and collaborative planning  | Agarwal, et al., 2007.  |
|                       | AP 2  | Increase frequency of new product development / introduction  | Agarwal, et al., 2007; Lotfi and Saghiri, 2017.   |
|                       | AP 3  | speed in improving customer service / response to customer needs  | Agarwal, et al., 2007; Swafford, et al., 2008; Carvalho et al., 2011; Lotfi and Saghiri, 2017                               |
|                       | AP 4  | Use of IT in coordinating / integrating design and development activities   | Agarwal, et al., 2007   |
|                       | AP 5  | Use of IT to coordinate/integrate Manufacturing / company activities  | Agarwal, et al., 2007; Swafford, et al., 2008; Lotfi and Saghiri, 2017.   |
|                       | AP 6  | Supplier’s flexibility / ability to change delivery time of supplier’s order  | Swafford, et al., 2008; Carvalho et al., 2011.  |
|                       | AP 7  | Use of IT to coordinate/integrate procurement activities  | Swafford, et al., 2008  |
|                       | AP 8  | To accommodate changes in production mix / Flexible equipment to produce different products / accommodate changes in production mix | Swafford, et al., 2008; Lotfi and Saghiri, 2017   |
|                       | AP 9  | Increasing level of product customization   | Swafford, et al., 2008;   |

### 5.1. The conceptual model

Firstly, we present a framework of industry 4.0 technologies enabling lean and agile SC strategies for improved performance in figure 1. The framework shows the inter-relationship between industry 4.0 technologies, lean and agile strategies together with organizational performance. For clarity and neatness of the conceptual model, the specific matching of industry 4.0 technologies with lean and agile practices was first presented in a “relationship matrix” shown in table 2. Subsequently, the matrix was transformed into a “conceptual model” as shown in figure 2.

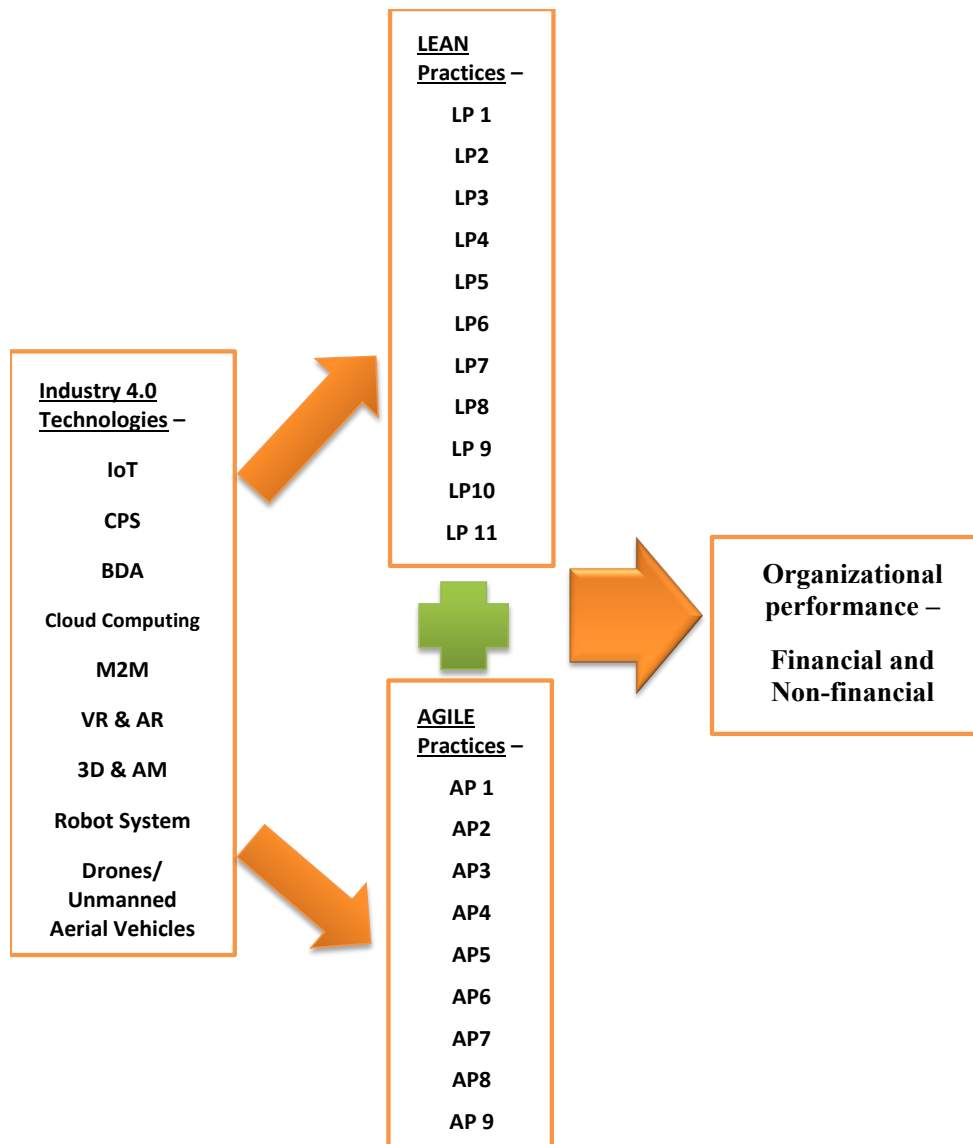


Figure1: Framework

Table 2 and figure 2 show the specific matching of the technologies with the practices of lean and agile strategies. The matching was anecdotally done from literature and subsequent research is geared towards empirical validation using case study research on some supply chains that have been implementing some of the technologies.

Table 2: Relationship matrix

| S/N | Technology (i)                   | Lean strategy enabled by technology i | Agile strategy enabled by technology i |
|-----|----------------------------------|---------------------------------------|--|
| 1   | IoT                              | LP1; LP2; LP3; LP5; LP6; LP9; LP10    | AP1; AP3; AP4; AP5; AP6; AP7;          |
| 2   | CPS                              | LP1; LP2; LP3; LP4; LP6; LP10; LP11   | AP1; AP3; AP4; AP5; AP6; AP7           |
| 3   | BDA                              | LP1; LP2; LP3; LP5; LP6; LP10; LP11   | AP1; AP3; AP4; AP5; AP7;               |
| 4   | Cloud Computing                  | LP1; LP2; LP3; LP4; LP6; LP10; LP11   | AP1; AP3; AP4; AP5; AP6; AP7           |
| 5   | M2M                              | LP1; LP4; LP6; L8                     | AP2; AP5; AP8                          |
| 6   | VR & AR                          | LP2; LP4; LP6; L9; LP11               | AP2; AP5; AP7                          |
| 7   | 3D & AM                          | LP1; LP4; LP7; L8; LP11               | AP2; AP3; AP5; AP8; AP9                |
| 8   | Robot System                     | LP1; LP4; LP5; LP7; LP11              | AP2; AP5; AP8; AP9                     |
| 9   | Drones/ Unmanned Aerial Vehicles | LP1; LP4; LP5; LP8                    | AP2; AP3; AP5                          |



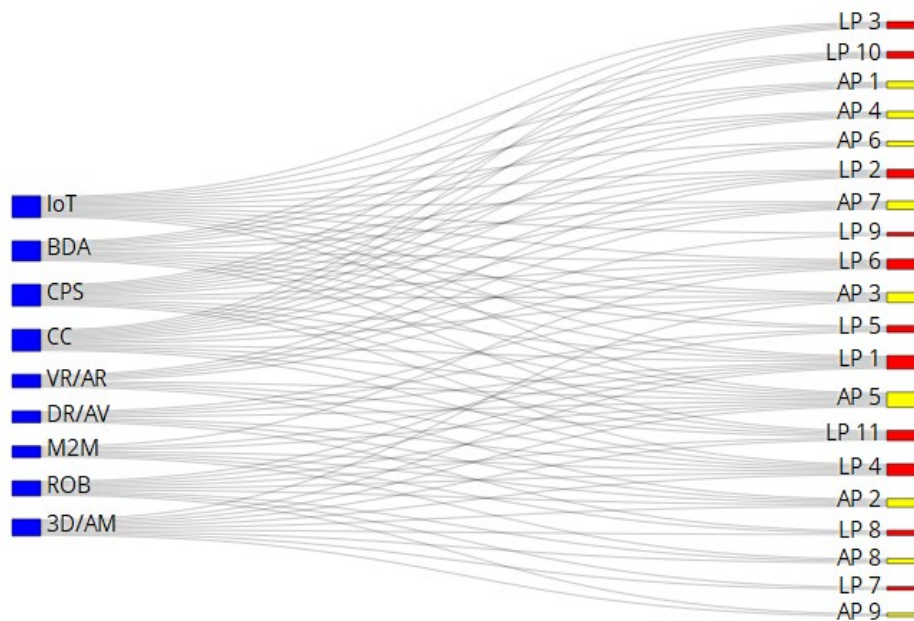


Figure 2: Proposed Conceptual model

IoT is capable of driving JIT practice of lean as well as centralised and collaborative planning practice of agile strategy. Other practices that could be enabled by IoT are as shown in the table and model. Corresponding practices enabled by each of the other technologies are as depicted in the table and model.

## 6.0. Conclusion

The continuous global competition is compelling companies to expand and connect their “internal improvement processes” with “external customers and suppliers”. Success in this phase of competition requires careful adoption of SC strategies alongside innovative capabilities such as Industry 4.0 technologies to enable such SC strategies. Lean and agile are critical strategies whose integration has been proven to ensure efficient use of resources and prompt response to dynamic market environment.

With performance improvement in mind, several studies have considered integration of different strategies/paradigms and their associated impact on SC. However, few have considered how Industry 4.0 technologies could enable these SC strategies for improved organizational performance. This study thus presents a conceptual model that matches diverse practices of Lean and Agile SC with industry 4.0 pillars (as drivers) for overall performance improvement. To achieve the aim, an overview of the relevant industry 4.0 technologies as well as practices of lean and agile strategies is first presented. Subsequently, a conceptual model is developed by specifically linking the principles/practices of lean and agile with industry 4.0 technologies as enablers.

Asides contributing to theory, this work has managerial implications as the identified practices of lean and agile SC can support practitioners to identify practices to adopt in line with organizational goals. Also, the conceptual model provides a “decision supporting tool” to “identify” potential industry 4.0 technologies in the context of lean-agile SC by way of motivating them on specific pillars of industry 4.0 to adopt for specific lean-agile strategies in achieving overall organizational goals.

Theoretically, the work provokes some future research agenda. As it is practically infeasible for companies to implement all the industry 4.0 technologies, it is important to categorize the technologies in order to prioritize which is more important for the most critical lean and agile practices being deployed in the company. Also, the proposed model which is anecdotally based on literature provokes development of empirical research studies and/or case studies to explore and validate the linkage depicted in the model.

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