

Hybrid Lean-Agile Manufacturing System Strategic Facet in Automotive Sector

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ABSTRACT

The lean production system has been successful in the cost-based winning order criterion markets. However, the automotive market has been volatile and the new criterion of winning orders has been availability, which has called for an agile system. The present paper argues that because of fierce competition the current automotive market winning order criterion is now a blend of cost and availability. It shows how a hybrid lean-agile system can strategically meet such a challenging criterion. The study presents the drivers, attributes and providers in lean manufacturing, agile manufacturing, and hybrid lean-agile manufacturing systems. It investigates how the strategic facet of the proposed hybrid lean-agile manufacturing system addresses the six manufacturing competitive dimensions. It presents as well the hybrid lean-agile manufacturing key performance indicators. The strategic facet of the proposed hybrid lean-agile manufacturing system has been validated through industrial case studies in automotive sector. A cost-benefit ratio qualitative analysis has been conducted on the proposed system and the benefits outweigh corresponding costs resulting in positive present value.

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INTRODUCTION

A key feature of automotive business nowadays is that it consists to a greater degree of competing value chains, and to a lesser degree of individual firms. The success or failure of businesses in value chains is to a greater degree determined in the marketplace by the end consumer. Hence customer satisfaction and marketplace understanding are crucial elements for consideration when attempting to establish a winning value-chain strategy. Only when the constraints of the marketplace are understood can a firm attempt to develop a strategy that will meet the needs of both the value chain and the end customer. Matching availability and cost to actual customer requirements is a distinguishing feature of most of the modern successful manufacturing businesses. Hence, the goal of competitive manufacturing strategy should be strategic flexibility that is a company becomes able to switch manufacturing gears relatively quickly and with minimal resources [1].

According to Womack significant interest has been shown in recent years in the idea of 'lean manufacturing' and the broader concept of the 'lean enterprise' [2, 3]. The focus of the lean approach has essentially been on the elimination of waste. The recent upsurge of lean manufacturing can be traced back to the Toyota Production System (TPS), with its focus on virtual elimination of waste, as suggested by Ohno or more practically and realistically on the minimization of waste [4, 5]. Shigeo Shingo documented the TPS in 1980 and added to it the concepts of Single Minute Exchange Die (SMED), mistake-

proofing, and Zero Quality Control (ZQC) [6]. Evidently, lean concepts work well where demand is relatively stable and hence predictable and where variety is low. Yet, the demand in the current automotive market is volatile and the customer requirement for variety is high which together demand for a much higher level of agility.

Lean manufacturing has distinguished legacy past and is thriving in the present. However, for some years now it has been argued that it is not a universal recipe for staying ahead of competitors [7]. As a matter of fact, the cyclical nature of "order qualifiers" versus "order winners" means that this year's competitive advantage becomes next year's price of entry [8]. Hence, it is not surprising that becoming competitive in terms of cost, an attribute of lean manufacturing, can cause the value chain to become threatened in terms of availability, an attribute of agile manufacturing. Likewise, becoming competitive in terms of availability, an "agile" attribute, can cause the value chain to become threatened in terms of cost, a "lean" attribute. Thus, seeking to meet the blend of winning order criteria of cost and availability may be a right strategic decision in the current environment in the automotive sector.

Changes and uncertainty have been the prominent attributes of the current manufacturing business environment. Although this environment has been the cause of most failures in the manufacturing industry as reported by Small, Drucker and Shari found that those entrepreneurs who succeeded in this environment searched for change, responded to change, and

exploited change as an opportunity [9, 10, 11]. The basis of competition, which used to be the product's price, has switched to quality, delivery time and customer satisfaction. The loss of market share, failure of products, and waste are to a great extent results of poor quality planning [12]. The prevailing concept of economy of scale, which for a long time has been utilized in the low cost strategy, has been challenged by the new vision of economy of scope. The methods have been used to cure problems in productivity of traditional systems, such as lean manufacturing and agile manufacturing, have been found insufficient to qualify for competitiveness.

In an endeavor to understand this manufacturing business environment, recent studies identified the factors that were driving the manufacturing business environment from being turbulent to being chaotic as follows: (1) the fragmentation of mass markets, (2) cooperative production relationships, (3) evolving customer expectations, (4) social pressures [13, 14]. Davis found that the biggest problem for executives in the current environment is to deal with change in terms of both responding to external changes and managing internal changes [15].

As a newer manufacturing approach than the lean manufacturing to deal with the change in the manufacturing business environment, the concept of agility emerged comprising two main factors: (a) responding to change in a proper way and in good time, (b) exploiting changes and taking advantage of them as opportunities. These two factors in turn necessitate having a basic ability to sense, perceive and anticipate changes in the business environment of the manufacturing business enterprise, as well as to make contingency plans in order to make up for unexpected changes.

Yet, this agile manufacturing approach has resulted in a cost challenge. Thus, today's automotive manufacturing enterprise's value chain is being rapidly restructured around vehicle system integration and modularity. In order to sense and respond more quickly to marketplace demands, automobile manufacturers are transferring their non-core competencies and responsibilities to module and sub-system suppliers to gain advantages in terms of time, cost, and agility. Tier-1 system-integrator suppliers are experiencing significant industry consolidation pressures as fewer and larger suppliers are increasingly providing a higher percentage of the vehicle's systems, while the number of Tier-2 suppliers may be slashed by a significant percentage within a few years. As a result, leading vehicle systems integrators and module suppliers are developing extended value-chain strategies to help increase economies of scale, as well as economies of scope and knowledge [16]. The key challenges to realize an effective value chain are the uncertainty of the performance of suppliers, networking suppliers in remote low-cost manufacturing bases, the reliability of manufacturing and transportation processes, and changing customer desires [17, 18]. Thus, a blend of leanness and agility can be a necessity in meeting such contemporary success criteria [19, 20, 21].

The present research introduces the strategic aspects of the proposed hybrid lean-agile manufacturing system. The next sections will present the research motivation, research objective, research methodology and research questions. Next, the existing manufacturing systems will be analyzed. The strategic aspects of the proposed hybrid lean-agile manufacturing system will then follow. A cost-benefit ratio qualitative analysis will then be presented. Finally, case studies and limitations of the proposed manufacturing system will be presented.

RESEARCH MOTIVATION, OBJECTIVE AND METHODOLOGY

Fierce global competition between enterprises is the catalyst behind the comprehensive reengineering of manufacturing business enterprises. This research stems from the changes in the manufacturing business environment in the automotive sector that have led to customers requirements of both competitive price and availability without a compromise of quality. These requirements affect the parenting strategy, which is part of the corporate strategy. The corporate strategy in turn shapes the business strategy, with a blend of cost focus and differentiation focus that can result in a differentiated and cost-focused business strategy. Such a business strategy in turn calls for a marketing strategy. The marketing strategy, as an approach to positioning, pricing, distributing and promoting products, is developed to lead the enterprise in a chosen strategic direction aimed at providing leverage for making sales, either through customer acquisition, customer retention, or a combination of both. The marketing strategy in the automotive sector aims at striking a balance between the main six competitive dimensions of manufacturing in the automotive sector, which are quality, delivery reliability, response time, low cost, customization and product life cycle, in addition to revenue. This marketing strategy requires a manufacturing strategy to support it. Such a manufacturing strategy is referred to in the present study as a hybrid lean-agile manufacturing strategy. This calls for a business model in order to implement such strategy that is referred to in this study as a hybrid lean-agile manufacturing system.

In the automotive sector, planners have a difficult balancing act. On the one hand, there are benefits from using common vehicle parts. On the other hand, there are more niche demands in the global market. The challenge that faces the entire automotive industry is to balance these two extremes cost-effectively and without compromising quality. The present research aims at meeting this balancing act. It investigates the strategic aspects of the proposed hybrid lean-agile manufacturing system in order to strike such a balance improving the value delivered to customers while increasing the benefits for the manufacturing enterprise's business stakeholders.

The research method adopted in this research is a theoretical approach that starts with literature review of the manufacturing systems in automotive industry. From this literature review research questions are derived. Answers to some of these research questions are answered from literature review. The rest of the research questions are answered from case studies and from the proposed system. The research questions in this study are as follows:

1. Under what conditions would a firm choose the lean manufacturing system when competing in automotive sector?
2. Under what conditions would a firm choose the agile manufacturing system when competing in automotive sector?
3. Does hybridization of the lean and agile manufacturing systems strategically make sense for automotive industry?
4. What is the strategic facet of the hybrid lean-agile manufacturing system?

Let us first examine the concept of perfect competition in automotive sector.

PERFECT COMPETITION

In general a perfectly competitive market is characterized by the characteristic that no single firm has influence on the price of the product it sells. What differentiates perfectly competitive markets from imperfectly competitive ones is whether or not firms treat price as a parameter or variable. In other words, perfect competition occurs at equilibrium price taking at which supply equates demand, according to the general equilibrium theory. A freely competitive market was defined by Adam Smith as one in which there is no impediment to free contracting and free entry and exit of productive resources [22]. Perfect competition according to classical economics implies that the more competitive a market is, the faster the average market price will adjust so as to equate supply and demand.

In a perfectly competitive market, the products on supply are substitutable to each other. In addition, in that perfectly competitive market, a firm's demand curve is perfectly inelastic. The arrival of new firms in the market causes the horizontal demand curve of each individual firm to shift downward, bringing down at the same time price. Eventually in the long run a firm will make only normal profit, i.e. zero economic profit. Therefore, in order to make economic profits rather than normal profits under such circumstance of perfect competition firms have to reduce cost of production. In an endeavor to reduce the cost of production, manufacturing enterprises nowadays build value chains.

A value chain is the stream of processes of moving goods from the customer order stage through the stages of raw materials, outsourcing suppliers, own production, assembly, warehousing, and distribution of products to the customer. The value chain consists of both company owned members and independent

members and has five dimensions which are manufacturing, location, transportation, inventory, and information. Value chain management involves coordinating and integrating three flows in the value chain that are: product flow, information flow, and finances flow. The product flow involves the movement of goods from a supplier to a customer. The information flow involves transmitting data on customer trends, transmitting orders, and updating the state of inventory and delivery. The financial flow involves making and managing credit terms, payment schedules, and ownership arrangements. Having understood the nature of perfect competition, the pragmatic reader might now well ask: "What are the conditions under which an enterprise adopts the lean manufacturing system and the agile manufacturing system?" The next couple of sections will answer this question.

CONDITIONS UNDER WHICH AN ENTERPRISE ADOPTS THE LEAN MANUFACTURING SYSTEM

Lean manufacturing is a production practice in which the expenditure of resources for any goal other than the creation of value for the end customer is considered as waste so that a target for elimination. It is a theme of increasing efficiency, decreasing wastes most of which are invisible, and using empirical methods to decide what matters. It focuses on reduction of the seven wastes, which are waiting, motion, transportation, processing, over-production, inventory, and defects, in order to improve overall customer value. Lean implementation is therefore focused on getting the right things, to the right place, at the right time, in the right quantity to achieve perfect work flow while minimizing waste and being flexible [23]. Historically, Taiichi Ohno and Shigeo Shingo developed Lean Manufacturing at Toyota over a period of 20-30 years [4]. Their intention was not to develop some sort of global theory for all sectors in industry. Wickham Skinner did not consider lean manufacturing to be an actual manufacturing strategy [24]. He likens it to "blocking and tackling" in football, a necessary skill but insufficient for consistently winning games. The manufacturing strategy should refer to an approach that starts with corporate and marketing strategies and then designs a manufacturing system to support them.

There are two approaches to lean manufacturing. The first of these two approaches is the identification and steady elimination of the underlying cause of waste, i.e. Muda, through a set of tools. As waste is eliminated quality improves while production time and cost are reduced [12]. Examples of these lean tools are Five S, Value Stream Mapping, Kaizen which means making simple and common sense improvements and refinements to critical business processes through continuous improvement teams and events, SMED, mistake-proofing, ZQC, Lean Sensei that is seeking for advice of third party experts, Senpai and Kohai that is mentoring process to think up and down the organizational structure, Poka-yoke that is error-proofing, and Autonomation that is to automate and to give the machines enough intelligence to recognize when they

are working abnormally and flag this for human attention. Having lean tools such as Autonomation implemented, humans would not have to monitor normal production and only have to focus on abnormal, or fault, conditions which reduces human routine and repetitive activity and makes human more effective. The most effective tool and the first to be implemented among the lean tools is the Five S. The Five S is a method for organizing a shared workplace and keeping it organized for improved safety and efficiency. It consists of Sorting, i.e. keeping only essential items in the work area, Setting in order, i.e. arranging the tools, equipment and parts so as to improve work flow and using labels, Shining, i.e. systematic cleaning, Standardizing, i.e. operating in a consistent fashion with clear responsibilities, and Sustaining the discipline [25]. These tools result in greater productivity, quality, and profits achieved with minimal cost, time, and effort invested [25]. In the second approach to lean manufacturing the focus is upon improving the flow or smoothness of work, thereby steadily eliminating Mura (i.e. unevenness) through the system and not upon 'waste reduction' per se. It is based on the fact that if production flows perfectly, there will be no inventory. Techniques to improve flow include Kanban cards system (pull production that is building to order rather than target driven Push), the Heijunka box (to collect data on variations in product mix and volume), and production leveling (to set production schedule based on average of variations in product mix and volume).

By enforcing very strict specification and quality criteria on component manufacture, Ford production system eliminated fitters' work. However, Ford's mass production system could not incorporate the notion of "pull production" so that it often suffered from over-production. Levels of demand in the Post War economy of Japan were low and the focus of mass production on lowest cost per item via economies of scale therefore had little application. Having visited and seen supermarkets in the USA, Taiichi Ohno recognized the scheduling of work should not be driven by forecasted sales or production targets but by actual sales. The disconnected nature of some of lean principles emerges from the fact that the Toyota Production System has grown pragmatically since 1948 as it responded to the problems it saw within its own production facilities. Thus what one sees today is the result of a 'need' driven learning to improve where each step has built on previous ideas and not something based upon a theoretical framework. Toyota's view was that the main method of Lean is not the tools, but the following steps: (1) reduction of three categories of production problems: Muda (i.e. non-value-adding work), Muri (i.e. overburden), and Mura (i.e. unevenness), (2) exposing problems systematically, (3) using the tools where the ideal cannot be achieved.

Given the fact that quality is a prerequisite for competition, a manufacturing enterprise adopts the lean manufacturing system under one of the following conditions: (1) in perfect competition where the only way to make economic profits is to

cut costs; (2) under the circumstance of price winning orders criterion until the equilibrium between supply and demand takes place.

The lean manufacturing system has the following distinguishing characteristics: (a) 'Design for manufacture' including standardization of parts and product life cycle since most costs are assigned when the product is designed [26], (b) 'Supplier total integration' which starts with segmentation, supplier reduction, then progresses to forming strategic partnerships, followed by systems integration including assigning quality checking to the suppliers [16], (c) 'Just in Time (JIT) production' by making only the quantity required, when it is required, (d) 'Cost-effective use of automation', (e) 'Total quality' that is everything is being improved all the time [27]; because everything is trying to be improved at once problems can arise with priorities so that highly focused improvement systems can be accomplished by ensuring the priorities are clarified first [12]; In addition, in the product design and manufacturing processes, the potential factors causing an overall defect are identified using the Ishikawa diagram [28], (f) 'Continuous improvement' which is done through elimination of waste; It necessitates a properly resourced major change programme first for the already established manufacturing enterprises [29], (g) 'Small lot size and frequent delivery', (h) 'Preventive maintenance of bottleneck equipment'. Having seen the conditions under which an enterprise adopts the lean manufacturing system, let us now turn our attention to investigating the conditions under which an enterprise adopts the agile manufacturing system.

CONDITIONS UNDER WHICH AN ENTERPRISE ADOPTS THE AGILE MANUFACTURING SYSTEM

Agile manufacturing is the responsive manufacturing to customer needs. It is an approach adopted by a manufacturing enterprise that has created the processes, tools, and training to enable the enterprise to respond quickly to customer needs and market changes while still controlling costs and quality. Having a manufacturing support technology that allows the marketers, the designers and the production personnel to share a common database of parts and products and to share data on production capacities and problems is an essential capability to enable the manufacturing enterprise to realize an agile manufacturing system. When manufacturing enterprises have to decide which manufacturing system to adopt, they have to look at the customer order cycle, i.e. the time the customer is willing to wait, and the lead-time for getting supplies. If the supplier has a short lead time, lean production is possible. If the customer order cycle is short, agile production is beneficial.

The agile manufacturing system has the following distinguishing characteristics: (a) Responsiveness to customer needs and desires, (b) Sensing and being ready for changes, (c) Using concurrent engineering in the design and

manufacturing processes which includes involving suppliers and assemblers in the design process, joint problem solving, and free movement of personnel and sharing ideas between suppliers and assemblers, (d) Forming a virtual enterprise of strategic partners, (e) Improved communication and shared correct information with the right partners in a short timeframe [30].

A manufacturing enterprise adopts agile manufacturing system under one of the following conditions: (1) in imperfect competition; (2) under the circumstance of product availability winning orders criterion. Without agility leanness can lead to shortages in the value chain in the event of varying demand since a lean process needs to operate in an environment that is characterized with: (a) A longer term view that is sufficient to flex major capacity step changes, (b) A knowledge of the current inherent unreliability of the value chain members and flexibility of their processes, (c) Sufficient buffer stock or capacity buffer to accommodate variability. This leads us to strategically investigate the proposed hybrid lean-agile manufacturing system.

STRATEGIC FACET OF THE PROPOSED HYBRID LEAN-AGILE MANUFACTURING SYSTEM

The proposed hybrid lean-agile manufacturing system is hybridization of the lean manufacturing and agile manufacturing philosophies. This blend effectively makes sense for the current automotive industry where the competition is imperfect and both cost and product availability together constitute the winning order criterion. Lean manufacturing is manufacturing without waste yet most waste is invisible so that its elimination is not easy [4]. A way of measuring lean manufacturing performance is by checking by how much the seven forms of waste exist. Unlike lean

manufacturing, agile manufacturing is a manufacturing system that is closely related to the concept of flow manufacturing. It utilizes the flow manufacturing concept to reduce lead time, improve asset utilization, and build customer demand by focusing on being able to respond quickly to customer requests. It assumes that the customer requirements, specifications and volumes are subject to continuous changes. A way of measuring agile manufacturing performance is by means of the enterprise's products delivery reliability and lead time. Key characteristics of an agile manufacturing enterprise are flexibility in organization and production. Indeed, agility as a business concept originated in flexible manufacturing systems (FMS). Initially it was thought that the route to manufacturing flexibility was through automation, enabling rapid change in terms of reduced set-up times and hence a greater responsiveness to changes in product mix or volume. Later this idea of manufacturing flexibility was extended into the wider business context and the concept of agility as an organizational orientation was born. In the present research paper, a further extension of the conception of manufacturing flexibility is presented in the form of a hybrid lean-agile manufacturing concept. Table 1 summarizes the core characteristics of agile manufacturing as opposed to lean manufacturing. This table shows that creating leanness and agility is much more than a technical problem. In terms of management, lean manufacturing emphasizes continuous improvement whereas agile manufacturing emphasizes leadership, support, motivation, and trust. Both of lean and agile manufacturing systems foster and are characterized with knowledgeable, skilled, and innovative workforce. Product and process design in the lean manufacturing system is predefined, optimized, and codified unlike agile manufacturing systems where such product design is customer driven and business processes are adapted and suppliers are integrated to realize this design. Marketing in the lean system is based on satisfying customers with standardized products whereas in the agile system it is based on more customized products.

Table 1. Core characteristics of agile manufacturing versus lean manufacturing

	Lean Characteristics	Agile Characteristics
1. Organization	Flat organizational structure and no organizational waste	Ability to synthesis new capabilities from physical assets and expertise of people
2. Management	Emphasis on continuous improvement	Emphasizes leadership, support, motivation, and trust
3. People	Knowledgeable, skilled, and innovative total workforce	Knowledgeable, skilled, and innovative total workforce
4. Design	Predefined, optimized, and codified design	Integrating suppliers, business processes, products, and customers
5. Production	Tooling and production processes are optimized	Ability to produce goods and services to customer orders in arbitrary lot sizes
6. Marketing	Customer satisfaction is based on perfect standardized products and services	Customer enriching along with individualized combinations of products and goods

Agility should not be confused with leanness. Webster's Dictionary makes the distinction clearly when it defines lean as "containing little fat" whereas agile is defined as "nimble". Leanness implies doing more with less and is often used in connection with lean manufacturing to imply waste elimination [2]. In practice, tactical buffers are used as Minimum Reasonable Inventory (MRI) instead of the no-inventory concept. Yet, many manufacturing enterprises that have adopted lean manufacturing as a business practice are anything but agile in their value chain. The automotive industry in many ways illustrates this phenomenon.

According to Ohno there are seven types of waste, within every activity, that add cost but not value in the manufacturing enterprise [4]. These are waiting, motion, transportation, processing, over-production, inventory, and defects. The first type of waste is called waiting that represents idle time created when material, information, people, and equipment are not utilized. Next, motion can be defined in this context as a movement of people that does not add value. Transportation refers to a movement of product that does not add value. Thus, it should be aimed at having every product and service travels a single, simple, and direct flow path. Processing in this context stands for any effort that adds no value from the customer's viewpoint. Over-production means producing more than the customer needs at any given time. Inventory represents the occurrence of having more materials, parts, or products on-hand than the customer needs at any given time. Finally, defects refer to any work that contains errors, requires reworking, includes mistakes, or lacks something necessary. The Ishikawa diagram is commonly used in product design and manufacturing in order to identify potential factors causing an overall defect [28]. Leanness may therefore be considered as an element of agility in certain circumstances, but it cannot alone enable an organization to meet the precise needs of customers in a timely manner. Likewise, agility cannot alone enable an organization to meet the precise needs of customers cost-effectively.

Whilst the lessons learned from the TPS principles have had a profound impact on manufacturing practices in a wide range of industries around the world, it seems that the tendency has been for the benefits of lean thinking to be restricted to the factory. Thus, in practice there are many paradoxical examples. One of these paradoxical situations is where vehicle manufacture is extremely efficient, with throughput time in the factory typically down to twelve hours or less, yet the inventory of finished vehicles can be as high as two months of sales. This signifies the need for adopting a hybrid lean-agile approach. The attributes of the lean value chains, agile value chains, and proposed hybrid lean-agile system are discussed in the following sub-sections.

Attributes of Lean Value Chains and Agile Value Chains

Lean value chain and agile value chain have six common characteristics in addition to their own distinguishing characteristics. Firstly, both agility and leanness entail high levels of product quality, based on customer satisfaction. Secondly, they are characterized with total lead-time compression by minimizing total lead-time, i.e. end-to-end lead-time. From the agility stand-point, total lead-time has to be minimized to allow agility, as demand is highly volatile and thus difficult to forecast. If a value chain has a long total lead-time, then it will not be able to respond quickly enough to demand. From the leanness stand-point, cycle-time reduction always leads to significant bottom-line improvements in manufacturing costs and productivity [31]. In addition, lead-time needs to be minimized in lean manufacturing, as, by definition, excess time is waste and leanness calls for the elimination of all types of waste. Thirdly, both lean and agile systems foster and capitalize on market knowledge. Fourthly, they both adopt value stream and integrated value chain. Fifthly, both of the lean and agile systems aim at delivering value to customer. Finally, they both develop and capitalize on human knowledge and skills.

The difference between leanness and agility lies in the following six attributes illustrated in [Table 2](#). They differ in the total value provided to customer since a lean value chain provides customers with low cost products whereas an agile value chain provides customers with availability of products that satisfy customers' needs and desires. This is particularly true since a lean value chain offers low product variety whereas an agile value chain offers high product variety. Thus, the dominant cost in an agile value chain is the marketability cost whereas the dominant cost in a lean value chain is the cost of physical facilities. A lean value chain can only be efficient if the market demand is predictable whereas an agile value chain can meet volatile market demand. Thus the penalties of stock-out in a lean value chain are based on long-term contracts whereas these penalties are immediate and volatile in an agile value chain. Because of the nature of market demand that a lean value chain can efficiently meet, the forecasting mechanism in a lean value chain is algorithmic whereas it is consultative and subjective in the case of an agile value chain. Understanding the common characteristics among lean value chains and agile value chains as well as the distinguishing attributes of each of them leads us to investigate the leanness-agility drivers, attributes, and providers.

Leanness-Agility Drivers

Enterprises are different in the way they face changes and in their vulnerability to these changes. In the automotive market where the competition is fierce, striking a balance between cost and availability of product and related services becomes indispensable. Therefore, adopting a hybrid lean-agile manufacturing system in the automotive marketplace becomes a preferable strategic choice. The unpredicted changes and