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Manufacturing Process Innovation Deployment Readiness from an Extended People, Process, and Technology Framework Viewpoint

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Abstract

Advances in digital technologies, amongst others, present process innovation opportunities in manufacturing which if appropriately exploited will increase performance and productivity. Central to successful implementation of process innovation initiatives is adequate preparation during pre-implementation phase and ensuring that the business is ready prior to the deployment of their process innovation initiatives. Akin to digital transformation, key elements of process innovation deployment include people, process, and technology. An understanding of these key elements of process innovation deployment readiness will help towards achieving successful implementation outcome. This paper explores manufacturing process innovation deployment readiness from an extended people, process, and technology framework perspective. The extension adds to the traditional PPT framework the context of the deployment. Attributes of manufacturing process innovation deployment readiness were obtained from the literature and the derived attributes form the basis for discussing the extended PPT view of deployment readiness. It is concluded that failure to either consider or grossly underestimate the role of people, processes, technology, and the context of the deployment will undermine implementations of process innovation in manufacturing.

Keywords: Process Innovation; Deployment Readiness; Manufacturing; PPT Framework.

1. Introduction

An important facet of increased productivity and competitive advantage in manufacturing is process innovation. Simply put, process innovation encompasses the development of an organization's production or service operations, input materials, task specifications, work and information flow mechanisms, and equipment through the introduction of new elements including new technologies and new practices [1],[2],[3],[4],[5].

The importance of process innovation has been demonstrated in a variety of studies including, for example, the introduction of new technology for shop floor data collection [6], lean philosophy adoption [7], and Cloud-based ERP adoption [8]. Innovativeness is seen as an enabler and key consideration in sustainable and smart manufacturing [9]. Transitions to higher levels of lean attainment demand process innovation thinking [10].

The consequences of successful process innovation include financial performance, market performance, competitive advantage, environmental performance, and employee performance [11]. As with most things, successful innovation of manufacturing processes demands, amongst other things, preparedness and achieving an appropriate deployment readiness level prior to implementing the innovation initiative in manufacturing environment. Preparing for deployment is a key step in the implementation of process innovation initiatives. Preparation for deployment is usually considered a part of pre-implementation phase of putting a process innovation implementation decision into effect [12]. Enterprises that fail to deliver process innovation successfully are typically those who do not meet an appropriate level of readiness to deploy [13], [14]. Deployment readiness is the extent to which deployment has run smoothly and relatively problem-free [13].

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In today's world of advancing digital technologies, digital transformation of manufacturing hinges to a large extent on process innovation. According to [15], 'Digital transformation is characterized by a fusion of advanced technologies and the integration of physical and digital systems, the predominance of innovative business models and new processes, and the creation of smart products and services.' Central to digital transformation and process innovation are the elements of people, process, and technology (PPT). The aim of this paper is to explore readiness for deploying process innovation from the PPT framework viewpoint. As part of the paper, the attributes of process innovation deployment readiness in manufacturing were highlighted and the attributes are consolidated into a list of factors by an expert panel. The consolidated list of factors is then used as a basis in the discussion of the PPT framework for deployment readiness.

The remainder of this paper is structured into four sections. In Section 2, the attributes of manufacturing process innovation deployment readiness obtained from the literature is highlighted. Section 3 contains the research methodology used in this study and this is followed in Section 4 by a consolidation of the attributes into factors and mapping of the manufacturing process innovation deployment readiness factors to an enhanced PPT Framework. The paper ends with conclusions and suggestions for future work in Section 5.

2. Attributes of manufacturing process innovation deployment readiness

Manufacturing process innovation (MPI) can be expressed in several ways, such as an organization-wide effort that involves fundamental rethinking and radical redesign of manufacturing related processes and systems to achieve dramatic improvements in manufacturing performance measures such as cost, quality, service, and speed [16],[17]. Process innovation in manufacturing is not limited to manufacturing processes, it extends to manufacturing operations, activities in the transformation of materials and components to the delivered product, the associated supply chain, logistics and support systems such as production planning, purchasing, administration, engineering, and management [16],[17].

Process innovation offers manufacturing firm a key source of long-term competitive advantage, allowing for both efficiency and effectiveness gains [18]. Reducing the internal cost to the enterprise is a key outcome of process innovation. However, process innovation is not to be directly related to organisation performance [19]. In association with marketing innovation, the effect of process innovation on financial can be more significant [19].

According to [17] three key phases can be delineated in manufacturing process innovation, namely: preparation, design and implementation. The preparation phase involves the key activities of getting ready for the MPI initiative including getting management on-board of the MPI initiative and securing their commitment, identifying the specific processes to be innovated, having clear process vision and targets, ensuring alignment of corporate and business strategies, and adopting project management best practices. Considering that MPI is an organization-wide effort, it is typical to recognise it as a collaborative project involving considerable change management. The design phase involves focused analysis of processes, exploration, and evaluation of process design alternatives.

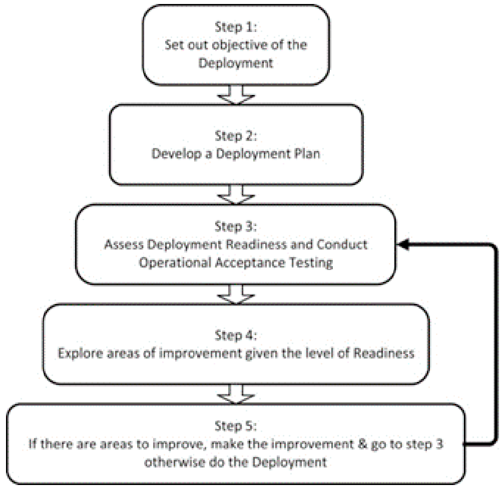

Fig. 1: Manufacturing Process Innovation Deployment Methodology. Adopted from [20].

Implementing process innovation involves many steps typically categorised as the pre-implementation, implementation, and post implementation phases. Preparing and getting ready to deploy process innovation initative belongs to the pre-implementation phase. Deployment readiness is key as not appropriately preparing for deployment can compromise the success of process innovation implementations. Using an appropriate deployment methodology is therefore central to realising the benefits of process innovation initiatives in manufacturing. A five-step methodology for manufacturing process innovation deployment is put forward by [20] as shown in Figure 1 above.

Ascertaining the vision and goals of the deployment is central to the first step of the methodology. In the second step, the focus is on planning for the deployment. Deployment planning in the second step specifies, amongst others, approach, scope and execution plan and risk considerations for the deployment. Readiness assessment and acceptance testing constitutes the third step. If target deployment readiness level is not reached an improvement step i.e. the fourth step is considered otherwise the deployment plan can be authorised.

Readiness assessment is the process of systematically analysing how ready a transformation stakeholder group is for a specific change. Evaluation tools for readiness assessment helps in the analysis and determination of the level of preparedness of the conditions, attitudes, and resources required in achieving a specific change. In terms of deployment, deployment readiness has a measurable outcome; this estimates the risk of the project and is often shown as a percentage. A higher level of readiness to innovate is identified through a number close to 100%.

On the other hand, a number close to 0% means a higher risk of failure. The overall readiness estimate of an organisation is a function of the readiness estimates of the individual influencing factors. There are several approaches for measuring deployment readiness and they include the analytical network process (ANP) [21], fuzzy cognitive maps inference [13], and a combination of fuzzy cognitive maps (FCMs) and the fuzzy analytical hierarchy process (FAHP) [13]. In [22], a simulation approach to readiness assessment is taken to more easily capture the complexities involved in modelling manufacturing processes and its operations.

Table 1 contains a list of attributes of process innovation deployment readiness compiled from the Literature. An emphasis in the compilation is on manufacturing enterprises. Several of the attributes relate to the inputs for readiness assessment in related work. For example, [14] is plan centric and includes factors that can impact on deployment plans. In the enterprise resource planning (ERP) setting, [12] identified three main areas that determines readiness to implement ERP, namely project management, organizational, and change management. The readiness for ERP implementation is further decomposed into project management, organizational, and change management areas and they are broken down into project, vision and goals, systems and processes, culture and structures, and human resources categories.

In smart factory settings, implementation of innovation is recognised as a risky undertaking that can be difficult but with numerous benefits [9], if the implementation is successful. According to [9], the key principles of smart factory implementation includes the facets of people (cultivating digital people), process (introduce agile processes), and technology (configure modular technology). [18] argued that high-quality realization mechanisms, principally strategy, collaboration, and culture are critical to achieve desired process innovation outcomes. In an empirical measure of process innovation, [19] used the following variables: imports advanced automatic quality restriction equipment/software, imports advanced programmable equipment, imports new process technology, imports new process technology, and adopts advanced CAD/CAM equipment.

3. Research Methodology

Aside from the literature review on the attributes of process innovation deployment readiness reported in Section 2 above, this study refers to aspects of a Delphi method conducted by the authors. The Delphi study approach has been used in a variety of ways; some researchers categorise the Delphi as a data collection technique while some others refer to it as a research method [35]. The Delphi method is a combination of best practices that allow participants to deliver their thoughts through various means of communication while analysing a complex problem [36]. This was developed in the 1950s by Rand Corporation as a data collection method designed to obtain comparability and discover opinion and consensus regarding topics in a discussion [37],[38].

The Delphi method is designed to encourage discussion to obtain answers from experts and at the same time give them the opportunity to refine their ideas and opinions during the discussion [39]. The method also provides an opportunity to gain better understanding of the topics covered [40]. Generally, participants in a discussion have a strong interest in the topic, bringing valuable knowledge and/or experience to that discussion [41]. Delphi approach involves a series of rounds of data collection. At the end of each round, the model or concept to be tested will be revised. These rounds continue until there is an agreement or disagreement that cannot be resolved [42]. The feedback is then analysed, and another questionnaire is developed based on the feedback received. It is also important to have a robust selection for the expert panel and the approach for an active and continuing participation in the discussion [40].

In this paper, the Delphi study of interest comprises of an expert panel drawn from the manufacturing and associated sectors and academics in the fields of manufacturing and innovation. Ten experts that consists of seven practitioners in the industry and three academics constituted the expert panel for the Delphi study. The average years of post-qualification experience of the expert panel is 24.3 years with a standard deviation of 4.5 years. The experience distribution is shown in Figure 2 below. The Delphi round of interest in this paper is that which relates to result of consolidating the attributes into factors. Following the consolidation of the factors by the Delphi study participants, a focus group of five experts drawn from the manufacturing industry each with over five years of engagement in continuous process innovation projects were constituted to validate the factors arrived at by the Delphi participants. The resulting factors is presented in Section 4 below.

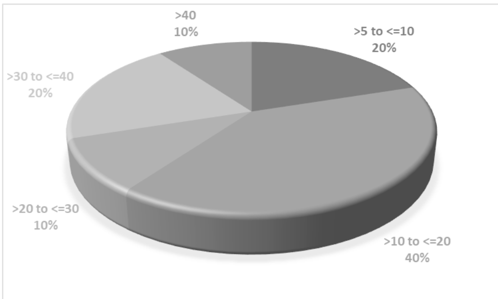

Fig. 2: Experience of the expert panel in Years.

4. Enhanced PPT Framework

Table 2 shows the consolidated factors obtained from the expert panel. The sixteen factors cover important aspects of process innovation deployment including resources and performance expectations. An enhanced people, process, and technology (PPT) framework is presented in this paper as a basis for conceptualising and discussing the factors. The enhanced PPT framework adds deployment context to the traditional people, process, and technology (PPT) model resulting in an MPI de-

Table 1: Attributes of Deployment Readiness found in the Literature

Attribute	Example citations
Market forces eReadiness.	[23]
Purpose, Mission and Goals, alignment to Market forces.	[23],[24]
Establishment of deployment plans and Implementation Vision , Business plan definition	[24],[25]
Strategy definition and Strategic Alignment, Link to customer and business strategy.	[26],[24]
Governance, Government eReadiness	[23]
Standardize procedures for deployment.	[27]
Legal environment, Government policy and vision - Regulations	[28],[24]
Organization open to new ideas (encourage innovation) knowledge sharing culture.	[27]
Organization Structure, Capability, Barrier	[29],[30],[24],[12]
Support services overview	[24]
Acquired leadership abilities, Understand and support, Management and Leadership	[27],[26],[25]
Ability to communicate vision and mission	[27],[31]
Ability to influence cultural readiness for change.	[27]
Willing to assess and accept changes.	[27]
Ability to handle staff with poor performance.	[27]
Aggressive about setting up targets and achieving them.	[27]
Resilient and able to deal with frustration.	[27]
Knowledge of new process	[29]
Infrastructure	[28]
IT Partnership	[26]
Maturity of the innovation - Technical maturity	[27]
Training (Education Requirements and Policies), coaching and learning opportunities, Training & education at all levels in the organisation	[27],[26],[25]
Organization encourages process ownership.	[27]
Employees feel free to report information on errors and defects.	[27]
Employees are motivated to self-enhance and adopt a learning culture and Educate on process capability indicators.	[27],[25]
Commitment to deployment and Assign Responsibilities.	[27],[12]
Organization promotes the involvement of all its employees in quality and CI.	[27],[23]
Availability of reward system and Educational level of employees.	[27]
Motivation , and HR system and Human Capability.	[29],[28],[30]
System Quality and Organizational process maturity.	[30],[24]
Availability of scientists and engineers and Technical skills development.	[24],[32]
Experience, selecting the right people.	[31]
Attitudes - Habits.	[29]
Skill, Employees' knowledge, and skills.	[29],[25]
Technological resources and Availability of latest technologies.	[23],[33],[32]
IT Partnership, Subcontractor engagement.	[26]
Decisions made based on facts.	[27]
Proactive quality system.	[27]
Data Source, Data Management and Data and Information Quality.	[26],[30]
Analytics Capability and Basic consideration of IT usage.	[30]
Potential value analysis.	[24]
Communication support design.	[24]
Project structure, Availability of project selection procedure and Presentation of the project.	[27],[24]
Production process sophistication - Determination and documentation of core value process.	[27],[32]
Understand the processes and its workflow.	[27]
Protection of innovation.	[24]
Communications tools implementation.	[24]
Impact on equipment evaluation and value chain evaluation - Value chain breadth.	[24],[32]
Distribution modes design- Control of international distribution - Local supplier quantity and quality.	[24],[32]
CI is aligned with business strategy.	[27]
Project selection criteria, Adequacy between the strategy and the project, Process selection and prioritisation.	[27],[24], [25]
Project management skills: setting agenda, setting, and keeping ground rule, determining meeting roles and responsibilities.	[27]
Financial, Budget elaboration and Financing plan definition, Financial risks and Financial security of partners, Resource Allocation.	[29], [24]
Deployment (planning) - Treasury plan, Investment plan.	[24],[34]
Project Championship - management commitment and resources.	[31]
Establish comprehensive measurement mechanism for the process and product performance, Reliable tools to measure and Valid measurement system - Performance measures (key internal and external) identified, defined, and developed.	[27],[25]
Evaluate process performance and Evaluate organizational/operational performance - Justification of process owners, responsibilities, authority, and process performance targets.	[27]
Training.	[34]

Table 2: Consolidated Factors and their Description

Factor	Description
Absorptive capacity	Absorptive capacity is the deployment team's ability to identify, assimilate, transform, and use valuable external knowledge towards achieving successful implementation.
Deployment control	Deployment controls are the application of processes to measure project performance against the project plan, to enable variances to be identified and corrected, so that project objectives are achieved. It is aimed at keeping a deployment on track by minimising the gap between the deployment plan and deployment execution to achieve the implementation objective subject to deployment constraints.
Deployment coordination	Deployment Coordination involves managing the day-to-day operations of the deployment, ensuring awareness of deadlines and tasks the deployment team and individuals are responsible for.
Deployment plan	Is the deployment project plan including a set of controls within project constraint particularly relating to time, cost, scope, and quality.
Dynamic capability	Dynamic capabilities are the firm's ability to assimilate, develop, integrate, and reconfigure internal competencies to appropriately fit the changing environment.
External factors	These are factors outside the organisation at both the micro-level (customers, suppliers, and the industry) and the macro-level (national and international context) that influence the deployment of process innovation. The factors include the influence of government support, policies and regulations, b) competitor's pressure and market forces, c) suppliers and contractor's and their cooperation, d) national and international business environment of supporting industries, and e) environmental and social uncertainty.
Financial resources	Finances and financial resource requirements including it is availability, adequacy, and stability throughout the deployment.
Flexibility	The deployment team is open to different ways of organising resources for an accomplishing the target implementation.
Human resources	Human resources are the set of people who makes up the workforce for the deployment. Emphasis is on availability, clarity of roles and responsibilities for the deployment, development and training, and stability of human resources during the deployment.
Innovation context	Innovation context is the set of circumstances, including intangible resources, that form the setting for the process innovation in terms of which its deployment can be fully understood. Emphasis includes the type of process innovation, associated technology readiness level, specific and enabling infrastructure, prior experience, and knowledge and understanding of the technological context required for the process innovation deployment.
Organisational and leadership context	Organizational context is the background or environment or atmosphere in which the organization operates, and within which the deployment is going to take place. It is basically a way of thinking about organisational culture, and motivating individuals within the group to successfully carry out process innovation deployment. Fundamental responsibility of leadership is consciously creating and sustaining organizational context.
Performance expectations	Performance expectations are requirements of the deployment team including expected outcomes, behaviour, and actions. Important is the appropriateness of the target outcome agreed in delivering the implementation with demonstrable improvements subject to constraints.
Prevailing cultural norms	Prevailing cultural norms are the currently agreed upon expectations, standards, and rules by which a culture guides the behaviour of the deployment team.
Process visibility	Process visibility is the ability to see end to end and understand all aspects of the deployment at any point in time.
Technical resources	Technical resources represent the availability of all the physical and non-physical technical assets that are required to support the deployment.
Vision and Strategic Plan	Vision outlines what the organisation is likely to ultimately achieve with the process innovation and gives purpose to the existence of the organization, presenting an anchor point for strategic plan.

ployment CPPT framework where 'C' signifies the deployment context. An exploratory mapping of the consolidated factor list (Table 2) to the CPPT elements is shown in Table 3. The exploratory mapping is based on the perspectives of a manufacturing process innovation team in the industry.

The context of deployment matters because there are significant contextual factors that must be taken into consideration. Deployment context is the circumstances that form the setting for the process innovation deployment, expressed in terms of which the process innovation implementation can be fully understood. In the MPI deployment CPPT framework, the external factors, innovation context, organisational and leadership context and prevailing cultural norms are considered key aspects of the deployment context. Organizational context is the background or environment or atmosphere in which the organization operates, and within which the deployment is going to take place. It is a way of thinking about organisational culture, and motivating individuals within the group to successfully carry out process innovation deployment. The fundamental responsibility of leadership is consciously creating and sustaining organizational context. Prevailing cultural norms are the currently agreed upon expectations, standards, and rules by which a culture guides the behaviour of the deployment team. External factors are outside the organisation at both the micro-level (e.g. customers, suppliers, and the industry) and the macro-level (national and international context) that influence the deployment of process innovation. The factors include a) the influence of government support, policies and regulations, b) competitor pressure and market forces, c) suppliers and contractors and their cooperation, d) national and international business environment of supporting industries, and e) environmental and social uncertainty.

People factor is important in preparing for process innovation deployment in manufacturing. The people factor is partic-

Table 3: Consolidated Factors and their Enhanced PPT Mapping from the Perspective of an MPI Project Team.

Factor	Enhanced PPT manifestations			
	People	Process	Technology	Context
Absorptive capacity	✓	✓		
Deployment control	✓	✓		
Deployment coordination	✓	✓		
Deployment plan		✓		
Dynamic capability	✓			
External factors				✓
Financial resources	✓	✓	✓	
Flexibility	✓	✓	✓	
Human resources	✓			
Innovation context				✓
Organisational and Leadership Context				✓
Performance expectations		✓		
Prevailing Cultural Norms				✓
Process visibility		✓		
Technical resources			✓	
Vision and Strategic Plan	✓			

ularly important because the knowledge and skills of the personnel involved in preparing for deployment will help in the planning, control, and coordination of the deployment. So also, is in considerations for the vision and strategy of the company regarding process innovation. When running a MPI deployment project, the need to collaborate with various stakeholders is important as it would involve people handling the key functions of control and planning for adequate process visibility. Effective deployment plan and control can improve the company's strategy which would be employed during design phase or when exploring lower cost design options. Early involvement can mean fewer change orders, more control over risk, and higher profits for your company. The people factor can also influence deployment capacity and capability. For effective collaboration, finding people with the necessary skills, and attitude is a necessary step in implementing MPI deployment plan and controls. This would involve having the required amount of information which would help in making sure that the changes that may arise due to the plan and control are planned for and making the necessary adjustments accomplishable. Readiness of the stakeholders is also key, as demonstrated for blockchain adoption readiness study presented in [43] in healthcare setting. The people factor transcends industrial sectors and readiness concepts.

The deployment itself is a process which will be influenced by the flexibility with which the deployment can be done and the ability to see the deployment process end to end i.e. process visibility. Process visibility can be significantly facilitated through information sharing and technology. Technology impact deployment readiness in several ways, principally the technological infrastructure and resources that are relevant to the implementation process. The tools for the deployment are typically provided by the technology element of the CPPT framework. Technical resources are central to deployment readiness and the technical resources will enable information sharing, amongst others. With the advances of digital technologies including Industry 4.0, adopting process innovation strategies that are founded on Industry 4.0 technologies can facilitate the adoption of lean practices and enhance the relationship between leanness of the process and operational performance, which also leads to higher economic outcomes [44]. It has been argued that for digitally enabled process innovation, new dynamic capabilities are needed by firms, encompassing digitally enabled sensing capabilities, digitally enabled seizing capabilities and digitally enabled reconfiguring capabilities [44]. Acquiring these capabilities and using them appropriately present key challenges, and recognition of the context, people, process and technologies involved can help.

The experts consulted in this study found absorptive capacity relevant to MPI as evidenced in the process innovation literature in general. Absorptive capacity is 'the firm's ability to recognize the value of new, external information, assimilate and apply it to reach the organization's goals' [45]. To leverage new knowledge obtained from external knowledge sources, internal processes and routines that will facilitate the assimilation, transformation, and exploitation of the new knowledge in the quest for successful process innovation is important [46]. Potential absorptive capacity, encompassing a firm's capability to acquire and assimilate external knowledge, is known to mediate the relationship between external knowledge search and process innovation [47].

Several of the factors encompasses several of the elements in the CPPT framework, e.g. financial resources. Whilst Table 3 entries can arguably be seen to be subjective, it nonetheless provides stakeholder opportunities for reasoning about the deployment readiness factors in terms of deployment context, people, process, and technology. Stakeholders need to find the right balance between the three critical elements of people, process, and technology within the context of the deployment.

The factors identified by the experts consulted in this work aligns with central factors and dimensions in the literature of innovation and performance. For example, [17] identified four central factors influencing innovation performance of an organisation namely, strategy, structure, culture and external environment. The 'Berkeley Innovation Index' focuses on five main factors impacting innovation, namely strategy and leadership, innovation culture at an organizational level, company operations and measures across functional and tactical areas, mindset of individuals in the company referred to as the 'innovation DNA of the people', and tactical measures [48]. The CPPT framework manifests in relationships amongst implementation readiness factors. [12] decomposed the readiness for ERP implementation into three areas, namely, project management readiness, organizational readiness, and change management readiness. The areas were linked to five key factors, namely project, vision and goals, systems and processes, culture and structures, and human resources in a hierarchical relationship model [12], implicit in the model are people, process, and technology. Extending the PPT framework to include deployment context will be helpful in a more rounded view of MPI.

5. Conclusions and Future Work

This paper considers an enhanced PPT framework mapping for process innovation deployment readiness in manufacturing. The enhanced PPT framework takes into consideration the traditional people, process, and technology elements of the PPT framework with the inclusion of deployment readiness context. A sixteen-factor model of deployment readiness is used in the mapping. The factors were obtained as part of a Delphi study. The factors are absorptive capacity, deployment control, deployment coordination, dynamic capability, external factors, flexibility, innovation context, organisational and leadership context, performance expectations, prevailing cultural norms, and process visibility. A view is presented in this paper that contextual factors play significant direct role in preparing for process innovation deployment readiness in manufacturing. The contextual factors include those associated with external factors, innovation context, organisational and leadership context, and prevailing cultural norms. A suggested future work is to validate the indicated factors and its benefits using an extended survey of participants drawn from manufacturing sector.

CRediT author statement

Funlade Sunmola: Conceptualization, Methodology, Validation, Investigation, Data Curation, Writing - Original Draft, Writing - Review & Editing, Visualization, Supervision. **Alireza Javahernia:** Methodology, Validation, Investigation, Data Curation, Writing - Original Draft, Writing - Review & Editing, Visualization, Project administration.

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