Assessing Agility Implementation in Manufacturing

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Abstract

Agility in manufacturing can be briefly defined as the ability to foresee, attend, and recover from an unexpected change. Tightly related to leanness and flexibility, its implementation requires different actions on each of the management, technology, and operations levels. This paper presents a 26-item measurement tool that assesses and detects the lack of Agility on those three levels. Data was collected through online interviews with managers from 140 large size US manufacturing companies. The constructs had high reliability coefficients and confirmatory factor analysis showed excellent fit indices yielding promising results. Future work might involve validating this model in a larger sample and checking whether it applies in different countries.

Keywords
Agility, Manufacturing, Flexibility, Automotive Industry, Confirmatory Factor Analysis.

1. Introduction

Challenging and changing environments can have a destructive impact on any business. Competitive markets, shifts in consumer needs, or even the spread of infectious diseases can be a fatal threat to any organization across the world. Compared to Darwinian evolution by Bessant et al. (2002), survival in the midst of these harsh conditions is a privilege of the fittest. In addition to being alert to unexpected changes in the environment, the authors further explain that intelligent, rapid, and proactive adaptation is key to staying ahead of the game.

Leanness, flexibility, and agility are renowned production models that can be applied in practice to ensure continuous and efficient operations under stressful conditions. Although being used interchangeably in the manufacturing production literature, they define related but different concepts (Sajdak 2013). Lean production mainly focuses on minimizing waste while maximizing productivity favorizing mass production. A recent paradigm shift away from this concept is due to an increasing rate of change in the business environment. Flexibility, superior to Leanness even if more costly as stated by Adeleye and Yusuf (2006), emphasizes the swift movement between tasks on a usual manufacturing procedure while Agility is defined as the ability to cope quickly with an unexpected change. Even though flexibility and agility share the rapid adaptation component, the main difference between them is that the former is operational in the sense that it deals with routine processes while the latter can also be strategic and has a forecasting nature (Fayezi et al. 2017). As pointed out by Elkins et al. (2004), another difference between them is that Agility deals with a turbulent environment in the most cost-effective way. The choice of either production models should rely on the market needs and the nature of the product being manufactured. If high volumes are needed then a dedicated production system is favored, otherwise, flexibility and agility should be considered as a smarter and more sustainable alternative.

2. Literature Review

Zhang and Sharifi (2000) described Agility as having four components. The first one, Responsiveness, ensures that reactive or proactive actions are taken to counter or recover from an unexpected changing situation. The second one is Competency in acquiring knowledge and technology while achieving cost-efficiency. Flexibility in production, communication, task-assignment, or decision-making across the organization, is also considered a part of Agility. The last component, Speed, emphasizes the quickness in production, innovation, operations, and delivery. Another inspiration for this work is a recent model by Dubey and Gunasekaran (2015) that presented Agility as a seven-dimensional model and identified its dimensions and indicators in the Indian context.

Gunasekaran (1998) emphasized the strategic form of Agility in response to unexpected changes that alter the rules of the game. Hence, setting a strategy based on increased efficiency goals while having an organizational culture fostering education, innovation, internal cooperation, and complementary external alliances, strengthen the mission and vision of the organization and equips it with adequate managerial skills to counter any threat to its survival.

Further to a well-established vision and a well-trained human capital, technologies are considered an additional asset to favorizing Agility in both production and communication processes (Dunlop-Hinkler et al. 2011). The use of robotics and CNC machines, among others, ensures advanced flexibility for rapid prototyping and innovation crucial to meet with any potential change in customers' needs. Furthermore, unifying functions in one system across all departments enhances communication and information flow.

Moreover, Meredith and Francis (2000) defined Operational Agility as the alignment of operations with the agile vision of the organization. The ability to continuously control material inventory, to optimize workloads, and to forecast raw material needs is crucial in swiftly adapting and responding to market changes. This adaptability is complementary to the other facets of Agility in making fast product customization and safe delivery possible.

Based on the three axes of Agility, identified from the existing literature, and in response to the gap and confusion organizational and supply chain Agility and Flexibility discussed by Fayezi et al. (2017), we aim to develop a reliable assessment tool based on the definition, components, and previously validated models of Agility measurement. Nevertheless, our tool can be used to measure a company's degree of Agility implementation on three levels: the strategical (vision of the organization), technological (production and innovation), and the operational (material handling and delivery). Additional references that were relevant to the choice of indicators and subscales can be found in Table 1.

3. Research Methodology

After conducting an exhaustive literature review of all existing literature on Agility in manufacturing, its definition, enablers and drivers, a set of indicators was created. The list was updated based on input from academics, practitioners, and experts in the field. Irrelevant items were deleted and ambiguous ones were reformulated in accordance with their applicability in the manufacturing field. The 26 remaining items were scored on a Likert-scale from 1 (Not implemented) to 10 (Fully implemented). A pilot study was then conducted to test the validity of this tool. Data was collected through online interviews with senior managers with more than 25 years of experience from 140 large size US manufacturing facilities. The statistical analysis of the data has been conducted using R Version 3.6.1.

Table 1. Constructs and Indicators

Constructs	Indicators	References
Tactical	TAC1: Planning daily decisions based on measurable goals to respond speedily to changes	Gunasekaran (1998), Gunasekaran and Yusuf (2002), Yao and Carlson (2003), Gehani (1995), Chalhoub (2011), Sahin (2000), Sharifi and Zhang (2001), Ismail et al. (2019), Maamari and Saheb (2018), Dagher et al. (2015), Karkoulian et al. (2019), Katayama and Bennett (1999), Maskell (2001), Sarkis et al. (2007), Sanchez and Nagi (2001), Strategic Decision (2019)
	TAC2: Designing a map of objectives for lively tracking of employees	
	TAC3: Having an organizational culture that promotes innovation, training, and education	
	TAC4: Gaining union/management buy-in for new processes and planning	
	TAC5: Assigning, precising, and reaching cost goals and objectives	
	TAC6: Involving different agents in the product development and production processes	
	TAC7: Forming strategic alliances based on core/complementary competencies	
	TAC8: Guiding needed rapid and sudden decisions through knowledge management	
	TAC9: Forecasting future market sales and needs based on data at hand	
	TAC10: Creating an efficient and flexible supplier relationship	
	TAC11: Building a strategy that thrives on minimizing time and waste while having a high sensitivity to changes in customers' needs	
	TAC12: Designing a backup recovery plan for an impactful change and studying the logistics of its implementation	
Technological	TEC1: Using technologies and favorizing automation via robots, CNC machines, pulse tools…	Dunlop-Hinkler et al. (2011), Gunasekaran et al. (2019), Gunasekaran (1998), Gunasekaran (1999), Marík et al. (2002), Goldman et al. (1995), Harik et al. (2008), Geyi et al. (2020), Meredith and Francis (2000), Ferreira et al. (2011), Gregory et al. (2014)
	TEC2: Controlling maintenance of equipment and machines during the manufacturing process (Visual inspection)	
	TEC3: Using technologies in process planning to maximize responsiveness to changes	
	TEC4: Combining functions and information in one system across all departments to increase efficiency for customized production	
	TEC5: Decoupling processes to isolate problem source	
	TEC6: Using modern software and computer-controlled machinery	
	TEC7: Increasing the autonomy of the system by running unattended for a long enough period	

	TEC8: Using technologies for rapid prototyping	
Operational	OPE1: Keeping track of inventory and material processing	Gunasekaran et al. (2019), Fliedner and Vokurka (1997), Venugopal and Saleeshya (2019), El-Kassar et al. (2020), Meade and Sarkis (1999), Meredith and Francis (2000), Forsythe and Ashby (1996), Sindhwani et al. (2019), Baraei and Mirzaei (2018)
	OPE2: Safely transporting and controlling the materials across the supply chain process	
	OPE3: Optimizing work and workloads	
	OPE4: Optimizing the flow of equipment with real-time data	
	OPE5: Forecasting your raw material requirements	
	OPE6: Implementing automated guided vehicle systems (AGVs); automated storage and retrieval systems (AS/RS)	

4. Results

We present Agility in Manufacturing as a three-dimensional construct with the following factors: Tactical (TAC), Technological (TEC), and Operational (OPE). The three dimensions are composed of twelve, eight, and six items, respectively. A brief description of the indicators can be found in Table 1.

Confirmatory factor analysis, with Maximum-Likelihood (ML) estimation, was conducted to test the validity of the proposed measurement model. Item reliability was investigated by examining the standardized loadings that should exceed the cutoff value of 0.70 as recommended by Chin and Todd (1995). All standardized loadings verified this condition except for TEC2 (see Table 2). However, loadings greater than 0.60 can still be considered acceptable according to McNeish and Hancock (2017). In addition, *t* statistics corresponding to the loadings were all significant ($p < 0.001$). According to the cutoff values suggested by Hu and Bentler (1999), the fit indices of the model were satisfactory: the chi-square statistic was $\chi^2 = 377.57$ (df = 296), the root mean square error of approximation RMSEA = 0.044 < 0.05, the non-normed fit index NNFI = 0.983 and the confirmatory fit index CFI = 0.985 were both above 0.95 indicating an excellent fit. Moreover, excellent Cronbach's alpha and composite reliability coefficients (> 0.90) were obtained for each of the factors stressing the high reliability of the suggested factors of Agility. The Average Variance Extracted (AVE) of the three dimensions was greater than 0.50 suggesting convergent validity of our model. More details about standardized factor loadings, reliability coefficients, and AVE are presented in Table 2.

Table 2. Reliability of the constructs and the standardized loadings of the indicators.

Constructs	Indicators	Standardized Loadings	Cronbach's Alpha	Composite Reliability	AVE
Tactical	TAC1	0.970	0.99	0.97	0.92
	TAC2	0.965			
	TAC3	0.965			
	TAC4	0.966			
	TAC5	0.967			
	TAC6	0.963			
	TAC7	0.971			
	TAC8	0.938			
	TAC9	0.930			
	TAC10	0.946			
	TAC11	0.944			
	TAC12	0.948			
Technological	TEC1	0.732	0.90	0.96	0.55
	TEC2	0.686			
	TEC3	0.747			
	TEC4	0.729			
	TEC5	0.765			

	TEC6	0.726			
	TEC7	0.737			
	TEC8	0.739			
Operational	OPE1	0.870	0.95	0.96	0.78
	OPE2	0.876			
	OPE3	0.866			
	OPE4	0.901			
	OPE5	0.875			
	OPE6	0.903			

5. Discussion

After the success of Toyota Production Systems, Lean management, the standardization of work, mass production, and the focus on reducing waste were praised for maximizing profit until machines were overburdened with increased utilization and more problems were occurring. Flexibility was then popularized as the ability to absorb the problems without impacting the throughput of the system, for example through scheduled maintenance of machines and cross-training of employees. However, the rate of change in the business environment imposed the need for a quick adaptation and recovery from unexpected changes. As Figure 1 illustrates, agility is now viewed as the pyramidion of organizational evolution. The need for its implementation is becoming a pressing topic especially with the unprecedented biological pandemic that the world has been witnessing since December 2019 along with its economic and societal impact.

This paper presents an assessment tool that can be used to identify the need/lack of Agility whether on the management, production, or operations levels. Implementation of Agility underlying the four components: Competency, Responsiveness, Flexibility, and Speed, differs according to the organizational level of application. For instance, building an organizational culture favorizing innovation, training, and education on one hand; and using an appropriate modern technology on the other, are both administrations of Competency. However, the former is related to the strategy and mission of the organization while the other to its technological resources.

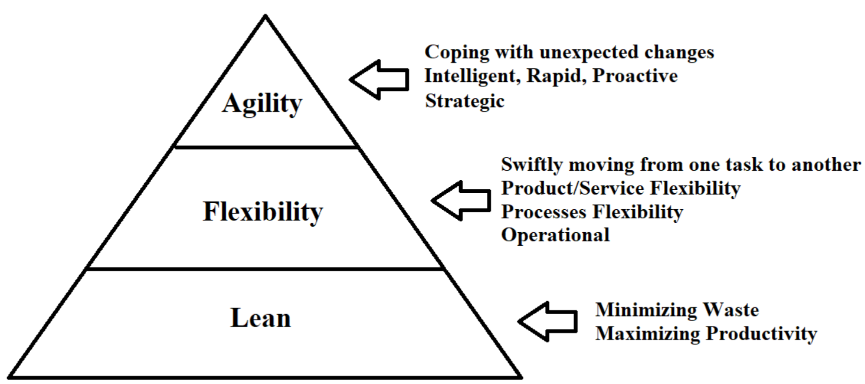

Figure 1. Organizational Evolution

Tactical Agility refers to flexibility in the global vision of the organization through the promotion of innovation while being cost-efficient. Moreover, Fahed-Sreih and El-Kassar (2017) argue that innovative capabilities were shown to be promoted by strategic planning and directly linked to more efficient overall performance. It also encompasses the ability to adhere to customers' needs and requires quick recovery from any unexpected change.

Technological Agility refers to the use of modern techniques and technology in the manufacturing process to achieve speed, autonomation, and "machine-multitasking". The last term refers to a machine that can be used to produce a range of existing products or that can be adapted to new ones. Technological advances such as simulation and computer modelling have also helped in the optimization of manufacturing systems' throughput while taking into consideration budget limitations and constraints (El-Khalil 2013, 2015; Musa at al. 2012). Other initiatives even helped in developing an intelligent system to ease the tedious job of employee recruitment (Rifai et al. 2007).

Operational Agility is related to operations, material handling, and delivery. Keeping track of the inventory and projecting the need for raw materials is key to achieving control over the foreseeable changes in needs and minimizing the impact of any unexpected change. For instance, Tarhini et al. (2020) have recently studied the optimization of transportation and delivery route through mathematical modelling. Future studies might involve the vehicle routing problem during a biological event such as a pandemic.

6. Perspective

This study is part of an ongoing project that is investigating the impact of different manufacturing philosophies such as Agility, Flexibility, Sustainability on Operational Performance Metrics. We further formulate three possible future directions for research based on this work:

- It would be interesting to validate our model in a larger sample and check whether it is applicable in other countries.
- It is known that Flexibility has a positive impact on operational performance metrics (El-Khalil and Darwish 2019). A similar impact is expected for Agility and future work might consider studying this effect.
- Another possible future direction for research is to understand the relationship between Agility, Sustainability, and their joint effect on the performance of the organization.

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