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Lean and agile performance framework for manufacturing enterprises

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Abstract

The overall performance of a manufacturing organization is a drastic function of the strategies applied to its physical sectors. Traditional strategies were based on the principle of economies of scale, which resulted in excess of waste and difficulty of reconfiguration. Global competition necessitates formulating efficient and effective paradigms in response to the global economies to improve the overall performance. Lean and agile manufacturing have been widely adopted in recent years' enterprises. Leanness mainly leads to eliminating the non-value added activities while agility focuses on leads to market responsiveness. This paper discusses the leanness and agility definitions, factors, paradigms, differences, and combination. A hierarchic framework is presented which can be used to measure the leanness, agility, leagility, and overall performance of an enterprise, further, to compare different enterprises. This enables using the multi-criteria decision making methods especially AHP and ANP. Levels of leanness and agility can be fed as input to define a variety of enterprises. Moreover, a different view is introduced for general features of an efficient/effective manufacturing organization irrespective to the definitions of leanness and agility.

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Keywords: Supply chain; Lean; Agile; Performance; AHP; ANP

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1. Main text

There is an increasing need to switch from the principle of economies of scale to global economies in the current competition environment. World-class performance becomes the goal of manufacturing organizations. Such performance is a moving target that requires never ending and alert processes of improvement in the applied manufacturing strategies. Manufacturing managers have sought performance improvements by adhering to currently popular paradigms, lean and agile manufacturing, or more broadly lean and agile enterprises. Notice that an enterprise is a collection of business processes that combined to produce desired results and a business process is a time ordered set of activities that accomplishes a purpose [1]. Lean means developing a value stream to eliminate all waste, including time, and to ensure a level schedule while agility means using market knowledge and a virtual corporation to exploit profitable opportunities in a volatile market place [2]. Virtual corporation/enterprise means cooperation among many enterprises culminating in a virtual partnership or virtual confederation of supply chain partners [3]. A major issue in the formation of the virtual enterprise is the rapid integration and reconfiguration of the business processes of the participating enterprises. A virtual enterprise is conceived when a need is recognized in the marketplace and a set of business objectives is established. To conceive a virtual enterprise, it is important to consider an understanding of the customer expectations and how to satisfy their expectations [4]. A supply chain is a system whose constituent parts include material suppliers, production facilities, distribution services and customers linked together via a feed forward flow of materials and feedback flow of information [5, 6]. The supply chain can be analyzed into three main physical segments; sourcing, manufacturing, and delivery [7, 8].

This paper is organized into four consecutive sections. After the introduction, section two discusses the supporting literature of lean and agile manufacturing. Section three explores the factors that affect the overall performance of a manufacturing organization. These factors are described and arranged, according to the mutual relationships, in different levels of a hierarchy to enable evaluating and comparing general, lean, agile, or leagile enterprises. Additionally, the degree of leanness or agility can be measured at specific levels in the hierarchy. Therefore, leanness and agility can be separated trying to eliminate the communal confusions that appeared in the literature. Section four discusses the conclusion and future works.

2. Literature review

2.1. *Lean an agile concepts*

While there is plethora of studies on lean and agile, there are still confusions about their definitions and structures. They have been often recognized as concepts, theories, capabilities, paradigms, systems, philosophies, strategies, or practices. Narasimhan, Swink [9] stated that lean manufacturing and agile manufacturing are distinct, yet overlapping paradigms. Haq and Boddu [10] mentioned that for many, lean manufacturing and agile manufacturing sound similar, but they are different. Lean manufacturing is a response to competitive pressures with limited resources. Agile manufacturing, on the other hand, is a response to complexity brought about by constant change. Lean is a collection of operational techniques focused on productive use of resources. Agility is an overall strategy focused on thriving in an unpredictable environment [11]. The determinants or performance measures of product-end-user value (i.e. value metric) can be combined as quality, lead time, service level, and cost. Those determinants are classified into two categories: market qualifiers and market winners. In lean concept, quality, lead time, and service level are identified as market qualifiers, whereas cost is the market winner. For agile, quality, lead time, and cost are identified as market qualifiers, whereas service level is the market winner [1, 12]. Other strategies may change the sets of qualifiers and winners. For example, a current winner may become a qualifier after one year.

The lean and agile paradigms, though distinctly different, can be combined within successfully designed and operated total supply chains via a decoupling point [6]. That is called termed leagility. The decoupling point separates the part of the organization oriented towards customer orders from the part of the organization based on planning. Positioning the decoupling point in the supply chain determines the form of leagility. For successful leagility, Purvis,

Gosling [1] suggested that leanness and agility cannot be employed at the same point in any supply chain. Lean should be applied upstream the decoupling point whereas agile should be applied downstream the decoupling point. The key characteristic of lean and agile are waste elimination and market responsiveness respectWomack and Jones [13]ively. Waste elimination refers to reduce/cut the Non-Value Added (NVA) activities from the supply chain process. Market responsiveness include reading (sensitiveness) and replying (flexibility, rapidness, and reliability) to the real demand volume and product types. Accordingly, lean is suitable when the customer demand is relatively stable and product variety is low while agile suites volatile demand and high product variety. The nature of NVA depends on the activities of the organization. Waste may be identified in three major types: unobvious waste, less obvious waste, and obvious waste. The obvious waste includes inventory, unneeded processes, excessive setup times, unreliable machines, and rework. The less obvious waste occurs as a result of variability sources such as process times, delivery times, yield rates, staffing levels, and demand rates [14]. Lean is capable of eliminate the obvious waste and reduce the less obvious waste. As a result, it can replace expensive buffers (such as inventory) with less expensive ones (such as capacity). Lean operations reflect performance improvements in the areas of cost efficiency, conformance quality, and delivery speed and reliability. Notice that delivery speed and reliability are enablers of agility, which shows some overlap between leanness and agility. The improvements stem from greater resource productivities and utilizations, lower overhead, lower inventories (especially work-in-process), and faster cycle and throughput times. Womack and Jones [13] identified the waste into eight types as follows.

1. Overproduction: Producing too much or too soon, resulting in poor flow of information or goods and excess inventory.
2. Defects: Frequent errors in paperwork or material/product quality problems resulting in scrap and/or rework, as well as poor delivery performance.
3. Unnecessary inventory: Excessive storage and delay of information or products, resulting in excess inventory and costs, leading to poor customer service.
4. Inappropriate processing: Going about work processes using the wrong set of tools, procedures or systems, often when a simpler approach may be more effective.
5. Excessive transportation: Excessive movement of people, information or goods, resulting in wasted time and cost.
6. Waiting: Long periods of inactivity for people, information or goods, resulting in poor flow and long lead-times.
7. Unnecessary motion: Poor workplace organization, resulting in poor ergonomics (e.g., excessive bending or stretching and frequently lost items).
8. Underutilization of employee: Unused employee creativity and skills to improve the processes and practices this refers to wasting the available knowledge, experience or skill of the staff/workforce by under-employing them or not using them in the proper department. This can be due to poor hiring techniques and task delegation on the part of management.

Lean and agile manufacturing can be characterized as a collection of practices. Practices that commonly associated with lean include JIT, TQM, equipment management and total preventive maintenance, Kaizen, design for manufacturing and assembly, supplier management, human resource training and involvement, decision support systems, and variability reduction [14, 15]. Practices that associated with agile comprise JIT, TQM, customer linkages, supplier alliances and information sharing, wide range of skill training, advanced information and manufacturing technologies, decision support systems, communications, motivation, concurrent teams, worker empowerment, and modular facilities [1, 3, 16]. Such practices can be divided into sub-practices to facilitate measuring the NVA/waste and market responsiveness of a manufacturing organization [17-19]. Houshmand and Jamshidnezhad [20] claim that lean is supposed to accomplish three common actions: design of the production system as a level of managerial action, control of the production system in order to achieve the desired goals, and leadership of the improvement of production system. McCullen and Towill [21] argue that partnership arrangements and close relationships with suppliers, JIT production, and advanced technologies are important enablers of agile manufacturing. The authors also emphasis on

the importance of highly skilled, knowledgeable and empowered workers. This means that the agility is strictly information based rather than inventory based. An overlap is obvious between lean and agile practices. Therefore, the literature indicates chronological and/or dual relationships between lean manufacturing and agile manufacturing with keeping the key characteristic of each concept. McCullen and Towill [21] implied that agility can be a precursor to leanness. Hormozi [22] suggests that reaching world-class performance is developing lean manufacturing to agile manufacturing. In other words, leanness could be an antecedent or foundation of agility, which is dominant in the literature.

2.2. *Enterprise performance measurement*

Performance measurement is the process of quantifying the efficiency and effectiveness of actions that lead to performance [23]. The essential function of a performance measure is to assess how well the activities within a process, or the outputs of a process, achieve specified goals. This involves a comparison of actual operation results with predetermined goals and an assessment of the extent of any deviation from those goals. Ahmad Ahmad and Dhafr [24] mentioned that the target level of performance is usually expressed as a quantitative standard, value, or rate. Monitoring performance and achieving the goal requires measuring the performance of the manufacturing areas in the form of key performance indicators (KPI) based on internal or external data collected during operations. The KPI includes objective and subjective measures. Objective measures use mathematical formulas to calculate the respective values, whereas the subjective measures use stakeholders' opinions and personal judgment [25]. Applying KPI improves business performance and changes the culture of people from intuitive to fact-based decision making [26]. It can be seen that performance measurement in business monitors performance, identifies the areas that need attention, enhances motivation, improves communication, and strengthens accountability [23].

3. An Enterprise Performance Framework

This section presents a comprehensive framework to measure the overall performance of a manufacturing organization at the enterprise level based on leanness and agility. The framework could be used to compare the performance of different enterprises. It associates the performance measurement to the strategic objectives of an enterprise. Agarwal, Shankar [27] developed an approach to compare three different paradigms: lean, agile and leagile supply chains. The approach was based on the Analytic Network Process (ANP). Lin, Chiu [28] developed a Fuzzy approach to index the agility in supply chains. Measures of the overall performance of an organization are categorized in general into financial and non-financial measures. Several researches have focused on measuring the overall organizational performance at the corporate level, business unit performance, and individual performance. Performance measures at the corporate and business unit level are more related to marketing and profitability (e.g. total sales growth, market share, return and investment, return on sales). Individual performance measures are task and job related (e.g. individual worker efficiency and effectiveness). Minimal researches have focused on measuring the performance at the plant level. This includes measuring quality, delivery speed, delivery reliability, flexibility, safety, machine run time, inventory turnover [29]. Therefore, this paper proposed a performance framework based on lean and agile components. The paper hypothesized lean and agile components as:

- Lean consists of two components, waste removal as the mainly weighted component and market responsiveness as a complementary weighted component which is not a prerequisite (see Fig. 2).
- Agile consists of two components, market responsiveness as the mainly weighted component and waste removal as a complementary weighted component (see Fig. 2).

The effective implementation of lean and agile is subjected to extensiveness understanding of their structure, practices and performance capabilities. Fig. 1 demonstrates a structure for agile concept, which is necessary information based. The structure can be easily converted to accommodate the lean. The agility cores, as displayed in Fig. 1, can be summarized as follows.

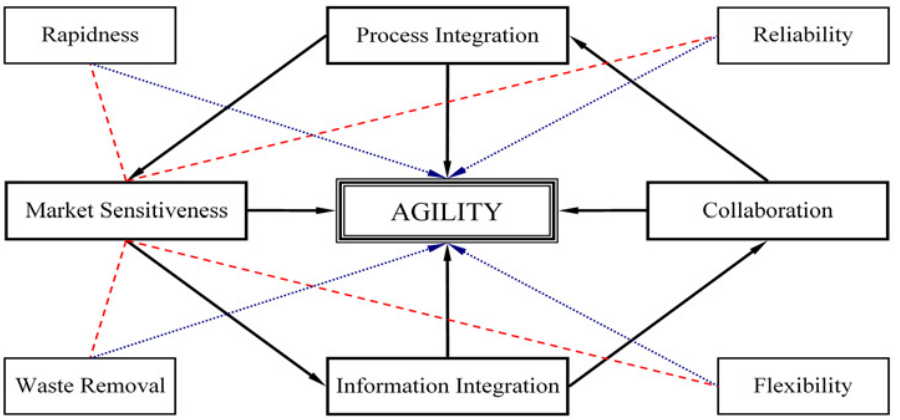

Fig. 1. A comprehensive structure for agile concept

- Information integration: utilizing advanced practices of information technology/information system (IT/IS) to share data between the supply chain partners (suppliers, customers, and manufacturer). Thus a virtual supply chain can be created. An advanced decision support system (DSS) is also needed.
- Collaboration: stimulating suppliers and customers beside distributed designers to share developing products, quality, etc. and finding solutions.
- Process integration: confederating partners into a linked network to achieve rapid partnership formation, strategic relationship with customers, close relationship with suppliers, trust-based relationship with customers/suppliers. That facilitates rapid decision making.
- Market sensitiveness: reading the real demand of product volumes and types as a result of the previous three cores. That is a core background of market responsiveness whereas supply chain reconfiguration (flexibility, rapidness, and reliability) is a core foreground.
- Waste removal: removing the non-value-added activities that may encounter the potential level of agility.

The vitality of IT/IS to support manufacturing enterprises has been widely recognized in the literature. Both lean enterprise and agile enterprise need to IT/IS and DSS with different requirements and manipulation. The IT/IS are regarded as enablers and facilitators of agile manufacturing [4]. As a part of IT/IS, automatic data collection system (ADCS) can be used to provide real-time status with respect to materials, operations, products, schedule, and locations of batches throughout the plant Yao [17]. The operators access the ADCS to feed operation data. A manufacturing DSS can be linked to ADCS to provide real-time status of all incidences in the plant especially the status of floor, WIP, and bottlenecks. From extensive reviewing the literature (see Section 2) and studying the practices in addition to the current definitions of lean and agile manufacturing/enterprises, the proposed performance framework is summarized as follows.

3.1. *Factors' Identification*

The factors that affect the performance (peak factor) of any manufacturing enterprise can be analysed and identified into two main categories, apical factors and root factors. Apical category encompasses three groups: strategic objectives, capabilities, and determinants. Root category comprises two groups: dimensions and enablers.

3.2. *Hierarchy Construction*

The groups of factors are located successively on a hierarchy having each group on a level and incorporating the potential relationships among all factors, as demonstrated in Fig. 2. The relationships between factors are mainly branching (sub factoring) relationships from a group to a lower level group. Further interdependency relationships may exist between factors within the same level and/or factors in different levels. However, a factor can be sub factored, if needed for the purpose of the assessment accuracy

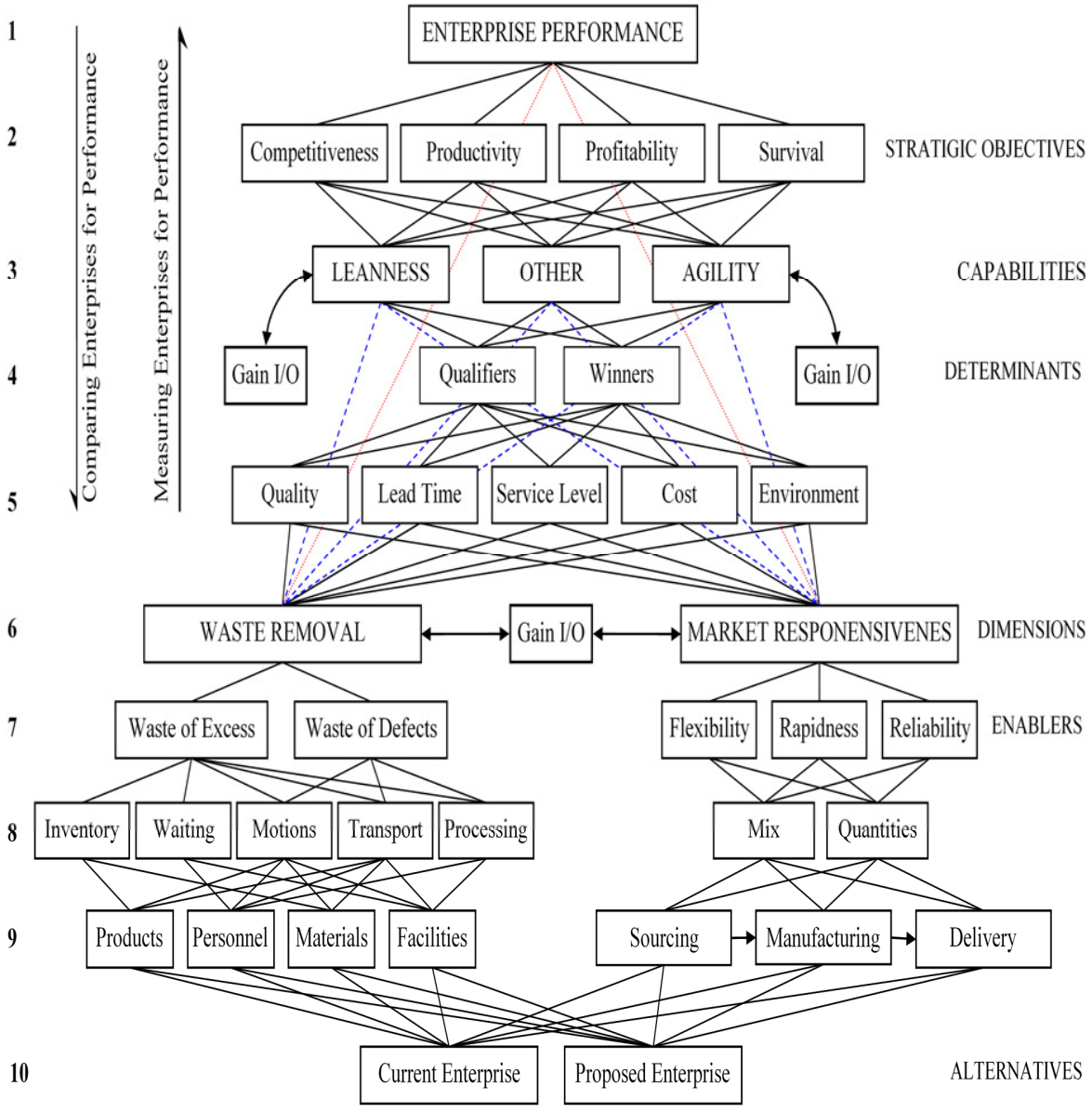

Fig. 2. Suggested performance framework for manufacturing enterprises based on lean and agile.

3.3. *Decision Making*

3.3.1. Comparing performances of alternative enterprises

Worldwide AHP and ANP approaches are most suitable for that purpose. Both are weighted multi-criteria decision making approaches, based on pairwise comparisons of the problem factors. ANP is applied if some interdependencies subsist; otherwise, AHP becomes sufficient [30]. The Expert Choice® and Super Decisions® are two powerful software that were developed to apply AHP and ANP respectively.

3.3.2. Evaluating performance of an enterprise

This process consists of two phases. First, AHP/ANP approaches can be used to quantify the relative effect (weight) of each factor on the overall performance of an enterprise. This is applied from *level 2* up to *level 9* of the hierarchy shown in Fig. 2. Second, a ranking/pointing mechanism is used to assess how much the factors of *level 9* are fulfilled by an enterprise. Subsequently, scores are calculated and accumulated upward for each factor until reaching the performance level (*Level 1*). A simple formula can be used as;

$$Q_{jh} = w_{jh} \sum_i w_{il} Q_{il} \quad \forall j \in h \tag{1}$$

Where, Q_{jh} and w_{jh} represent weighted score of factor *j* on level *h* and its weight, respectively. Q_{il} and w_{il} are those of the related factors on the lower level *l*. Other methods can be amended, like those used in measuring the supplier performance.

3.3.3. Setting levels of leanness and agility to an enterprise

A score can be assigned in advance to leanness and/or agility at *level 3*. Then, this score is distributed downward up to *level 9*; i.e., the calculations are reversed

3.4. *Supplementary Propositions for Suggested framework*

This paper suggested two propositions that supplement the successful implementation of the performance framework (c.f. Fig. 2.). These proposition are discussed as following:

3.4.1. Proposition 1

A manufacturing enterprise reflects the interaction between the organization contents. Therefore, it can be represented as a front of a package as shown in Fig. 3. The modulator on front sets the way of interaction between the contents.

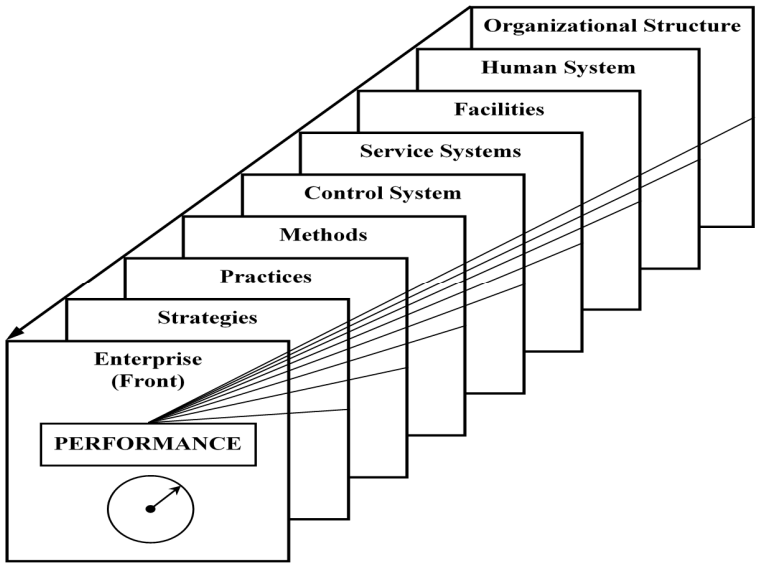

Fig. 3. A general performance model for an enterprise.

3.4.2. Proposition 2

The key characteristics of any manufacturing enterprise, directed towards strategic objectives, should be waste removal and market responsiveness. Both dimensions can be integrated at different levels, no matter what paradigm is followed. Waste removal adds to market responsiveness and vice versa. Hence, it can be suggested to discontinue arguing the terminologies lean, agile, and leagile enterprises. This paper define another terminology for an integrated enterprise, called *healthy enterprise*. If it is possible to set an enterprise at zero waste and maximum market responsiveness, it can be thought an *ideal healthy enterprise*. Therefore, we can relate the enterprise performance directly to the two dimensions, waste removal and market responsiveness. The performance framework of Fig. 2 shrinks by removing the levels 2–5. On this basis, the proposed framework can be reapplied.

4. Conclusion

Lean concept focuses on eliminating non value-added activities while agile detecting and responding to uncertain changes of the market. Challenges for competing in the business environment makes lean and agile as vital capabilities of a manufacturing organization. Both concepts are able to achieve strategic objectives (competitiveness, productivity, profitability, and survival) through improving the overall performance. Many research suggest that combining lean and agile via decoupling point increases the organization benefits. This paper redefines lean and agile, and describes a comprehensive methodology for performance analysis at enterprise level based on both concepts. Including, a hierarchic framework is built to encapsulate the factors that affect the organizational performance. Then, another terminology is introduced, healthy enterprise, which simplifies the application of such proposal. Therefore, we can accumulate the practices of lean and agile in a practice list for the healthy enterprise. However, the success of an enterprise depends on understanding the real business environment particularly the threats that may face the organization. Finally, the authors suggest four points for future research. First, best location and multiplicity of the decoupling point for leagile. Second, introducing overall cost and benefit functions to measure the impact of migration to lean and/or agile. Third, possibility of identifying a general term as proposed in this paper. Fourth, applying the proposed methodology to different manufacturing organizations.

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