A Collective How-To-Become-Agile Approach

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Abstract

Agile Manufacturing is a quite new concept that intends to improve competitiveness in firms. Manufacturing/service processes based on agile manufacturing are characterized by supplier-to-customer integrated processes including product design, manufacturing, marketing, and support services to be able to response to changes as quick as possible. Agile manufacturing needs to enrich the customer; to cooperate with competitors; to organize to manage change, uncertainty and complexity; and to leverage people and information.

Despite the obvious benefits of agility, firms which are operating in complex environments such as international markets, face challenges in implementing the measures necessary to increase their agility. These challenges stem from the expense associated with the complex operations and management structures which may be necessary to support the desired attributes.

So how to be/become agile is an issue significantly important to be addressed from different perspectives aiming to provide guidelines to harness the international markets vortex, although it cannot be formulated and generalized in detail for all industries and scopes.

This paper collects different ideas from different researchers and papers on steps to become agile and based on these findings, tries to expand and develop models and comparative/collective tables which will be helpful for further empirical studies and practices.

Based on such new model and comparative tables derived from different theories and thesis, a synthesis phase is defined to present a chain of practical questions and answers to shape a guideline to determine becoming-agile framework. Such a framework makes the general image of How-to-become-agile instruction.

Keywords:

Agility, Agile manufacturing, Methodology, Enablers, Flexibility
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1- INTRODUCTION

1-1 BACKGROUND

In 21st century survival and manufacturing success is going to become more and more difficult to ensure. Root cause is laid under the business new significance for that “change” is known one of the main characteristics.

The uncertain situation has led businesses to a significant revision in priorities, visions, strategies, validity of conventions, tools and methods which have been in use so far. All revisions are to adapt to changes.

Nowadays to be able to adapt to changes happening in business environment and to take proactive techniques to approach to market and customer needs are significantly empowering those businesses who want to win the competition.

The Agility Forum has defined agility as the ability of an organization to thrive in a continuously changing, unpredictable business environment. Simply put, an agile firm has designed its organization, processes and products such that it can respond to changes in a useful time frame.

Agility is a new system of commercial competition, a successor to the still dominant system that was developed around mass production-based competition once it was coupled to the modern industrial corporation. Agility was made possible by the synthesis of innovations in manufacturing, information, and communication technologies with radical organizational redesign and new marketing strategies. Moreover, agility functions as a comprehensive, strategic response to structural changes which are fundamental and irreversible and tend to undermine the economic foundations of mass production-based competition (Goldman et al. 1995).

In fact, basic competitive factor is not price only any longer; in fact, quality of the final product or service, delivery time, and customer choice or in a general sense, customer satisfaction, play more important role in market competition now.

“Agility in concept is a strategic response to the new criteria of the business world, and in practice, is a strategic utilization of business methods, manufacturing and management
processes, practices and tools, most of which are already developed and used by industries for certain purposes, and some are under development to facilitate the capabilities that are required for being agile.” (Sharif and Zhang 1999, pp 11)

Because agility incorporates such a wide range of ideas, its proponents and practitioners are not all reading off the same sheet of music yet. For example, some define agility as the next level of effective business practices, while others see it as including smart equipment and robots. (Litsikas, 1997)

“Agility in concept comprises two main factors. They are:

- Responding to change (anticipated or unexpected) in proper ways and due time.
- Exploiting changes and taking advantage of them as opportunities.

These, indeed necessitate a basic ability that is sensing, perceiving and anticipating changes in the business environment of the company.” (Sharifi and Zhang 1999, pp10)

By looking at strategies from economic perspective also we obviously see that the prevailing strategy of economy of scales has been challenged by the new vision of economy of scope. Mass production systems are being seriously questioned for their viability in challenging the changing nature of the business environment. The new methods that have been used to cure the problems in productivity of traditional systems, such as flexible manufacturing and lean manufacturing and all techniques and tools associated to them, are found insufficient in the way they have been managed and utilized. (Sharifi and Zhang 1999)

“Agile manufacturing that was sometimes mixed up and confused with previous thought schools of manufacturing management such as flexibility and lean manufacturing has been backed for having novel concepts beyond the former remedies.” (Sharifi and Zhang 1999, pp 9)

However, agility can be effectively achieved without significant changes in equipment, as Bill Adams, president of Agile Web Inc, says “it is not the equipment that needs to be flexible, it is the business practices and people; you can be agile even with dedicated equipment”, General Motors (GM) Powertrain Engine Plant found that agile machines enhanced its agility. (Litsikas, 1997)
Therefore, responding to changes and taking advantage of them through strategic utilization of managerial and manufacturing methods and tools, are the pivotal concepts of agile manufacturing. (Sharifi and Zhang 1999)

Sarkis (2001) has a comparative approach to close concepts propounded and applied for competitive manufacturing enterprises. First, he describes: “the concept of agility is part of an agenda set forth by a diverse body of industrial firms for improving and maintaining the US manufacturing base’s competitive advantage”. He believes “agile” along with “lean” and “flexible” are strategic organizational philosophies that have been accorded much attention in the past few years.” He refers to The Department of Defense summary of these principles and the principles’ relative context to each other:

- “Lean manufacturing: a set of practices intended to remove all waste from the system, striving to minimize usage of resources.
- Flexible manufacturing: a structure as opposed to a strategy and addresses a production line that can be easily reconfigured or customized for producing different products.
- Agile manufacturing: a strategy that contains lean manufacturing and flexible manufacturing and addresses the business enterprise world.

According to these definitions, lean and flexible fall within the scope of agile, with others have stated that these are distinct and separable philosophies.

These concepts are at different levels of practical and academic maturity.” (Sarkis, 2001, pp 89)

1-2 AIM OF THE RESEARCH

This research has far passed agility as “what” could be a savior in such turbulent business environment or “why” agility can potentially play the role of such savior however agility as the answer of these two questions is accepted as pre-assumptions. For enterprises which have reached to the necessity of “agility”, it is more important to know where the start point is, what the specifications are, which predecessors come prior to the next, and finally how the steps should be taken on. So, this research is going to step little further into “how to become agile” from a general perspective.
Although “agility” is such a wide and general concept that is extendable to a range of scopes, from single activities and operational processes to departments (complex of processes), businesses, and the whole organization. Yet this research is narrowed to “agile manufacturing” concept which is still the heart of production and manufacturing enterprises who are struggling not only to survive but also to compete durably experiencing chances to win.

In this paper approaching to the agile manufacturing has been carried out from different perspectives and through using various tools. The main purpose of this paper is to collect these approaches altogether to derive the best practices to fit any specific industry with specific requirements in specific situations. Although for any case study, there shall be practical customizations in details.

To find out how to design and implement an efficient agile manufacturing system, this paper intends to provide a collective literature review enriched with comparative tables which facilitate using various resources containing different ideas and points of view.

The idea in this paper, primarily takes the methodology offered by Sharifi and Zhang in 1999 as the baseline and improves it by bringing in other variables to define the level of need to become agile/agiler. The scoring model developed and offered in this paper, is a supplementary for Sharifi and Zhang (1999) methodology and an extension to the approach how-to-become-agile, so it can count the new revision of their scoring model. Although it’s not validated practically in the scope of this paper, this model can provide a new frame-work for further studies and practices.

1-3 RESEARCH DIRECTIVES

What defines agility, is not just a complex of certain characteristics. Agility is defined based on how quick and how efficient a body/organization would react to changes come from turbulent environment. So obviously, it is impossible to generalize “how to become agile” in detail for different industries/businesses, different scopes and different environments. Rick Dove (2001) underlines: It is not just a few steps as what you should do to be agile! It talks about what is behind the decision that someone might make, or, what managers should consider when they choose a strategy.
Therefore, it is impossible to make a general prescription to apply for all steps to be taken to become agile. One size does not fit all.

But there are some basics and fundamental functions which should be considered and taken as guidelines for future steps. It makes an overview of what an agile manufacturer aims to get. Sharifi and Zhang in 1999, in their scoring model, tried to point at some variables as measures and indicators to consider when starting to think about getting agile.

To refine and improve the methodology described by Sharifi & Zhang in 1999, an attempt has been made in this paper to review the literature available on agile manufacturing to collect such practical basics, providing directives along 3 fundamental axes and 1 integrated body:

1. Methodology to become agile,
2. Enablers,
3. Design,
4. Implementation, for which all above comes into integration through an analysis and synthesis process.

Such directives include practical strategies and techniques which are to be identified.

1-4 OBJECTIVES & PROBLEM STATEMENT

Many industrial significant concepts have failed to implement in practice due to the lack of proper strategy to take advantage of the specifications of such concepts (e.g. “flexibility”). In many industries, traditional leaders have fallen behind due to their failure to apply flexible technologies “flexibly” (Dean and Snell, 1996). That is, they failed to build-up the proper organizational processes required to take advantage of flexibility as markets called for. These organizations have often encountered what McCutcheon et al. (1994) see as the “responsiveness-customization squeeze”. In hoping to attack markets from a traditional “market-based” viewpoint, these firms have failed to respond on time to demand because they have tried to set customization objectives according to strategic marketing prerogatives, and then have drawn
their operations function into some impossible mission to deliver the goods. Under such circumstances, operations were not allowed to liberate its full potential to survive in the face of hyper-competition. Such firms may actually fall apart due to inappropriate flexibility strategies. (Gagnon, 1999, pp 130)

But the fact is that there are a lot of questions facing such concepts in practice! When an enterprise steps out of the paper to practice, generally needs to answer questions such as:

- When to take action?
- How to think about it?
- What to think of?
- What is the start-point?
- What are tools, techniques and strategies?
- What about alternatives (different scenarios)?
- How to act (to customize)?
- How long does it take?
- How much does it cost?
- How far to become agile?
- How to measure it (or its efficiency)?
- How to integrate, maintain and manage it?
- How to make it sustainable?
- How to update/upgrade it?

Failure on any of these steps will lead to waste lots of time and money. How to avoid such waste is a problem to be/has been addressed from different perspectives.

In 1999, Sharifi & Zhang tried to describe a methodology to see and measure some variables or indicators which lead to answer some of these questions partially. Since then, there have been other attempts by others to look at the Agility concept through more practical perspectives, each one with a focus on one or more of these questions to answer.
This paper, standing on Sharifi & Zhang’s methodology (1999) as foundation while trying to refine, complete and improve it, also attempts to answer some of the above questions through different perspectives which have addressed this problem. Such attempt is taken place by gathering different ideas, suggestions and examples extracted from a collection of literature on agile manufacturing. Projecting a methodology to approach agility, introducing some enablers, sketching a design based on principles, and drafting for implementation are the main effort of this paper to cover some answers of the stated problem/s, with objectives to:

1. identify key strategies and techniques of agile manufacturing,

2. enlighten for some future research directions,

3. propose a framework for the development of agile manufacturing systems.

**1-5 LIMITATION**

This paper narrows agility to agile manufacturing territory, trying to make a general but tangible sense of steps required to be taken for its implementation. It considers principles and basics to make infrastructure as a support/back-up for all decision-making processes. It does its best to provide a general overview of what is required to be done to have an agile manufacturing enterprise.

Perspective through which agility is reviewed herein is not purposefully narrowed to one or a few approaches pursuing the same point of view. Although this paper counts a selection of thoughts in agility domain which are logically relating to each other or completing each other to make an integrated body of context. Therefore, the literature reviewed for this research has been selective, but the criteria were set to keep the semantic integrity from a general perspective. In one word, like all other qualitative researches, sampling in this paper has a nature of being “purposeful”.

Therefore, answers to questions such as “how far we need to become agile?”, “how long will it take?”, “how much will it cost?” and so on vary according to details of the practice, and therefore are not discussed in this limited insight.
Questions such as “how to measure agility?” or “how to integrate it all around the organization?” are also problems which involve long discussions, mostly from organizational and commercial perspectives. Although in defining methodology to become agile we will see some suggested models to measure agility or how agile you need to be, or among enablers we will encounter some integrating procedures, still measurement units and tools should be discussed in more details. For further study, such particular problems are recommended to be focused because of their strong effects on the agility implemented throughout the organization and overall harmonic movement of the whole body towards goals.

This paper could be used as a guideline for any industry, with any complexity and scope. But in practice any separate enterprise needs to customize this evolutionary process based on specifications of its own and effective factors. So, this paper does not work as a general prescription to make an invincible organization winning all competitions.

Moreover, the result is still a conceptual framework of success criterions, arguably within different scenarios. Therefore, the tables and model offered in this paper and all conceptual research findings, originated, interpreted and extracted from a wide range of literature on agile manufacturing with different perspectives, are illustrated as an efficient collection of techniques and strategies, however not empirically validated at this point.

The findings will be validated/applied, tested, and developed in further researches on development of agile manufacturing systems, coupling both the research and company domain considering input from both.

1-6 SUMMARY OF THE PAPER

In summary, this paper starts by describing its Research Methodology in chapter 2 and continues the study by presenting a theoretical framework in chapter 3. Approaches, theories and arguments about “agility necessity and preparation”, “agile manufacturing, enablers and strategies” and “design, support and sustainability” are reviewed in this framework by referring to different papers, theories and thesis and the outcome is reflected into two comparative tables.
Chapter 4 carries on with “empirics, implementation and validation” which puts spotlight on the basics of implementation and practical solutions.

In chapter 5, “result and analysis” is presented based on the new model developed to identify the need level of becoming agile. Also, in a combination of common tools and strategies being used presently in industrial organizations, and synthesis of effective possible infrastructural tools and strategies, an integrated image of step-by-step becoming agile instruction and some probable strategic questions which may help decision makers to evaluate if they really want to get agile, is presented and discussed.

In chapter 6, “summary and conclusion” is made and in chapter 7, “further studies” is reviewed.
2- RESEARCH METHODOLOGY

The method applied in this paper is a systematic literature review followed by a theoretical and conceptual analysis. The review process consists of three phases: 1) data collection, 2) data analysis and 3) synthesis plus fit together purposefully. This approach improves the quality of the review process and provides a collective, transparent, revisable and reproducible procedure. The literature reviewed is limited to agility and agile manufacturing. The purpose of the limitation is that the success criterion should be arguably within different scenarios.


The search was carried out in the framework of the following criteria: agility, agile manufacturing, agility in practice, production new theories, agility design, methodology, flexibility, agility implementation, enabling strategy, agile management, operational competition, virtual enterprise, concurrent engineering.

Some other databases were books recommended by consultants and researchers. The supervisor of this paper, Mats Jackson, recommended Rick Dove’s “Response Ability, The Language, Structure And Culture Of The Agile Enterprise” and Paul T. Kidd’s “Agile Manufacturing, Forging New Frontiers” besides Andreas Ask’s “Factory-In-A-Box, An Enabler for Flexibility in
Manufacturing Systems” and Mats Jackson’s “An Analysis of Flexible and Reconfigurable Production Systems”.

Stefan Jonsson from Uppsala University recommended and handed over Richard L. Daft’s “Understanding The Theory And Design Of Organizations”. He also recommended James D. Thompson’s “Organizations In Action, Social Science bases of Administrative Theory” and Richard M. Cyert and James G. March’s “A Behavioral Theory Of The Firm” which were provided from book stores.

Although this paper can count a peer-reviewed research based on the reviewers involved, including the supervisor, the examiner, and the opponents and helping teachers from Mälardalen and Uppsala University, mostly playing a role of consultant, still the quality of the research is evaluated medium by the writer, because of lacking experimental validation throughout industrial practices. Therefore, still there is a long way to improve this research by enriching it with experimental quantitative data input.

Browsing 133 articles, papers and dissertations from databases and mentioned books helped a lot to make an overview of basics however those which were used as the references are mentioned on REFERENCES section. This overview is represented into the overall structure of this paper constructed through synthesis and extraction of complementary ideas.

Like all other qualitative researches, the nature of the data in this paper is mostly narratives, quotations and descriptions.

In phase 2, data analysis, a combination of deductive approach and inductive approach was utilized. Although analysis on this paper, which is categorized as a qualitative research, has been naturally thematic and not statistic.

Through deductive approach, a large amount of descriptive information is turned into explanations and interpretations by highlighting the related ‘spoken/written word’, supporting context, consistency and contradictions of views, frequency and intensity of comments, their specificity as well as emerging themes and trends.
Continuing with such approach, this paper takes an exploratory perspective, driving the author to consider and code all data collected, allowing for new impressions to form and shape the interpretation in different and unexpected directions.

In practice, making notes of all different thoughts that came to mind during reviewing materials and writing summaries of transcripts, was helpful to start analysis. To condense all this information to agility themes and agility topics that could shed light on the research questions, all material was coded in a way to capture the essence of the content. By developing a coding framework, the material was split to descriptive topics. Still using deductive approach, the framework was fixed by pre-defined codes, while an inductive approach could help at this step to add new codes to the list to support the new model developed in this paper.

By abstracting themes from the codes (clustering codes together into themes), the underlying patterns and structures were more seen. By connecting such patterns and structure to the main theme, a comparative interpretative structure was generated which could shed light on the main questions, earlier presented as Problem Statement.

In phase 3, synthesis plus fit together purposefully, the body of conclusion is made by connecting the above newly-generated structure to the research questions, supported by organized theories and thesis. At this point some practical experiences drawn from industry helped to connect Problem Statement questions to clear answers and to shape a transparent chain of practical steps in the path of acquiring agility.

The conclusion is always open for further studies.
3-THEORITICAL FRAMEWORK

To develop a methodology to become agile, what needs to be considered before starting to become agile is introduced and reviewed in “agility necessity and preparation” section. In this section confrontation with change is analyzed and the level of need to become agile is measured based on a scientific approach.

Despite the extensive literature review carried out to support this paper, “agility necessity and preparation” content is mostly referred to one specific publication from Sharifi and Zhang, 1999, based on 2 reasons: 1- The “Agility Field Model” which will be introduced in coming chapters of this paper, has been developed on the foundation of “Agility need level determination scoring model” which is presented and described in the mentioned publication. So, it was important to open up the idea and clarify the methodology which was discussed in the publication, to provide the reader with an insight of the analysis approach and hypotheses. 2- The agility definition and basics used as a foundation for analysis in this paper is taken from this publication among too many different sources, and the argument of aroused there will be continued in this paper in the same direction.

In “agile manufacturing, enablers and strategies” section, enablers and strategies to become agile are reviewed while some variables and adaptive elements are discussed from different perspectives.

In “design, support and sustainability” section, theories to design and plan for a sustainable agile system are introduced, reviewed and studied.

3-1 AGILITY NECESSITY AND PREPARATION

The trends, which have made the present historical development happen, are continuing towards a business environment dominated by change and uncertainty. An organization can monitor the trends, estimate and anticipate some changes and therefore plan to response properly, efficiently and using opportunities brought up of them.
But on a long shot, “autonomous operating concepts from complex adaptive systems (chaos) theory cannot be forced onto a polar-opposite organization that lives and breathes a command-and-control culture.” (Rick Dove 2001)

“Business environment as the source of turbulence and change imposes pressures on the business activities of the company. These uncertainties, unpredicted changes, and pressures urge manufacturing organizations to approach appropriate ways that could lead them to a stable position and protect them from losing their competitive advantage.” (Sharifi and Zhang 1999, pp 12) From one situation to another and from one company to another these drivers could vary, and so the way they affect a company can vary as well. This necessitates a method or a mechanism to detect or recognize changes in business environment.

Companies do differently to response when they encounter changes and later on, their consequences. Therefore, it is obvious that no one can exactly define what to do to become truly agile in definite steps. Rick Dove (2001) believes that agility does not come in a can. He says “what people believe or know to be true is a product of their experience and environment and quite likely is proven true daily if their experience and current environment are in alignment.”

But a generalized methodology can provide companies with an approach for such situations in which “change” happens unexpectedly. The approach will equip decision makers with a thought behind related decisions which should be made, and will affect how underlying principles and so on organizational behaviors are going on. It will imply the culture of the organization which will lead to an identity for the enterprise. So, in long term the enterprise is known as an agile one among competitors.

Bill Schneider, a clinical psychologist focused on organizations, argues that reengineering works when the underlying principles of new management practices are translated into concepts compatible with the underlying culture, and does not work otherwise. (Rick Dove 2001)

Taking proper action towards becoming agile involves steps which vary according to the circumstances (mission, vision, strategies and priorities, etc.) specific for the enterprise. Also, proper action should be defined based on the type of change which the enterprise deals with,
strategic intent to become agile considering sectors which will be affected by agility, agility need level, etc. This approach will base developing two models offered farther in this review from which one is derived out of the other and can count as its extension or the new revision.

In relation with the methodology foundation, the action step will consist of two parts: agility capabilities, and agility practices. In an interaction with the agility drivers will form a practical approach for a company to take agility into its characteristics (Sharifi and Zhang 1999)

Agility capabilities and practices are combined in the extended model adding a few more factors on. The combination is called “Readiness” in Agility Field chart introduced farther in this review. This chart could be a helpful tool for companies to find out where on agility field they are placed at time.

Sharifi and Zhang (1999) emphasize on the necessity of “a mechanism or a method to detect and recognize changes in the business environment” to be able to take a proactive strategy against it. Therefore, they offered a methodology map which includes five main steps. Each step will be described briefly as follow.

At the first step, they focus on agility derivers to realize the kind of change among a generalized classification of change’s types. Considering all general changes which can happen in marketplace, competition, customer desire, technology, social factors, regulations, etc. they offer a classification of probable changes in which changes are categorized in three distinct groups based on their era of occurrence, entity, and function.

The number of changes and their type, specification or characteristic could not be easily determined and probably is indefinite. Different companies with different characteristics and in different circumstances would experience different changes that are specific and perhaps unique to them. A change that may be a harmful incident for a company may not be bad for another company or even the same company in a different situation. It could even be an opportunity in a different time or place. (Sharifi and Zhang 1999)

But there are common characteristics in changes that occur, which could bring about a general consequence for every company. This could provide a basis for suggestion of some categories
that would lead to a generalization of the concept. A classification of the various changes that could happen in the business environment of the company will help to generalize the model for every company and simplify the process of recognizing the type of change and the capabilities required for recovering them. (Sharifi and Zhang 1999)

Based on similar works and outcomes from the research, three ways of categorization are suggested. The first is the general areas of change, the next is a detailed list of common and inclusive changes as sub-items of the general areas which are more or less faced by manufacturing companies, and the third is from the way that change can affect the company. (Sharifi and Zhang 1999)

So, changes are categorized into three domains, “each requiring a different type or level of response and hence different capabilities to respond to change”. What makes the company able to realize correctly the type of change it faces is the ability to sense, perceive and anticipate changes. This is a “must” for any manufacturer that wants to be agile and stand in a trustworthy position, whatever the required level of agility is. (Sharifi and Zhang 1999)

They also believe (Sharifi and Zhang, 1999, pp 17) “there are some MUST(s) for each level that should be taken into consideration by manufacturers. These are the basic movements to receive and perceive the changes, make a rapid response to it (if necessary), review and re-evaluate the company’s business strategy and/or operational strategies. As the change could be in a wide range of varieties and may differ from one situation to another, and also from one company to another, there will be optional alternatives for the required capabilities that should be clarified, measured for its level of impact and importance, verified for its position in the company, and a decision be made for approaching it through relevant practices.”

The second step talks about how agile the company needs to be. The level of need should be defined based on factors such as turbulence of the business environment, the environment the company competes in, the characteristics of the company itself, etc. Agility need level determination scoring model, which is offered by Sharifi and Zhang (1999) can help as a proper metrics to measure the need level of agility in an enterprise. The result will be used as a basis for further actions. The model allocates ranging scores to some predefined changing factors.
In this model, a series of factors are considered as measures that could form a foundation for assessing the turbulence of the environment and the specific conditions of the company. These factors are used to determine an estimation of the importance, severity, and urgency of approaching abilities for becoming agile. This will appear in the form of a scoring model that is shown in a blank format in Fig. 1. (Sharifi and Zhang 1999)

The proposed factors will be assessed and scored based on its turbulence and/or the impact it would have on the company's performance as a factor of pressures from outside environment or an internal element that makes the circumstances more harsh and severe for the company, such as complexity of the product development process. (Sharifi and Zhang 1999)

The scoring is designed so that each score represents a proportional rate of the factors with regard to the highest possible level in that specific area. This will provide the possibility of taking the average score of the total items as a measure of the agility need level. The outcomes are specific to individual companies and would not be a comparative measure for the company's position relative to its competitors or other companies. (Sharifi and Zhang 1999)

### Agility need level determination scoring model:

**Factors;**

1- Marketplace nature  
   1= Stable with the least changes .......... 5= Highly changing and turbulent  
2- Competition circumstances  
   1= Stable with the least changes .......... 5= Highly changing and turbulent  
3- Technology changing situation  
   1= Stable with the least changes .......... 5= Highly changing and turbulent  
4- Customer requirement change level and rate  
   1= Stable with the least changes .......... 5= Highly changing and turbulent  
5- Social/Cultural changes  
   1= Stable with the least changes .......... 5= Highly changing and turbulent
6- Products/Processes complexity

1= Not complex (simple) ................................ 5= Highly complex

7- Criticality of relations with suppliers

1= Not complex ........................................ 5= Highly critical

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Fig. 1. The scoring model for determining agility need level (Sharifi and Zhang 1999)

The third step in Sharifi and Zhang (1999) methodology map is to find out how agile is the company at the present time using agility metrics/measures. In former step the company has recognized the level of its agility needs, and so in this step the company should assess itself to find out what is the level of agility it already has had.

Although there is still no established work in this subject as a reference, according to the basic definitions used in the methodology, a preliminary method is being developed to assist companies. (Sharifi and Zhang 1999)

To measure how agile is the company, main capabilities (characteristics) of being agile should be scored. These main capabilities, by which agility is recognized in their scope, are indicated by Sharifi and Zhang (1999) as responsiveness, competency, flexibility, and speed.
Classification of the capabilities which are mentioned in Sharifi and Zhang (1999, pp 17&18)’s paper includes four above basic categories. Those are major capabilities that if an organization have them, it would be able to respond properly and efficiently to changes as an agile organization. They are specified as:

“Responsiveness: which is the ability to identify changes and respond fast to them, reactively or proactively, and recover from them. This has been itemized as follows:

- Sensing, perceiving and anticipating changes,
- Immediate reaction to change by affecting them into system,
- Recovery from change

Competency: which is the extensive set of abilities that provides productivity, efficiency, and effectiveness of activities/reactions towards the aims and goals of the company. Following items form the capability structure:

- Strategic vision,
- Appropriate technology (hard and soft), or sufficient technological ability,
- Products/services quality,
- Cost effectiveness,
- High rate of new products/services introduction,
- Change management,
- Knowledgeable, competent, and empowered people,
- Operations efficiency and effectiveness (leaness),
- Cooperation (internal and external),
- Integration.

Flexibility: which is the ability to process different products/services and achieve different objectives with the same facilities. It consists of items such as:

- Product/service volume flexibility,
- Product/service model/configuration flexibility,
• Organization and organizational issues flexibility,
• People flexibility.

Quickness: which is the ability to carry out tasks and operations in the shortest possible time. This will include items such as:

• Quick new products/services time to market,
• Products and services delivery quickness and timeliness,
• Fast operations time.”

Sharifi and Zhang (1999, pp 12) claim their model “will consist of general factors such as: how responsive is the company against changes in its business environment, how able is the company in proactively capturing the market and customers desire and in taking the competitive advantage of unpredicted opportunities in the market, etc. Each of these general questions and factors could be subdivided into sub-factors in place to establish a measure for estimating the current strength and abilities of the company in terms of agility.”

These capabilities have been typically main challenges in industrial management era for years. As the general concepts, they have been studied, developed and approached in different ways. In Sharifi and Zhang (1999, pp 18)’s research these ways are called “the practices, models, methods, and tools that could be practiced in different levels of the organization, from top managerial decision and strategy making to shop floor techniques for operations improvement. There are some methods and tools referred to as agile techniques that have been developed very recently or under construction by researchers, and theoretically are found to be necessary for gaining the required capabilities of agile manufacturing.” This research counts them as enablers which are embedded in organizational structure (lay out, interactions, etc.) to make a proactive flexibility for the body.

Sharifi and Zhang (1999) provide a list of used practices, associated to capabilities. Manufacturers can use it as a guide but they will be practical just when they are equipped by proper tools.

The forth step in the methodology is gap analysis through which a company can find its status in the turbulent environment and take a proper strategy to achieve required agility. This step would
result in different implications such as “the company don’t need to be agile, or the company is agile enough to respond to changes that might face in future, or the company needs to take action in order to become agile but not as an urgent agenda for the company, or the company needs to be agile it needs it fast and strongly, or etc.” (Sharifi and Zhang 1999, pp 12)

At the fifth step, “after the initial evaluation of the company’s agility need level and its current agility level, a company should take the following steps to put agility into action, and make itself agile, as reasoned above: (the first item is modified based on this paper’s articulation)

1. Classify the detected, analyzed and recognized change(s) and determine its (their) specification;

2. Determine the required capabilities to challenge and overcome the change(s); (A classification of capabilities to respond to changes are offered as following).

3. Define the required strategy (ies), if necessary;

4. Determine the practice(s) or initiative(s) that could help in achieving the required capabilities, and put them in the company’s action plan; (described briefly as following).

5. Measure and evaluate its performance in agility;

6. Make correction based on performance measurement results.” (Sharifi and Zhang 1999, pp 15)

They (Sharifi and Zhang, 1999, pp 18) also developed a tool to assist the companies to implement the proposed methodology. The tool is “in the form of a table which will be scored by some authority in a company, and the result will be guideline to take action by referring to the next table and choosing the proper practices and putting them into the plans and programs of the company.” So, the complementary table is developed also to “propose the relevant set of practices and related tools and techniques that could be applied in order to gain the specified capability.”
3-2 AGILE MANUFACTURING, ENABLERS AND STRATEGIES

Agile manufacturing concept propounded at Lehigh University in 1991.

“The main issue in this new area of manufacturing management is the ability to cope with unexpected changes, to survive unprecedented threats of business environment, and to take advantage of changes as opportunities. This ability is called agility or agile manufacturing”. (Sharifi and Zhang 1999, pp 9)

“Agile manufacturing (AM) has been defined as the capability of surviving and prospering in the competitive environment of continuous and unpredictable change by reacting quickly and effectively to changing markets, driven by customer-designed products and services.” (Gunasekaran 1999, pp 1)

Agile manufacturing, in concept is a step forward in generation of new means for better performance and success of business, and in practice is a strategic approach to manufacturing, considering the new conditions of the business environment. (Sharifi and Zhang 1999)

“An agile manufacturer, in this way is an organization with a broad vision on the new order of the business world, and with a handful of capabilities and abilities to deal with turbulence and capture the advantageous side of the business.” (Sharifi and Zhang 1999, pp 10)

Andrew Kusiak (1998) specifies characteristics of agile manufacturing as: greater product customization (product variety at low unit cost, quick response to changing market requirements, upgradable products) designed for modularity, disassembly, recyclability, and reconfigurability, dynamic reconfiguration of processes and systems - to accommodate swift changes in product designs or the introduction of new products.

The agile manufacturing enterprise can be defined along four dimensions: (i) value-based pricing strategies that enrich customers; (ii) co-operation that enhances competitiveness; (iii) organizational mastery of change and uncertainty; and (iv) investments that leverage the impact of people and information. That is, agility has four underlying principles: delivering value to the customers; being ready for change; valuing human knowledge and skills; and forming virtual
partnerships (Gunasekaran 1998). This research narrows the argument on these four broad dimensions to four key concepts: (i) Quality; (ii) Partnership; (iii) People; and (iv) Information Technology.

Although no businesses have been reported to possess all the required specifications of agility, a number of evidences of approaches for newly minded strategies and practices have made ground for providing some realistic and applicable models. (Sharifi and Zhang 1999)

Agile manufacturing is not simply concerned with being flexible and responsive to current demands, though that is an obvious requirement. It also requires an adaptive capability to be able to respond to future changes. This has two elements: (i) development of internal capability, (ii) ability to configure the company’s assets (human and capital) to take advantage of future short-lived opportunities. (Gunasekaran 1999)

For the first element, some basic goals such as lead time reduction make guidelines to use related methods such as JIT (Just-In-Time) or MRP (Master Resource Planning). It leads to some processes to be re-engineered/re-designed, developed and/or to be equipped by proper tools. These internal capabilities should match and be in-line with other agility’s capabilities/abilities.

The second element will be defined based on using technologies, flexibility of organization lay-out (people and equipment) and reliability/viability of the assets (human and capital).

The important point for many researchers such as Booth (1996) is that “agile and lean are not synonymous”. Booth (1996) highlights different supplier relationship in lean and agile systems. He puts spotlight at Japanese auto makers as lean manufacturers with general characteristics. He believes that to find the best suppliers, for any needed services, is always possible by searching an open and competitive global market, and successful manufacturers are aware of that.

Lean claims a considerable cost fall through its proper implementation, practice and adoption. But Booth (1996) believes that at recession, lean production is a relentless drive for many companies, to reduce their costs. At such a situation “the companies are more starved than lean” (according to Booth, 1996), and are not able to take sufficient advantage throughout the recovery process; because in general they have already lost their skilled staff, in addition to the basic
design and improvement capabilities, particularly if they had had a firm one in-place before. Booth (1996) believes that for becoming agile the other, “forgotten aspects of lean production”, have to be the center of focus. “Flexibility and speed of response” should be set up as the aim in a way to ensure they are embedded in an adaptable mechanism for future changes in the market.

The opinions on how manufacturing companies could succeed are so diverse that a general consensus could hardly be reached. Emphasis on new priorities of business are some but a few to name of regularly suggested solutions for increasing the ability of an organization in responding to change and maintaining the competitive advantage. These priorities are: time (achieving speed in delivery and lead time) and flexibility, deploying new technologies (Advanced Manufacturing Technology, AMT, and etc.) and methods, tools and techniques, utilization of information system/technology and data interchange facilities, more concern on organizational issues and people (knowledgeable and empowered workers), integration of whole business process, enhancing innovation all over the company, virtual organization and cooperation, production based on customer order (mass-customization), etc. (Sharif and Zhang 1999)

This will only be achieved through changing the way of looking at manufacturing business, manufacturers’ relationships with suppliers and customers, and their cooperation with competitors. “The new mindset required for this purpose should support a new strategic vision beyond the conventional systems and move to new dimensions of competition rather than only cost and quality. Surviving and prospering in this turbulent situation will be possible if organizations have the essential capabilities to recognize and understand their changing environments and respond in a proper way to every unexpected change. Also, opportunistic actions in capturing new markets and responding to new customer requirements is another important feature necessary for success in the contemporary form of the business environment.” (Sharifi and Zhang 1999, pp 9)

So, to employ agility in a manufacturing system, some enablers are needed to create those capabilities for the company. In this respect, according to Gunasakaren (1998, pp 1226) it is important that “In order to achieve agility in manufacturing, physically distributed firms need to be integrated and managed effectively so that the system is able to adapt to changing market conditions.”
However, agile manufacturing is a young concept and there are not lots of papers approaching it from different perspectives, a comprehensive review on existing literatures shows there are various definitions of an agile enterprise entity. Therefore, although nearly all these definitions are polarized/ convergent in a similar direction, still there are different enablers introduced by different scientist/researchers based on different aspects of an agile enterprise. Most definitions seem to highlight concept of flexibility and responsiveness achieved through enablers such as virtual enterprises, automation and information technologies, strategic management and product design. Accordingly, different strategies and technologies have been introduced to be used to make and maintain an enterprise agile.

Dahmardeh and Banihashemi (2010) enumerate three enablers for agility capabilities which named in pillars in their paper. In their figured model, these pillars are:

- a) leverage people and information technology as foundation
- b) master change and uncertainty as control
- c) collaborative relationships as strategy

Although Sharifi and Zhang (1999) in their conceptual model of agility specified practices, methods, and tools as providers of agility in a longitudinal relationship with innovation, people, technology, and organization however with the same function of Dahmardeh and Banihashemi’s (2010). Magnifying the model, here just two different titles are counted for each group to deal with them distinctively according to their function and how they interact with each other and with agility concept. Therefore, innovation, people, technology, and organization as agility providers develop/ define/ support/ use practices, methods and tools as agility enablers.

Gunasekaran (1998) has proposed agile manufacturing system enablers under seven main rubrics:

- (i) Virtual enterprise (VE) formation tools/metrics
- (ii) Physically distributed teams and manufacturing
- (iii) Rapid partnership formation tools/metrics
- (iv) Concurrent Engineering (CE)
He also developed a conceptual model in the form of a figure to illustrate the interaction between an agile manufacturing system and its enablers.

A framework for agility projected by Goldman (1994) includes four major dimensions focusing on inputs, outputs, external influences, and internal operations:

(i) Outputs: customer enriching “solution” products.
(ii) Inputs: cooperating to enhance competitiveness.
(iii) External influences: unpredictable change and social values.
(iv) Internal operations: leveraging the impact of people and information.

Dove (1995) offers a comprehensive organizational approach which makes an overview including the agile manufacturing interacting with other organizational components. He believes that drivers of agility can be determined by relationships that exist among entities within an organization. One such driver is the relationship between opportunistic customers and adaptable producers that may be defined as opportunity management. Another important linkage and driver for an agile environment is the link between adaptable producers and ceaseless technology that may be defined as innovation management. These driver examples show that the relationships that exist within an agile environment include both inter- and intra-enterprise situations. The goal of agility and these management principles is to reduce the toll of change on product cost, product quality, product availability, organizational viability, and innovation leadership. The principle of change management is significant within the set of agile definitions. A more robust, theoretical foundation is still a necessary requirement in aiding the transformation of agility and its principles to a science. (Sarkis, 2001)

De Vor & Mills (1995) have a quite similar definition of agility but from a quite different approach. They define agility as the ability to thrive in a competitive environment of continuous and unanticipated change and to respond quickly to rapidly changing markets driven by customer-
based valuing of products and services. The key concept for them is a new and post-mass production system for the creation and distribution of goods and services. They describe how to focus on product design and distribution of goods as the proper practical agile strategies and offer to use flexible manufacturing systems, data communication, data processing and wide area network (WAN) as the most efficient technologies.

Whereas, Gupta and Mittal (1996) believe that agility concept stresses mostly on the importance of being highly responsive to meet all needs of the customer while trying to be lean. They explain that agility puts responsiveness on a higher priority than cost-efficiency while a manufacturer with a goal of being lean, mostly sacrifices responsiveness for cost-efficiencies. From their points of view, it’s very important to focus on integrating organizations, technology and people into a meaningful unit, and that can happen by deploying a kind of advanced information technology and a flexible and nimble organization structure through that those highly skilled, knowledgeable and motivated people can be supported. Based on such a definition, Gupta and Nagi (1995) focus on virtual organization as the best strategy and offer technologies such as automated high-level process planning system, CAD (Computer Aided Design), CAPP (Computer Aided Process Planning) and virtual reality.

Adamides (1996) who defines agility as a responsibility-based manufacturing (RBM), focuses on most adjustments for process and product variety to take place dynamically during production without a priori system. He introduces the responsibility-based manufacturing (RBM), distributed decision making, heterarchical coordination, and system reconfiguration as the effective strategies and accordingly suitable technologies are flexible manufacturing system, robots’ control systems, and intelligent agents from his point of view.

While some researchers such as James-Moore (1996), Kidd (1996), and Gould (1997) prefer to project a relative definition of agility as “more flexible and responsive than current” and focus on new ways of running business and casting off old ways of doing things, other ones such as Abair (1997) takes a longer step forward and defines agility as “to provide competitiveness” and focuses on key concepts such as customer-integrated process for designing, manufacturing, marketing and support, flexible manufacturing, cooperation to enhance competitiveness, organizing to manage change and uncertainty and leveraging people and information.
Throughout this approach Abair (1995) offers strategies such as virtual organization, supply chain, and temporary alliances with the help of technologies such as information technology, CRE, and MRP II.

Abair (1997) improves his offer, like what Gunasekaran (1998, 1999) and Yusuf et al. (1999) do, and expand the complex of efficient strategies to virtual enterprise, rapid partnership formation, rapid prototyping, alliances based on core competencies, multidisciplinary teams, supply chain partners, flexible manufacturing, computer-integrated manufacturing and modular production facilities. To implement such strategies, they offer convenient and practical technologies such as internet, e commerce, computer-supported cooperative work, flexible manufacturing systems, information technologies such as multimedia, internet, database, electronic data interchange, computer-aided design, computer-aided engineering, computer-aided process planning, etc.

Some similar definitions such as of Hong et al. (1996) and Kusiak and He (1997) project different strategies, technologies and tools for implementing agility. Hong et al. (1996) define agility as flexibility and rapid response to market demands. Kusiak and He (1997) have a similar definition of an agile enterprise as driven by the need to quickly respond to changing customer requirements. These definitions demand a manufacturing system to be able to produce efficiently a large variety of products and be reconfigurable to accommodate changes in the product mix and product designs and design for the assembly.

But the strategy and tools Hong et al. (1996) offer is different from Kusiak and He (1997). Hong et al. (1996) believe the best strategy is flexible tooling and flexible fixturing using operations research models and information technology (focusing on flexible technologies such as rapid prototyping, robots, internet, AGVs, CAD/CAE, FMS, CAPP and CIM); while Kusiak and He (1997) prefer to focus on design for manufacturability and design for assembly, using flexible manufacturing systems and system analysis.

So, based on the scope of work, and the need level of agility and the urgency of response and other effective factors in methodologies priorities, taken strategy and efficient technology may vary. But in a generalized view, researchers such as Cho et al. (1996), Gunasekaran (1999), and Yusuf et al. (1999) consider a general definition as a base and according to its key concepts to
focus, they offer some practical strategies, technologies and tools as the most efficient ones generally. Some of them such as Gunasekaran (1999) go much further in details of implementation of agility in contemporary industrial sectors.

The general definition mentioned above recognizes agility as a “capability to survive and prosper in a competitive environment of continuous and unpredictable change by reacting quickly and effectively to changing markets” (Gunasekaran and Yusuf, 2002, pp 1357). This general definition focuses on virtual enterprise, e-commerce, strategic partnership formation, and rapid prototyping, standard exchange for product models, concurrent engineering, and virtual manufacturing. Therefore, technologies such as prototyping software, control systems, information technology, communication, workshop, benchmarking exercise, training and education could be efficient to drive an agile enterprise.

Through a close-up, main capabilities for an agile manufacturing enterprise could be prioritized. “In 1978, Wheelwright (1978) proposed four major competitive priorities for manufacturing: efficiency, quality, dependability and flexibility. Efficiency refers to both cost and capital efficiencies. Quality includes the dimensions of product quality and reliability, service quality, speed of delivery and maintenance quality. Dependability concerns delivery and price promises. Two principle dimensions of flexibility include product and volume changes.” (Vokurka and Fliedner, 1998, pp 167)

“In 1979, Hayes and Wheelwright (1979) suggested that firms could gain a competitive advantage from a strategic matching of product and process life cycles. They proposed a product/process matrix where for each major product line there should be a proper match between the stage of the product life cycle and the choice of production process. They postulated that a trade-off occurs between the paired priorities of efficiency/dependability and quality/flexibility.” (Vokurka and Fliedner, 1998, pp 167)

“More recently, in order to reflect international, dynamic, customer-driven and fragmented markets, various researchers have expanded the list of competitive priorities. For example, one list includes thirteen priorities:
• product flexibility (customization);

• volume flexibility;

• process flexibility;

• low production cost;

• new product introduction;

• delivery speed;

• delivery reliability;

• production lead time;

• product reliability;

• product durability;

• quality (conformance to specifications);

• design quality (design innovation) and;

• post-sale customer service (Markland et al., 1995).

Although the number of competitive priorities enumerated has increased, they can arguably still be grouped according to the original four capabilities; efficiency, dependability, quality and flexibility.” (Vokurka and Fliedner, 1998, pp 167)

But as firms’ operations have improved in response to changing competitive environments, the conventional wisdom of manufacturing capability trade-offs has come into question.

“In a study of large European manufacturers, Ferdows and De Meyer (1990) found that the conventional wisdom of trading off one of the four strategic performance capabilities for another may be false. They concluded that the nature of the trade-offs among these capabilities is more
complex than previously thought and depending on the approach taken for developing each capability, the nature of the trade-offs changes. Their principle finding suggests the capabilities could be attained in a cumulative and lasting manner depending on the order in which objectives related to these capabilities are sought.” (Vokurka and Fliedner, 1998, pp 168)

All approaches, which are reviewed above, and supportive concepts that the approaches are focusing on, and suggested enablers & strategies, come into below table summarized and tabloid.

<table>
<thead>
<tr>
<th>Name</th>
<th>Approach</th>
<th>Focus</th>
<th>Enablers</th>
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<tbody>
<tr>
<td>1</td>
<td>Hayes and Wheelwright, 1979</td>
<td>Strategic matching of product and process life cycles</td>
<td>Trade-off between the paired priorities of efficiency/dependability and quality/flexibility</td>
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<tr>
<td>2</td>
<td>Goldman, 1994</td>
<td>Customer enriching “solution” products, Cooperating to enhance competitiveness</td>
<td>External influences: unpredictable change and social values</td>
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<td>3</td>
<td>Dove, 1995</td>
<td>Interaction of organizational components</td>
<td>Reduce the toll of change on product cost, product quality, product availability, organizational viability, and innovation leadership</td>
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<tr>
<td>4</td>
<td>De Vor &amp; Mills, 1995</td>
<td>A new and post-mass production system for the creation and distribution of goods and services</td>
<td>Product design and distribution of goods</td>
</tr>
<tr>
<td>5</td>
<td>Gupta and Nagi, 1995</td>
<td>Flexible optimization framework for partner selection</td>
<td>Virtual organization &amp; optimal partner selection</td>
</tr>
<tr>
<td>6</td>
<td>Abair, 1997 &amp; 1995</td>
<td>Provide competitiveness by customer-integrated process for designing, manufacturing, marketing and leveraging people &amp; information</td>
<td>Virtual organization, Flexible manufacturing, Competitiveness, Change management, Supply chain, Temporary alliances</td>
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<td>7</td>
<td>Booth, 1996</td>
<td>Differences with Lean</td>
<td>Supplier relationship</td>
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<td>8</td>
<td>Gupta and Mittal, 1996</td>
<td>Highly responsive to meet the total needs of the customer while simultaneously striving to be lean</td>
<td>To integrate organizations, people and technology into a meaningful unit</td>
</tr>
<tr>
<td>9</td>
<td>Adamides, 1996</td>
<td>Adjustments for process and product variety to take place dynamically during production without a priori system</td>
<td>Responsibility-based manufacturing (RBM), Distributed decision making, Heterarchical coordination, System reconfiguration</td>
</tr>
<tr>
<td>10</td>
<td>Hong et al., 1996</td>
<td>Flexibility and rapid response to market demands</td>
<td>Flexible tooling and flexible fixturing using operation research models and information technology</td>
</tr>
<tr>
<td>12</td>
<td>Kusiak and He, 1997</td>
<td>Driven by the need to quickly respond to changing customer requirements</td>
<td>Design for manufacturability and design for assembly</td>
</tr>
<tr>
<td>13</td>
<td>Gunasekaran, 1998 &amp; 1999</td>
<td>Integration of physically distributed firms</td>
<td>Physically distributed teams and manufacturing, Capability &amp; configurability, Quality, Partnership, People, IT</td>
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<td>Name</td>
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<td>Enablers</td>
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<tr>
<td>Sharifi and Zhang, 1999</td>
<td>Changing the way of looking at the business, the relationships with customers and suppliers, and the cooperation with competitors, A new mindset to support a new strategic vision beyond the conventional systems and move to new dimensions of competition rather than only cost and quality</td>
<td>Essential capabilities to recognize/ understand changing environments and respond in a proper way to unexpected change, Opportunistic actions to capture new markets and to respond to new customer requirements, Speed in delivery and lead time, New priorities of business such as time, flexibility, innovation, organizational issues and people (knowledgeable and empowered workers), Integration of the whole business process, Flexible production based on customer’s order</td>
<td>New technologies such as AMT, methods, tools and techniques, Information system/ technology and data interchange facilities, Mass-customization, Virtual organization and cooperation</td>
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<tr>
<td>Gunasekaran and Yusuf et al., 1999</td>
<td>Four underlying principles: delivering value to the customers; being ready for change; valuing human knowledge and skills; and forming virtual partnerships. Expand the complex of efficient strategies to focused concepts &amp; enablers</td>
<td>virtual enterprise, rapid partnership formation, rapid prototyping, alliances based on core competencies, multidisciplinary teams, supply chain partners, flexible manufacturing, computer-integrated manufacturing and modular production facilities</td>
<td>internet, e commerce, computer-supported cooperative work, flexible manufacturing systems, information technologies such as multimedia, internet, database, electronic data interchange, computer-aided design, computer-aided engineering, computer-aided process planning</td>
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<td>Sarkis, 2001</td>
<td>Reduce the toll of change on product cost, product quality, product availability, organizational viability, and innovation leadership when change happens</td>
<td>Change management, Benchmarking</td>
<td>Total quality management (TQM), Reengineering, Continuous improvement techniques, tools &amp; metrics</td>
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<tr>
<td>Name</td>
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<tr>
<td>17 Gunasekaran and Yusuf, 2002</td>
<td>capability to survive and prosper in a competitive environment of continuous and unpredictable change by reacting quickly and effectively to changing markets</td>
<td>virtual enterprise, e-commerce, strategic partnership formation, rapid prototyping, standard exchange for product models, concurrent engineering, virtual manufacturing</td>
<td>prototyping software, control systems, information technology, communication, workshop, benchmarking exercise, training and education</td>
</tr>
<tr>
<td>18 Dahmardeh and Banihashemi, 2010</td>
<td>Innovation, people, technology, and organization as agility providers develop, define, support and use practices, methods and tools as agility enablers through a longitudinal relationship</td>
<td>Leverage people &amp; IT, Master change &amp; uncertainty, Collaborative relationships</td>
<td>Foundation, Control, Strategy</td>
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</table>

Table 1. Collective Agility approaches, focused concepts and suggested enablers & strategies to implement agile systems
3-3 DESIGN, SUPPORT AND SUSTAINABILITY

When strategies are convergent and strengthened in the way of agility, it is required not only to build up fundamentals in flexibility by gathering elements in a basket, but also to think of a proper design and layout of those elements to ensure its sustainability and to keep alive those competitive advantages derived from such flexibility. “Operations managers should become the guardians, ensuring that key sources of competitive advantage (e.g. new product development processes) are continuously upgraded so that competitors are unable to copy them. Operations strategy could then focus on making trade-offs in “resource” (or advantage, or asset) management, determining the sustainability of the firms’ competitive strengths.” (Gagnon, 1999, pp 130)

Gagnon (1999) believes “organizational agility would depend directly on operations’ proficiency in analyzing, developing, and leveraging resources, capabilities, and competencies. Thus, operations management would not simply be a matter of structuring processes, but especially a highly intelligent activity geared to ensuring that a firm knows well what tangible and intangible resources it has, where they are headed, and how to protect them in avoiding their decay or stagnation”. (Gagnon, 1999, pp 132)

Collis (1994) suggests three levels with increasing potential to offer sustained advantages: (1) functional capabilities (e.g. making a plant layout); (2) change capabilities (e.g. reengineering); and (3) management capabilities (e.g. strategic insight).

On a wide perspective when an enterprise attempts to obtain the essence value of strategies in the way of agility, it seems to be no ultimate imaginable for competitive advantages. Collis (1994) says: the problem would be a kind of infinite regression toward ever higher levels of competencies within the hierarchy, as firms compete on tougher grounds each time. So, Gagnon (1999) discusses: the solution in the face of hyper-competition is not simply to reach out the most strategic operations, but especially to graduate towards the hard-to-copy or hard-to-diffuse capabilities (Slater, 1996; Zander and Kogut, 1995).
Although formerly it was pointed out that operations strategy should provide opportunities to help make core competencies and capabilities more tacit and untouchable, so that operating excellence leads to more sustainable competitive advantages (Wright, 1996).

Therefore, only a few excellent companies may be able to graduate to the top of hierarchy and sustain competitive advantages over long periods of time; but even the strongest industry leaders are still vulnerable to built-in rigidities which may prompt their own downfall. (Gagnon, 1999)

Leonard-Barton (1993) also refers to the issue when he says: once capabilities have reached the strategic core of an organization, they can easily become core rigidities. That is, best practices can progressively become major impediments to operational innovation.

Through the same aspect, Miller (1993) shows that operating excellence might not be hampered and affected by such rigidities if some forms of simplicity are applied in strategies. As a leading firm comes to abuse of a winning formula, and as it becomes so focused, it comes to lose touch with its environment. (Gagnon, 1999)

To avoid such rigidities some researchers such as Kusiak (1998) prefer to refer to general rules for agile manufacturing design. He even formulates those general rules to make more tangible and practical perception of them. He instructs to step on with a “modular system design” by “decomposing a complex system into several independent units”.

Kusiak (1998) also refers to “a robust product design” as a rule being implemented by “designing a product with robust scheduling characteristics”. He specifies that the goal of such a design is to “minimize the impact of disruptions on a production schedule due to change in the product mix and production demand”.

The other rule Kusiak (1998) specifies is “to streamline the flow of products”. To make a tangible comparison between streamlined system and non-streamlined system, he uses Johnson’s algorithm and heuristic rule. Also, through different examples shows that flow shop type flow works as a model for streamlined system comparing with job shop type flow which implies a non-streamlined system.
Kusiak (1998) projects the next rule as “to design short assembly line” by “reducing the number of stations in an assembly line”. He believes that long assembly lines are difficult to balance, have behavioral problems and cause NP-completeness of the scheduling problem. (NP stands for "nondeterministic polynomial time" where nondeterministic is just a fancy way of talking about guessing a solution. A problem is in NP if you can quickly (in polynomial time) test whether a solution is correct (without worrying about how hard it might be to find the solution). Problems in NP are still relatively easy: if only we could guess the right solution, we could then quickly test it. NP does not stand for "non-polynomial". There are many complexity classes that are much harder than NP. (ICS 161: Design and Analysis of Algorithms, Lecture notes for March 12, 1996))

The last rule Kusiak (1998) emphasizes on is “to simplify the flow of products” by “designing products to simplify the flow of products in a multi-product assembly system”. He suggests five types of product flows as: repeat, serial, by-pass, backtracking, and branch/merge. To implement this rule, he suggests eliminating cycles by redesign.

Some others such as Browne and Zhang (1999) have different approach to focus on designing agile manufacturing enterprises. They believe “In today's global economy, manufacturing enterprises must be viewed in the context of their contribution to the total value chain. Extended enterprises and virtual enterprises, consisting of tele-computing mediated chains of suppliers, manufacturers, assemblers, distributors and customers, compete to supply quasi-customized products to discerning markets.” (Browne and Zhang, 1999, pp 30)

Browne and Zhang (1999, pp 30) believe “manufacturing enterprises are now facing the challenge to break their conventional isolation in business and work together across the total product value chain. The extended enterprise and the virtual enterprise are two of the emerging manufacturing paradigms. The extended enterprise defines an environment where business partners work together for long-term business purposes based on mutual responsibility and loyalty while the business partners of the virtual enterprise temporarily come together to exploit niche market opportunities based on short-term and dynamic co-operation among the partners.”

Bititci et al. (1999, pp 190) in their paper, look at the issue of a proper structure to implement a viable agility, from a different perspective. They believe “modern business process thinking and
the VSM (viable system model) provides the foundations for a viable business structure which maximizes opportunities for managing agility.”

They explain VSM dimensions and specifications based on modern business process thinking. They also demonstrate “how VSM and modern business process thinking combine to provide a powerful structure for planning and managing today's modern organization in an uncertain and dynamic environment.” Referring to the use of this model in several practical cases, they claim that the viable systems structure presented by them, efficiently provides a very powerful framework for the strategic analysis, planning and management of the agility in a business through improving responsiveness.

Christopher and Towill (2001) present a hybrid lean-agile strategy (different from new-propounded concept of Leagility). Their focus is on design of agile supply chain which from their points of view makes the infrastructure for a viable agile manufacturing design. Their contention is that “lean methodologies can be a powerful contributor to the creation of agile enterprises. In particular where product ranges can be separated according to volume and variability and/or where the de-coupling concept can be applied, a real opportunity exists for employing hybrid lean/agile strategies.” (Christopher and Towill, 2001, pp 242)

“There is also one important sense in which lean precedes agile, and which has been advanced by Victor and Boynton (1998) in the context of moving towards mass customization. This is because real and effective change requires the mapping and understanding of all the relevant business processes. Thus, in an industrial engineering scenario the lean knowledge base is there to be exploited in enabling further performance improvements including building in agility (Childerhouse et al., 2000).” (Christopher and Towill, 2001, pp 242)

They suggest a three-level framework summarizing their view of the agile supply chain. However, the concept of such a framework was already presented by Werr et al. (1997) their framework for agility is contingent upon the context in which the business operates. They bring together the lean and agile philosophies to highlight the differences in their approach, also to show how they might be combined for greater effect. Increasingly, managers need to understand how market
conditions and the wider operating environment will demand not a single off-shelf solution, but hybrid strategies which are context specific.

Vernadat (1999, pp 39) goes further in details of manufacturing system design and control. He notes: “In terms of agility, the goal is to build more understandable, controllable and predictable manufacturing systems. The challenge is then to better understand the boundaries, roles and interactions of elements of the enterprise which must be integrated (Kosanke and Nell, 1997). To achieve this, further work needs to be done in terms of: enterprise engineering (EE) methods, reusable components and enterprise modeling and integration (EMI) technology.”

Vernadat (1999, pp 39) explains enterprise engineering (EE) methods as: “systematic engineering methods and computer support tools which are required to reengineer or define, specify, analyze, plan implementation and put into operation integrated manufacturing systems.”

A first step in this direction has been made with the development of GERAM (Generalized Enterprise Reference Architecture and Methodology) by an IFAC-IFIP Task Force in relation with ISO TC 184/SC5/WG1 work (IFAC/IFIP Task Force, 1997). “GERAM is a generalized framework for enterprise architecture and business process engineering which is used for enterprise integration.” (Vernadat, 1999, pp 39)

GERAM combines and utilizes methods such as:

CIMOSA, which stands for Computer Integrated Manufacturing Open System Architecture. It is an enterprise modeling framework which aims to support the enterprise integration of machines, computers and people. The framework is based on the system life cycle concept, and offers a modeling language, methodology and supporting technology to support these goals.

GIM, which stands for GRAI Integrated Methodology which is a structured approach to guide the application of the methodology for Integrated Manufacturing Planning And Control System. GRAI stands for Graphs with Results and Actions Inter-related

PERA, which stands for Purdue Enterprise Reference Architecture. It provides the framework and guidelines for integration of the enterprise.
“The goal is to completely engineer the system on the basis of a comprehensive set of complementary models to deal with function, information, resource, organization and performance aspects of the system to analyze all properties and behavior of the system before it is implemented. Part of these models could then be used to control system operations.” (Vernadat, 1999, pp 39)

Vernadat (1999, pp 39) refers to reusable components as: “to make the manufacturing system easily modifiable and reconfigurable. The idea is to engineer it from a set of exchangeable modules or reusable components. This can be true for business processes, information systems, resource components, application systems and even knowledge sources. Building or modifying a system would then be approached in a “plug-and-play” fashion. However, this can only happen if standard languages exist to represent families of idealized enterprise components (to be built or to be bought). This assumes that it is possible to define a common conceptual basis for the description of the structure, capabilities and interaction of these components.”

“To this end, the development of a unified enterprise modeling language (UEML) covering technological, organization and human aspects of a business entity has been recently suggested as an international effort (Petit et al., 1997).” (Vernadat, 1999, pp 39)

The last area that is required to be focused in forming the foundation of agile enterprise design from Vernadat’s (1999, pp 39) points of view is enterprise modeling and integration (EMI) technology, which is explained so that: “enterprise modeling provides the necessary modeling tools to understand, analyze, reengineer and optimize the manufacturing systems and its reusable components while enterprise integration provides the necessary integrating infrastructure (or set of integration services) to enable enterprise-wide people and system inter-operation.

The theories reviewed above regarding agility design, support and sustainability is summarized and tabloid in below table.
<table>
<thead>
<tr>
<th></th>
<th>Name</th>
<th>Focus</th>
<th>Advantageous output</th>
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<tbody>
<tr>
<td>1</td>
<td>Leonard-Barton, 1993/ Miller, 1993</td>
<td>Capabilities core rigidities</td>
<td>Simplification</td>
</tr>
<tr>
<td>2</td>
<td>Collis, 1994</td>
<td>functional capabilities, change capabilities, management capabilities</td>
<td>An ultimate imaginable for competitive advantages</td>
</tr>
<tr>
<td>3</td>
<td>Wright, 1996</td>
<td>Operation Strategy</td>
<td>tacit and untouchable core competencies and capabilities</td>
</tr>
<tr>
<td>4</td>
<td>Kusiak, 1998</td>
<td>modular system design robust product design to streamline the flow of products to design short assembly line to simplify the flow of products</td>
<td>Non-rigid core capabilities</td>
</tr>
<tr>
<td>5</td>
<td>Gagnon, 1999</td>
<td>Operation Management</td>
<td>hard-to-copy or hard-to-diffuse capabilities</td>
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<tr>
<td>6</td>
<td>Browne and Zhang, 1999</td>
<td>total product value chain</td>
<td>Extended enterprises virtual enterprises</td>
</tr>
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<td>7</td>
<td>Bititci et al., 1999</td>
<td>modern business process thinking VSM (viable system model)</td>
<td>powerful framework for the strategic analysis, planning and management of the agility of a business through improving responsiveness efficiently</td>
</tr>
<tr>
<td>8</td>
<td>Vernadat, 1999</td>
<td>enterprise integration</td>
<td>enterprise engineering (EE) methods reusable components enterprise modeling and integration (EMI) technology</td>
</tr>
<tr>
<td>9</td>
<td>Christopher and Towill, 2001</td>
<td>agile supply chain</td>
<td>hybrid lean-agile strategy (different from new-propounded concept of Leagility)</td>
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Table 2. Agility design, support and sustainability theories
Besides those were named, different researchers argue about design and control a viable agile manufacturing enterprise, their tools and enablers. Some examples of different perspectives which are mostly focused exclusively (and they can’t be addressed in this short literature review) are “innovation management”, “knowledge management”, “reconfigurability”, “concurrent engineering” and “virtual enterprise”. But in all fundamental designs there have been same key concepts which are highlighted. Among those quality, partnership, people and information technology, based on four main dimensions of agility design from Gunasekaren’s (1998) points of view, are spotlighted in this paper.

Quality

Agility not only encompasses many quality-related ideas, it actually needs them solidly in place before the journey toward agility can begin. (Litsikas, 1997)

Patterson, industry president and chief executive officer of Agility Forum, says: “agility is a combination of quality and customer satisfaction. Give the customer what he wants throughout changing needs and throughout the life of the product, and he won’t have to go anywhere else. Quality is a given, it is just the ticket to admission and is no longer a competitive advantage.”

Ferdows and De Meyer (1990) show that improvements in cost efficiency do not necessarily lead to higher quality levels. However, Vokurka and Fliedner (1998) argue that improvements in cost efficiency can be a consequence of superior quality. Consequently, they suggest that management attention and resources should first be directed toward achieving and then expanding quality objectives. After achieving quality-related goals and while quality efforts are further expanded, attention should be directed toward the dependability of the production system. (Vokurka and Fliedner, 1998)

“Once significant progress toward meeting quality and dependability related goals has been achieved and while pursuing these objectives further, resources may be directed toward improving production flexibility (or reaction speed). Finally, while efforts continue toward achieving and expanding quality, dependability and flexibility goals, attention can then be directed toward improving cost efficiency.” (Vokurka and Fliedner, 1998, pp 168)
They suggest that “the pursuit of these objectives in this successive fashion may lead to cumulative and lasting benefits.” Unlike the theory that trade-offs exist among competitive priorities, Ferdows and De Meyer (1990) conclude that lasting cost efficiency in production can be achieved only through improvements in other capabilities.

But still some researchers challenge the significance of quality in the agility journey. DanNorth.net faces such challenges by an effort to clarify the main meaning of quality. It asks if “quality” means “well-crafted software” or “hit the original estimates” or “hit all the KPIs”. It finally defines quality as “how well a solution achieves its purpose”. To the question “where is the quality in agility?” DanNorth.net answers: “completeness of the solution, ease of adaption, and ease of management”.

According to Varnedat (1999) regarding product design, agility means the ability to produce a variety of products of high quality at low cost for greater product customization. However, besides the development of advanced CAD and CAE (computer-aided engineering) tools and methods, the answer to this need has been concurrent engineering (CE) (Solhenius, 1992).

People’s role in assuring quality as a base for agility implementation also is a point on which papers are written. But “although the quality professionals can be a catalyst for the move toward agility, they cannot be the sole keeper of the flame.” (Litsikas, 1997, pp 34)

**Partnership**

Ideally the partnership of agile manufacturing firms is a virtual enterprise in which each manufacturer realizes a portion of the product design and cooperates with the other members of the enterprise to lower the product’s cost, improve its quality, and reduce the time span necessary to bring the product to market. In the virtual enterprise, the partners exchange electronically information concerning design, process planning, production planning, inventory management, testing, distribution, and billing. In addition, the partners should establish business processes that allow them to exchange such data and to process the necessary transactions. (Minis et al., 1996)
Some researchers such as Parkinson (1999) refer to the concept of partnership under different titles or expressions. She refers to this concept as a contributing factor to the ability to become an agile manufacturer. She calls it “development of manufacturing support technology” that allows the marketeers, the designers and the production personnel to share a common database of parts and products, to share data on production capacities and problems - particularly where small initial problems may have larger effects.

Let’s generally assume that an enterprise designs the product and joins with other enterprises to manufacture the products. To form a successful partnership, the enterprise needs to create a superior/overall design and select/pick up the proper partners that best fit the scope of the VE (virtual enterprise). So, it should first provide methods to assess/evaluate the proposed design with regards to the capability of candidate partners. Second it should provide tools to select those partners which best fit the design’s requirements. These two decisions should be coupled, and should be treated simultaneously. “The integration of design evaluation and partner selection allows critiquing of the design considering the partner-specific strengths that are related to the product’s manufacturing requirements (not the manufacturing plant’s general performance). It also provides vital design feedback at a point when modifications to improve the fit between the design and the partners are less costly.” (Minis et al., 1996)

Partner selection comes after the creation and evaluation of manufacturing alternatives based on the design. “The partner selection approach allows the designer to identify the most suitable manufacturing processes to realize the product design and the most preferable manufacturing plants to perform these processes.” Minis et al. (1996)

The partner selection approach is projected by Gupta and Nagi (1995). On the implementation step they explain “the designer may reduce the number of partner alternatives under consideration (1) by excluding those alternatives that are dominated by some other alternative with respect to any combination of criteria, and (2) by excluding those alternatives that are inferior with respect to user-specified thresholds for one or more criteria. The designer provides a weight for each performance criterion. For example, these weights allow the designer to convert all criteria to dollars.” (Minis et al., 1996)
People

To reply to the question “who will run the machines?” A. C. Montag (1998) believes that to achieve truly flexible and agile production requires better schools and simpler manufacturing system software, and so all operators could work as an expert.

Gagnon (1999) says: Essentially, there is a need to find the various coherent systems that can be built out of many competitive dimensions, and creates organizational processes which embody them all in the right proportions needed to face hyper-competitive markets. The build-up of such processes would be made with especially one key resource that is knowledgeable worker, which would form the basis for long-term sustainability of processes. In a world where nurturing markets would be increasingly difficult, this perspective would call instead for creative strategies to nurture competencies and capabilities (Hamel and Prahalad, 1994).

Jackson (2000) believes: if we want to be valued high on the market we need to actively work to promote knowledge and competency within operations. He mentions the focus of market value on “brain power” and believes: for such purpose companies need to invest in high technology and in products and processes. He points out: “companies that are largely dependent on knowledge and competence of employees have created the definition: “knowledge intensive enterprise”. A definition of such companies is that they are characterized by non-standardized, creative, strongly individual dependent, and complex problem-solving activities.”

Owusu (1999) in his paper provides a method of forming teams for the purpose of improving management systems in an agile environment. He demonstrates that such a management system is progressive and proactive in achieving its goals and objectives and cultivates close communication with its employees and customers. In agile management systems, such a “people oriented organizations” are created that highly value their customers and employees. In Owusu’s paper, the strategic importance of communication and employee involvement for agile world-class management systems is discussed. Also, a model for employee involvement for agile management systems is offered. The paper claims that the driving force behind employee involvement and human resource development in agile management systems is proper communication.
Phil Roether, vice president of the systems group and manager for product production processes from Texas Instrument Defense Systems, which was one of the handful of pioneer companies that was ready to embrace agile manufacturing in 1990s, says: the most difficult part of the agility journey for us was the people. This difficulty took two forms: cultural changes and technical training. He says: it was not intuitively obvious that our technologically trained people did not have the necessary team-building skills. We did not think we needed to spend the effort to learn those skills, but what we found is that we were not as good as we thought and we had to back up and formalize our training policy. He claims: we went from being an organization that discouraged talking among employees to one that encourages communication. He believes: a knowledgeable workforce is a vital part of our agility infrastructure; no doubt we could not have this degree of agility today if it were not for our skilled people. (Litsikas, 1997)

Jackson (2000) points at four main dimensions which are “importance of intellectual capital, increase of knowledge contents in products, information and communication technologies, and a shift in values towards work” as influencing factors to manufacturing industry.

**Information Technology (Virtual Corporation)**

Bill Adams, president of Agile Web Inc, says: We organize the virtual corporation to take advantage of the member companies’ core competencies and we configure our core competencies and capacities to meet the customer needs. (Litsikas, 1997)

In such novel and emerging agile manufacturing paradigm, where multiple firms are supposed to cooperate in a flexible virtual enterprise structure, there would exist a great need for a mechanism to control, monitor and manage information flow among these collaborating partners.

“Information system/technology in its utmost level of timeliness, coverage, communication ability, data banking and interchange, etc., is a major differentiator of an agile manufacturing company compared to traditional systems.” (Sharifi and Zhang, 1999, pp11)

The central concept is a nationwide factory network in which a large base of diversified suppliers will be linked electronically. This network would facilitate concurrent engineering and
manufacturing among corporate partners. Frequent and dynamic interactions among partners in agile manufacturing entail the crucial role of a flexible, dynamic and integrated mechanism to manage partner information flow. (Song and Nagi, 1996)

Song and Nagi (1996) on their paper point at some existing specifications and problems. “In the agile manufacturing environment, however: (1) agile partners have full autonomy, and there is no hierarchical organization in an agile enterprise: partners are autonomic peers. (2) product data and knowledge are distributed across partner sites. (3) existing manufacturing applications and databases lack the desired compatibility and portability due to heterogeneities in partner data models and applications. (4) agile virtual enterprises are product oriented and formed dynamically.” (Song and Nagi, 1996, pp 2)

To resolve such problems, Song and Nagi (1996) project a framework which can share distributed information by partners at different collaborative levels, whereas “inter-database dependencies are maintained dynamically, and the information flowing in/out of a partner is controlled by the management policy of the partner.” (Song and Nagi, 1996, pp 2)

About agile manufacturing information requirements Song and Nagi (1996, pp 3) describe: “In order to support collaborations among product designers, process planners and manufacturing resource planners at various stages of product development, agile manufacturing information systems must possess the following functionalities:

1. Provide consistent information to dispersed partners who are distributed geographically and may use different local data replications or databases. Inconsistent data at different partner sites will lead to product mis-description or even manufacturing chaos. Data constraints representation and maintenance, and data updating concurrency management are essential to provide consistent data.

2. Provide multiple information views to partners. Agile partners are from various domains and perform various tasks in the product development process. Different information views are necessary to support partner collaborations across various domains. It is up to the Agile Manufacturing Information System (AMIS) to provide shared information for partner
collaborations. Representation, manipulation and updating of shared information at multiple views and at multiple working levels are essential.

3. Provide flexible schemes to reflect company-specific policies and procedures. An agile partner in an agile virtual enterprise is dependent and independent. It is dependent in the sense that it cooperates with others to develop products; it is independent in the sense that it has full autonomy in executing its policies. Flexible schemes must be provided so that partners’ autonomy is unaffected in a virtual agile enterprise.

4. Accommodate partner heterogeneity in computer hardware, database systems and applications, which is the reality in virtual enterprises.

5. Provide necessary information security to partners. Cooperation between agile partners is agile and dynamic. Necessary procedures must be provided to ensure individual partner informational securities. For instance, a partner may have limits in retrieving or updating another partner’s data.”

The virtual information system that Song and Nagi (1996) projected has the following features:

“1. Each partner is connected to the network through a Client and a Server. The server is responsible for serving other partners. It receives queries, interacts with the DataBase Management Systems (DBMS) to execute the queries and sends the results back to the inquirer. The client is responsible for coordinating the workflow execution. It sends subqueries to other partners and receives results.

2. The local Workflow Manager (WM) controls the information flow. Based on the query from the user, the workflow manager has to retrieve relevant rules from a Knowledge Base System (KBS), analyze the query, and form workflows to be executed by the client to keep system data consistency.

3. The correct workflow execution is ensured by the cooperation of partner servers and clients. The client at the global workflow initialization site becomes the temporary workflow coordinator.
It uses dynamic Two-Phase-Commit protocol to ensure the workflow execution atomicity.” (Song and Nagi, 1996, pp 4 & 5)

The architecture they offered should have following characteristics:

“1) The system is open and modifiable; a partner can be connected to or disconnected from a joint-venture system.

2) The working partners are fully autonomous; each partner has a stand-alone framework which controls the information exchange between itself and the outside world.

3) When a partner joins a virtual enterprise, its framework becomes a part of the virtual enterprise information management system.

4) By integrating its members’ systems, the enterprise information system manages partner information flow dynamically and consistently.” (Song and Nagi, 1996, pp 5)
Market behaviors time to time necessitate new concepts, tools, ways and technics. In other word: new solutions to emerge for use of firms which need to cope with market’s needs in order to survive in a tight international competition. An example is mass customization which emerged in the late 80’s and very soon many enterprises within manufacturing industry started to strive to get the vision by focusing on flexibility in their manufacturing system. (Ask, 2006)

Short after, many manufacturing theories popped up, derived from different mass customization approaches, to describe theoretical solutions or guidelines for this concept. However, after more than 3 decades, there is still a considerable lack of practical enablers to help practically the realization and implementation of the concept.

Recently, most markets are characterized by fast pace of change, as well as a tight international competition. One of the reactive concepts emerged recently to fulfill such markets needs is “agility” which has been discussed formerly. Like “mass customization”, different investigations and theories have been developed to describe how the best and the most efficient way is to deal with this concept. Although we don’t expect to have some certain enables and strategies in hand as a to-do-list to follow to become agile.

Among what is reviewed as validated theories, suggested approaches and focuses, and recommended enablers and strategies, which any of those leads to a different bunch of ways to become agile, what is highlighted in almost all of them as the same guide point is that: Agile Manufacturing does not necessarily require new equipment, but it does need a certain mindset.

To find out what such a mindset and its components are, many started from or focused on failures and failed systems in implementing the concept. By studying the failure’s factors, root causes, effects and consequences, they’ve come up with a synthesis which in most cases has led to a theory or approach.

For instance, focus on organizational operation is one of the approaches brought up of Gagnon’s (1996 & 1999) investigation through former failures. He says: “Unfortunately, the implementation of best practices has not been as effective as expected at first. As recently as the
mid-1990s, surveys still indicated high failure rates for TQM (Total Quality Management), BAR (Business Process Reengineering), and JIT (Just In Time), ranging as far as 66 percent for TQM (Brown, 1994; Ramarapu et al., 1995; Tippet t and Waits, 1994). This may be indicative of some fundamental flaws in the operations strategy supposed to guide these efforts. Common to all of these failures is one alleged reason, which may have been that too many business leaders would have turned to these best practices for the sake of cure-all solutions, and would reveal fundamental management deficiencies (Gagnon, 1996).

It would have led to a so-called management fad bubble fueled by a complex process of which management consultants make the core (Abrahamson, 1996). This process is often claimed to be an important factor for the lack of operating performance, as it takes management away from the fundamental principles of running an organization and reduces the cognitive capability of the firm within the limited hands of some turnaround doctors (Mintzberg, 1996). In the end, business leaders miss the mark and fail to grasp the fundamental managerial revolutions behind such new approaches (Grant et al., 1994).” (Gagnon, 1999, pp 132)

Gagnon (1999) believes: “operations strategy is the integrator of all change initiatives within the organization, as operations progressively learn how to dominate market rules and create new ones in hyper-competition.” (Gagnon, 1999, pp 133)

He concludes: investment on the organizational infrastructure is both supportive and generative for operating excellence. (Gagnon, 1999, pp 134)

At implementation phase, such failures can happen either because of misinterpretation of the concepts or improperly-used tools or when the contradictions overlap. Even such failures may be inevitable to happen when some probable changes, with a low probability to count into consideration, happen and overlap while the firm is getting agile against a bigger change. Same as the entity of changes, the entity of getting to a proper level of agility is based on probability and there is no certain success or failure per se.

Therefore, practical resolutions should be applied on such point of effectiveness as a trial and error, and through a systematic problem-solving process. For example, when agile concurrent
engineering is contrasted with the existent Concurrent Engineering (CE), Allied Concurrent Engineering (ACE) can put the problems of resource sharing into special consideration. Its realization requires as little as possible reform of the current organizational structures of enterprises. Additionally, ACE is more applicable to the product development in firms, especially in medium-sized or small companies.

“In a seminal paper on strategy, Skinner (1969) discusses trade-offs, which occur in competitive priorities. For example, in the design and operation of a production system, Skinner suggests there are trade-offs in such variables as cost, time, quality, technological constraints and customer satisfaction. The premise of Skinner’s “the focused factory” (1974) argues that factories attempt to perform too many conflicting production tasks within one inconsistent set of manufacturing objectives. Part of his findings in working with a number of plants in various industries was a “factory cannot perform well on every yardstick”. Namely, there are performance trade-offs, which must be compromised to meet several goals simultaneously.” (Vokurka and Fliedner, 1998, pp 167)

In 1986 “Nakane (1986) suggests a cumulative type of model for the attainment of strategic objectives and capabilities. Specifically, he suggests that a definite order exists for the pursuit and attainment of these objectives consisting of: 1) quality; 2) dependability; 3) cost efficiency; and 4) flexibility.” He claims, “if this suggested order of pursuit is not followed, a chaos condition and failure will likely result” and “each of these capabilities, beginning with quality is a precondition for the successful attainment of the successive objective. Ferdows et al. (1986) and De Meyer et al. (1989) further document Nakane’s model.” (Vokurka and Fliedner, 1998, pp 168)

These primary efforts show the initial tries to consider probability of change or the capability to react properly to such change. Still to implement agility in practice, some enterprises prefer to start with such trial and errors by command-and-control strategy. But others prefer to initiate customized practical strategies, techniques and tools with regards to certain changes that even they may plan for those. Some examples come as follow.

Quinn et al. (1997) define agile manufacturing as “the ability to accomplish rapid changeover from the assembly of one product to the assembly of a different product.” Based on this
definition they argue a practice for agile manufacturing workcell implementation on which “rapid hardware changeover is made possible through the use of robots, flexible part feeders, modular grippers, and modular assembly hardware. The devision of assembly, feeding and unloading tasks between multiple robots is examined with perioritization based upon assembly time. Rapid software changeover will be facilitatated by the use of a real-time, object-oriented software environment utilizing graphical simulations for off-line software development. And innovative dual [Virtual Manufacturing Enterprise] VME bus controller architecture permits an open software environment while accomodating the closed nature of most commercial robot controllers. These agile features permit new products to be introduced with minimal downtime and system reconfiguration.” (Quinn et al., 1997, pp 901)

One of the presented enabling strategies for implementation of agility is CALS. CALS (continuous acquisition and life-cycle support) strategy “was originated in the American military in 1985”. As a strategy for an organization, enabling it toward an agile management system, CALS strategy enables and makes an enterprise easier to become agile through building a “digitized product life-cycle supporting environment.” (Lyu, 1999, pp 41)

“A report in the UK states: CALS enables major business processes improvements, such as concurrent engineering, to happen, and when these improvements are applied across the supply chain and through the product life cycle, the virtual enterprise can become a reality. Based on the statements above, apparently, the CALS strategy builds a solid foundation for an agile enterprise to become realistic.” (Lyu, 1999, pp 42)

“CALS, or commercial CALS, can be defined as a strategy that supports enterprise efforts to transit from paper-intensive processes to highly automated, integrated processes for product marketing, design, manufacturing, and life-cycle support. Based on this definition, CALS includes some key elements as follows: process improvement, adopting international standards, creating a shared information environment.” (Lyu, 1999, pp 42)

Lyu (1999) recommends tactics for successful implementation of CALS. He believes “an enabling strategy to achieve agility of an enterprise is to build the effective linking of all the key stages throughout the life cycle of a product or a project, even when the products or projects are
completed by complex supply chains. This strategy is called CALS and has been widely embraced by many countries, treating it as their national strategy.” (Lyu, 1999, pp 43)

He summarizes the characteristics of the CALS strategy and identifies the key elements of it. In his paper, also the possible barriers in the implementation of CALS are described and the possible tactics are also provided. He claims “if an enterprise or a country can apply the CALS strategy successfully, it is more likely that the enterprise or the manufacturing industry in that country can have greater agility, which certainly results in higher competitive advantage in the next millennium. So, whether CALS-compliance is to be or not to be is not such a hard question to answer.” (Lyu, 1999, pp 44)

Another functional strategy for agility practices is benchmarking. “Benchmarking is a business practice that will aid in the study, refinement, and application of agility principles.” (Sarkis, 2001, pp 88)

Sarkis (2001, pp 88) focuses on two issues: benchmarking agile environments and agile benchmarking requirements. In his paper benchmarking process, tools and metrics issues are discussed within the perspective of agility requirements. He believes “the process, tools and metrics discussion allows for a simultaneous study of the two major issues in integrating benchmarking and agility.”

Sarkis (2001, pp 91) defines a number of potential directions and enablers based on current practice and emerging mechanisms for agility and benchmarking. He believes “benchmarking is a total quality management (TQM)/reengineering/continuous improvement technique brought to the forefront in the last few years.” He reviews previous studies and present that “the benchmarking process has a number of levels that can be used in the analysis of an organization. These include (Camp, 1989):

(1) Internal benchmarking - benchmarking against internal operations or standards, usually in a multi-division or multinational enterprise.

(2) Industry (or competitive) benchmarking - benchmarking against other companies in the same industry, whether they are direct competitors or not.
(3) Process (or generic) benchmarking - benchmarking generic processes (e.g. order receipt and dispatch process) against best operations or leaders in any industry.

Pozos (1995), presents another category, strategic benchmarking, which is defined as: Proactive analysis of emerging trends, options in markets, processes, technology and distribution that could affect strategic direction and deployment.” (Sarkis, 2001, pp 92)

“Benchmarking for agility can serve a number of purposes, depending on the level of analysis. For example, since agility is a “national vision” concept, the program on agility and its impact may need to be benchmarked against other national manufacturing policy-setting programs that may have been sponsored by private industry or government institutions. Agility can be benchmarked at the industry level and research institution level, to determine how well certain aspects of agility would work in various competitive industries.” (Sarkis, 2001, pp 95)

Sarkis (2001, pp 95&96) believes “whether or not benchmarking, as currently practiced, will be appropriate for agility is an issue that needs to be addressed. At some levels of analysis, traditional approaches, metrics and tools for benchmarking will certainly be applicable to agility. At other levels, i.e. the “virtual” enterprise and forward-looking metrics, traditional approaches to benchmarking may prove inadequate. Additionally, with the lack of a discrete discriminator for agility, benchmarking may take on the role of a characterization and definitional tool, rather than just a tool for managing business improvements.”

Benchmarking, however still counts a helpful strategy, but necessity of customization in agility implementation may affect its effectiveness in most of the cases.

Focusing on flexible manufacturing as a predecessor to agile manufacturing Abdel-Malek et al. (2000) in their paper presents the FMSD method (Formal Methods in System Design) to aid traditional manufacturers, in particular small and medium sized enterprises, in adopting flexible technologies. “The method consists of nine steps that are divided into three phases. The steps are designed to promote and foster innovation in the design process.” (Abdel-Malek et al., 2000, pp 194)
“In the first phase an audit is administered to the manufacturer. The aim is to identify the causes of inflexibility. Then the second phase uses flexibility measures as well as a database to suggest alternative technological solutions. Consequently, the third phase, utilizing a computer-based procedure, compares the affordability and implementation difficulty of these proposed solutions.” (Abdel-Malek et al., 2000, pp 194)


The factory-in-a-box concept has the key characteristic of a modular production unit that is flexible, mobile and quick to ramp up. It is developed, exemplified and realized in some internationally competitive manufacturing companies in Sweden successfully. (Jackson et al., 2008)

The factory-in-a-box concept contains some standardized modules to be installed for example in a container which could be transported by vehicle, for instance train or truck. The modules then can quickly be merged into production system which could be reconfigured and customized for a new product or/and scaled to handle new volumes. Production capacity as a mobile and flexible resource can be rapidly tailored to fit the company’s needs, at a certain time. The stress on mobility of the factory-in-a-box concept is very important however geographic limitations need to be considered. (Jackson et al. 2008)

Ask (2006) investigates if and how the factory-in-a-box concept is an enabler to realize flexibility in manufacturing systems. He identifies some key generic requirements that need to be fulfilled to succeed in implementing the factory-in-a-box concept in a manufacturing system.

Jackson et al. (2008) who practiced the factory-in-a-box concept on some manufacturing enterprises point out: “a factory-in-a-box could be placed close to product development or customers within the distribution chain. A likely scenario is that the factory-in-a-box can be rented or leased from production specialists, i.e. a type of functional sales of production capacity.”
Factory-in-a-box concept counts a functional proper agility practice as it provides solutions for the availability and mobility of flexible production capacity, and its main features such as mobility, flexibility and speed enables agility basics practically.

In practice “the use of standardized production modules provides autonomy and reusability. A factory-in-a-box installed at a company should be integrated with the company’s existing technical production capacity and its present workforce. The intention is to balance automation and manual labor in the factory-in-a-box modules. Thus, each configuration will include e.g. automation requirements, operator staff requirements, configuration simulation modules and case-based experience/knowledge databases.” (Jackson et al., 2008)

On a wider view, Jackson (2000) referring to other researches says: Production as a whole, must be seen as an integrated process that converts materials into goods. In the systems concept, the factory is not a place at all; it is a stage in a process that adds economic value to materials. In theory, at least, the factory cannot and certainly should not be designed, let alone built, until the entire process of “making” – all the way to the final customer – is understood.

The process of structures, strategies, techniques and tools initiation to implement agility as efficiently as possible still is going on based on key concepts and agility principles. Some projected production systems models such as Holonic Manufacturing Systems, Fractal Company, and Bionic Manufacturing Systems intend approaching agility based on modularity and autonomy in practice. Such visionary models should mature as an effective practice for agility implementation.
5-RESULT & ANALYSIS

What is reviewed through last chapters does not formulate a prescription for “how to become agile”. However, reviewing what others have practiced so far, will broaden our view towards potential solutions by providing us with guidelines and visionary steps.

When it comes back to the objectives and problem statement, this paper has considered Sharifi & Zhang’s methodology as a baseline and by developing a supplementary scoring model, it has done a literature review to answer some questions, already highlighted in practical implementation of agility, while generally has narrowed it down into “agile manufacturing”.

5-1 WHEN TO TAKE ACTION?

Agility for an organization has been defined as an ability, capability and potency of being agile, meaning quickly reacting to changes in an efficient way. In other word, it counts an attribute of an organization to be agile enough. No doubt the realization of when and how to react depends on capability of the designed infrastructure and implemented enablers, but still agility is a dynamic concept so that it always depends on approaches and strategies to take (and concepts to focuses on) at different situations.

Consequently, “when we really need to start becoming agile”, is a basic question which its answer may be so essential for stakeholders and decision makers to allocate resources and budget. Although the answer will never be a clearly digitalized one, but based on qualitative investigations, we can formulate the behavior of an organization in confrontation with change by bringing the main variables into a simple mathematical function. Such a function is described in a sub-model, developed here based on previous theories and models.

The sub-model which is developed in this paper for agility need level is standing on the basic concepts which are focused by Sharifi and Zhang (1999). Although in this model, their steps one, two and three (described in section 3-1) are almost combined to form a chart representing where on Agility Field the company stands. For instance, changes detected and recognized as agility derivers listed in first step of their methodology map, and, the method of realizing them is the same which will be used in this extended model as well. However, the probability of these
changes’ occurrence and the business, organization, function or process which is affected by each change is considered separately, i.e. related indicators are defined individually for each entity affected by the change.

This sub-model tries to describe Agility need level as interaction of two concepts: severity of the change and the company’s (or sub-organizations’/sub-functions’) readiness to reflect quickly and efficiently to that change. The first with an external nature (however initiated internally) and so, uncertain to happen (to happen based on probabilities) and the latter containing internal factors which mostly are under control however qualitative to measure and even sometimes comparative.

For such model, a time frame is needed, limited to a determined period of time, in which these two concepts and their interaction are more tangible to be measured and possible to be studied in detailed characteristics; and obviously the shorter the period is, the more precise measures are obtained. Changes recognized and listed in first step of Sharifi and Zhang’s model, their probability of occurrence, and their severity, also need to be limited to the same period of time i.e. they have to be probable to happen only in the same time interval.

If the determined time period is not reasonable and short enough, the model needs to consider the speed of change as well, which can be effective on agility need level and consequently on enablers and design. Speed of the change is a variable which is not considered in the scope of this paper and all changes are assumed to be happened at once and not gradually.

In this model, the two mentioned concepts are simulated mathematically in functions which are defined by measurable variables. The two functions are defined as below:

- **Probable Effect Severity (PES)** which is per se an indicator for severity of the change and in fact its effect’s severity.
- **Readiness (R)** which is per se an indicator for the entity’s (business, organization, function, process, or any other entity affected by the change) ability and capability to respond properly to the change.
PES (Probable Effect Severity) is a score function defined for each change separately and generated by four variables and three indexes: (changes are already recognized and tabled as per methodology map's first step instruction, method offered by Sharifi and Zhang (1999)).

\[ \text{PES}(ijk) = p(i) \times m(ij) \times s \times q(k) \]

Where,

\( p; \) Probability of the change\((i)\) occurrence in a fixed time period

\( m; \) weight of the entity/function/process on which the change\((i)\) will affect (constant for entity\((j)\), (ranging from 0 to 5)

\( s; \) severity score implies how tense does the change effect on the entity/function/process (ranging from 0 to 5)

\( q; \) probability of the severity\((k)\) occurrence

\( i; \) index for changes (ranging from 1 to the number of changes recognized and effecting on entities/functions/processes)

\( j; \) index for entities/functions/processes (ranging from 1 to the number of entities/functions/processes being affected by changes)

\( k; \) index for severity scores (ranging from 0 to 5)

Based on the above parameters, PES would vary between 0 and 25.

For Readiness, variables to define the function are mostly the same that Sharifi and Zhang (1999) specify in third step of their methodology map as the main capabilities (characteristics). They believe agility is recognized in the scope of an entity by these main capabilities and indicate them as responsiveness, competency, flexibility, and speed/quickness.

For different case studies, this model also adds variables or brings some sub-items of the main headings/capabilities above, such as competitiveness or stamina (with the same method of
scoring) to the main variables effecting on the readiness score. The readiness score for entity j is brought up of all these variables determined and scored for entity j. The methods applied by Sharifi and Zhang (1999) is applicable to define and score this factor, however in further studies, some pre-initiated ideas will be improved and developed as more suitable methods for this sub-model.

Agility Field, offered by this model, is a chart (Fig. 2.) which is defined by the two concepts described above and their mathematical functioning simulation as its axis: Probable Effect Severity (PES) and Readiness (R). The area defined by these two concepts/axis on the chart can be divided to four zones each one representing the status of agility need level for a specific change effecting on a specific entity/function/process.

This evaluation based on the scoring models is an assessment which needs to be run periodically. So, as already said, all factors and variables are defined for an interval, in order to be more tangible and arguable in terms of the market and environment turbulences.

Agility Field is a simple tool to facilitate the primary stage of current agility status analysis. It shows where (and with which level of agility) a company or an entity (organization, function or process) stands in terms of a probable change with a probable severity which will happen in a certain period of time.

Of course, strategic priorities also are effective to define urgency and necessity level of becoming agile or agiler.
In Agility Forum Patterson says: “you cannot recognize overnight. That is tantamount to suicide.” He suggested prioritizing what needs to be done first and focusing on one or two areas that will “leapfrog” the company forward. (Litsikas, 1997)

Agility Field model is a simple helpful tool for an estimation of time to start implementation of agility or to speed up the ongoing process of becoming agile. However, variables such as the type of change (the industrial area change happens), severity of change, and the probability of each, can indicate when is the best time to take action or speed up the ongoing process of implementation.

5-2 HOW TO THINK ABOUT IT?

When an organization is standing on the red area in Agility field model, Fig.2 (Page 66), it’s time to start becoming agile (or agiler). But to look at the Agility concept and customize it to an
applicable practice in the organization, it’s important to take a perspective or approach fitting the industry and its characteristics.

Table 1 (Page 35) contains most of the common approaches used in Agility researches. This table can help organizations to find the best match according to their organizational culture, top strategies, organizational priorities and speed/severity of the change and turbulence of the competition in the market around.

By using this tool (table 1), based on the approach/s an organization takes, it’s automatically linked to the area/s or concept/s it needs to focus on. The best match/s in focus area/concept, will be found based on the production type, complexity of the technology/ies being used, and the existing infrastructure in the company.

By taking the best match/s from the focus area/concept column in the referred table, the thoughts and ideas are narrowed down to a few approaches and focus areas/concepts which will fit the organization and will shape a guideline for further steps.

Although, the table is sorted by the year in which the theory/paper was presented, by browsing the ideas in a glance, it’s obvious that most of the open-minded, innovative and pioneer organizations which put priority on people, innovation, technology and partnership, will pick up approaches such as numbers 5 (Gupta and Nagi, 1995), 9 (Adamides, 1996), 14 (Sharifi and Zhang, 1999), 15 (Gunasekaren and Yusuf et al., 1999), 17 (Gunasekaren and Yusuf, 2002) and 18 (Dahmardeh and Banihashemi, 2010) to start their long journey towards agility. However, other approaches listed in this tale still are valid scientifically and maybe picked up by any organization either open-minded and innovative or conventional and conservative.

On the other hand, for an organization, what shapes the overview of the path towards agility is: the level of agility which is needed against determined change/s and the level of agility at the moment (defined through some scores and metrics), analysis of the gap between these two levels and defining proper design, containing proper strategies and enablers, providing advantages to fill out such gap.
Such gap-analysis can be performed for each focus area/concept which is corresponding the approach taken by the organization, from the Table 1 (Page 35). But the outcome of such analysis shows us what exactly an organization is lacking to fill out the gap or in other word, what advantage/s will fill out the gap properly. Such advantage/s in Table 2 (Page 45), are specified as “advantageous output” taken from the proper design.

The “advantageous output” column in the table 2 (Page 45) links us to corresponding design from most of the “design” patterns introduced so far. So, the Advantage/s lacking to fill out an agility gap, will lead an organization to a recommended pattern for further sustainable design and support.

Later on, such design will contain all related enablers and strategies needed to provide the organization with the best practice. However, corresponding to the selected approach and focus area/concept, the same table, Table 1 (Page 35) offers a bunch of enablers and strategies matching and supporting the approach (based on the scope of research and theory presented by the writer and extracted from the entire literature review), but there may be more enablers and strategies for each focus area/concept (or a combination of current ones) which can be presented and discussed according to previous practices or extended theories.

Now, the organization who has come with us step by step knows how to think about agility, how to use the sub-model presented in section 5-1 to find out if it needs to get agile/er at all, how to see itself in the industry and market it wants to survive, how to use the tables provided in this paper, how to find the best approach from the table 1 (page 35), how to narrow down to the best focus areas/concepts through the same table, how to analyze the agility gap for the focus area/concept using Sharifi & Zhang model (1999, page 22), how to find the best advantage to fill out the gap by using table 2, how to be linked to the best sustainable design to provide proper support to take the needed advantage/s, and how to find the best offered enabler/s and strategy/ies by a flash-back to the same table 1, corresponding the focus areas/concepts and approach picked up.
By such a start, the organization is standing at a point to see what to do with things in hand: in one hand, a few design options, and on the other hand, a bunch of recommended/related enablers and strategies.

5-3 WHAT TO THINK OF?

Methodology to become agile presented by Sharifi and Zhang 1999, and their scoring model for determining agility need level (Fig. 1. Sharifi and Zhang 1999, Page 22) is offering a bunch of general factors to think about before starting to become agile and in gap-analysis phase.

Also, in each step described in section 5-2, what an organization needs to think about is defined, addressed and offered.

But now, the main step is to use what is in hand as the output of the process described in section 5-2: in one hand, a few design options, and on the other hand, a bunch of recommended/related enablers and strategies.

A try-out of which design can contain which enablers and strategies, and to find the best customized match, is what an organization needs to think about at this step.

Later, in future study section, we will point at the further possible investigations regarding computerizing even the process of becoming agile, and there, possibility of programming a software for such try-out will be seen closely. But now, such try-out counts very specific for each organization and manufacturing line, and lots of potentials should be considered to pick up the best sustainable design containing the best enablers and strategies.

Although, the tables 1 and 2 containing the agility basic info are just extractions from the literature review scope of this paper and are not containing all theories and hypothesis regarding agility in the world! And they are not verses from the heaven, fixed and rigid! Therefore, for cases (organizations) which have an approach or focus area/concept outside the table 1, or cannot find the advantage/s they need to fill out their agility gap through the table 2, the tables simply can count as a guideline to invent their customized hypothesis and expand the table accordingly.
The sub-model and tables offered in this paper as references, function as a process map or a methodology for taking practical steps towards becoming agile. So, what an organization needs to think about at this step, is just if it can find the best design and enablers through references offered here or not. If yes, based on the writer and year of the theory issuance, end section in this paper, can help them to find out more details about the paper and the theory. If not, they can take the closest design theory and try to expand enablers and strategies or combine some current ones and make a customized set based on what is applicable for their organization. Another suggestion for the latter group is to take the best enablers and strategies based on their best fit with their organization and try to customize the design by getting guideline from the closest offered theories.

Tools to apply intended strategies and enablers, design of the lay-out and arrangement (location wise for the hardware and sequence wise for the process), systems to implement and to keep the sustainability are all what are needed to think about in further steps.

Analysis and reports can be input for or output from any of above factors to help for further steps, and so worth of thinking as well.

5-4 WHAT IS THE START-POINT?

As described before, the start-point to think about agility is to check if it’s really a need to become agile/er. For this purpose, a sub-model was developed and presented in Fig. 2. (Page 66).

Coming further, to find the best way for agility practice in the organization, the start-point is to find the best matching approach and focus area/concept in addition to perform gap analysis. In this respect, still the “methodology to become agile” presented by Sharifi and Zhang 1999, and their scoring model for determining agility need level (Fig. 1. Sharifi and Zhang 1999, Page 22) are the best pattern.

Also, before starting agility practice, it’s wise to define, discuss and invent any other tools and models that can help to determine the exact variables in any customized Agility trend.
But when it comes to the start-point for agility implementation, as long as the affecting factors are recognized, the need level of agility is determined, current level of agility is indicated and measured, the gap is analyzed and lacking factors are identified, the strategies and enabling factors are found, and the steps of implementation is defined in a proper design, becoming agile (or agiler) can be considered/defined as a “project” with a start-time, finish-time and a set of goals, based on different desired levels of agility.

Through such perspective, the agility project will have a life cycle of 5 steps (according to PMBOK, Project Management Body of Knowledge, the international standards and guidelines for Project Management, issued by PMI, the international Project Management Institute): initiation, planning, execution, control, and closure.

Agility as a project, will be designed at initiation phase. Its feasibility study should be performed, the project team should be formed, budget should be estimated, data-flow should be designed, and processes/departments which are involved should be detected at the same phase.

At planning phase, which is the most important phase in each project, WBS (Work Breakdown Structures) for the project is made, a reasonable time frame is allocated to activities, and the critical path is detected. At the same phase, resource allocation and resource leveling is planned, risk assessment is performed, and mitigation plans are made, financial plan and quality plan is made, procurement plan and contract with suppliers are made, stake-holders are identified, and report frequency and channels are explained likewise.

At Execution phase and control phase, time management, cost management and control, quality management, change management and control, risk management, procurement management and communication management should be systematically performed. Like in product and system development in which a design results in a specific set of product requirements, the convergence is measured by prototypes, tests, and reviews.

The Closure phase typically is known and highlighted by a formal written “project review report” which includes the elements as follow: a formal acceptance of the final product/service/system (by the client which can be internal or external), Weighted Critical Measurements (what
compared to the initial requirements is laid out by the client against the final delivered product), lessons learned, project consumed resources, and a formal project closure notification to higher management. Review, complete and archive all the project’s documents also is performed at this phase.

Luckily, modern technology has provided a variety of templates which takes an organization from start-to-finish and makes the entire project management cycle much user-friendly, no matter what the level of management experience may be.

5-5 WHAT ARE TOOLS, TECHNIQUES AND STRATEGIES?

As said before, to implement agility in practice, some enterprises still prefer step into some trial and errors by command-and-control strategy. But there are some others who prefer to initiate some new customized practical strategies, techniques and tools dealing with certain changes.

One step deeper, where the foundation is spotlight, even infrastructural tools, techniques and strategies are invented, developed and established to provide the different phases of agility implementation with proper data input and more flexibility. As a complete apparatus, such analytical tools, preparatory techniques and operative strategies normally should be customizable and may be a bundle of merged enablers which are already defined to implement and support the agility.

It is helpful to remind what was said once before: among what is reviewed as validated theories, suggested approaches and focuses, and recommended enablers and strategies, which any of those leads to a different bunch of ways to become agile, what is highlighted in almost all of them as the same guide point is that: Agile Manufacturing does not necessarily require new equipment, but it does need a certain mindset.

Such mindset in practice brings in infrastructural enablers, i.e. enablers which empower the infrastructure to ease provision of agility and implementation of agility enablers.

Gagnon believes: investment on the *organizational infrastructure* is both supportive and generative for operating excellence. (Gagnon, 1999, pp 134)
Although tools, techniques and strategies which count enablers for infrastructure are much newer concepts in agility arena, still known decision models such as OR (Operation Research) or multiple attribute decision making (MADM) process, are valid enough to be utilized as infrastructural enablers.

Concepts such as “Distributed Manufacturing”, also known as distributed production, cloud producing and local manufacturing, could count one of those inventive infrastructural strategies which offers its own tools and techniques. Distributed manufacturing, as a form of decentralized manufacturing, in a network of geographically dispersed facilities which are normally coordinated using information technology, increases the organizational reconfigurability based on distributed location of modules.

Although strategic management for distributed manufacturing is much more complex and risk assessment for such strategy should be performed in very high level, especially for those which are distributed between different countries and different political districts, still geographically distributed modules and facilities enable the organization to response differently to the same change/s and like different arms of a robot, take different scenarios and utilize different tools, techniques and strategies by ability of reconfiguring faster than the whole organization.

“Factory-in-a-box” is another infrastructural enabler concept, presented by Jackson et al., 2008, which has the key characteristic of a modular production unit that is flexible, mobile and quick to ramp up, and consequently needs to utilize tools and techniques which are complying its specifications.

The factory-in-a-box concept contains some standardized modules to be installed for example in a container which could be transported by vehicle, for instance train or truck. The modules then can quickly be merged into production system which could be reconfigured and customized for a new product or/and scaled to handle new volumes. Production capacity as a mobile and flexible resource can be rapidly tailored to fit the company’s needs, at a certain time. The stress on mobility of the factory-in-a-box concept is very important however geographic limitations need to be considered as well.
As it was mentioned before, Jackson (2000) believes: Production as a whole, must be seen as an integrated process that converts materials into goods. In the systems concept, the factory is not a place at all; it is a stage in a process that adds economic value to materials. In theory, at least, the factory cannot and certainly should not be designed, let alone built, until the entire process of “making” – all the way to the final customer – is understood.

Some projected production systems models such as Holonic Manufacturing Systems, Fractal Company, and Bionic Manufacturing Systems also intend to approach agility based on modularity and autonomy in practice.

Another infrastructural concept which can supports agility concept in implementation phase is Plant Simulation. Plant Simulation is a computer application for modelling, simulating, analysing, visualizing and optimizing production systems and processes, the flow of materials and logistic operations.

Applications such as Tecnomatix Plant Simulation, by simulating the production process, enable an organization to analyse the production status, plan and optimize material flow, resource utilization and logistics at different levels from global production facilities to local plants and even just a specific line. Features such as Experiment Management allows the organization to compare complex production alternative scenarios, and try out different production strategies, designs and enablers as well as tools and techniques derived out of (or offered by) selected enablers.

Plant Simulation can be used by individual production planners as well as by multi-national enterprises, primarily to strategically plan layout, control logic and dimensions of large, complex production investments.

Combination of Plant Simulation and Virtual Reality could count a revolution in production and manufacturing engineering. Virtual Reality is a computer technology that can simulate a user’s physical presence in a virtual or imaginary environment by generating realistic images, sounds and other sensations. A person using virtual reality equipment is able to "look around" the artificial world of the factory (production environment) and move around in it and interact with virtual features or items.
As another infrastructural strategy, in an agile manufacturing workcell design, the innovative dual VME (Virtual Machine Environment) bus controller architecture permits an open software environment while accommodated the closed nature of most commercial robot controllers.

At such design, rapid software changeover is being facilitated by the use of a real-time, object-oriented software environment, modular software, graphical simulations for off-line software development, and an innovative dual VMEbus controller architecture presented by Quinn et al., 1997.

Robots, flexible part feeders, modular grippers, and modular assembly hardware are some effective enablers that depending on the phase of agility implementation, can count as infrastructural enablers.

CALS (Computer Aided Logistics Support) strategy, presented by Lyu in 1999, also enables and makes an enterprise easier to become agile through building a “digitized product life-cycle supporting environment.”

CALS is a business strategy which uses digital data to enable better and more efficient product development, business transactions, and business management. By CALS, business processes are reformed and standardized based on international standards.

Another functional strategy for agility practices is benchmarking. Benchmarking counts as a business practice which supports the study, refinement, and application of agility principles.

By such infrastructural enablers, we will be always agile to change the process of becoming agile, strategies and designs over time when it necessitates. However, they never are limited to what is mentioned and described above, and always new methods, techniques and approaches could be invented, developed and customized according to needs. At different case studies, any of factors and variables could be spotlight and focused by more influence or probability or severity they have, while at other occasions they may be less focused or totally ignored.
Furthermore, time restrictions at quick changes, cost restrictions at tight finance situations, quality/technology restrictions and specifications of the product, legal restrictions or partner restrictions at any time, etc. may cause the strategy or approach to vary remarkably.

Therefore, there is a loop of strategic decision making for infrastructural enablers and agility enablers, and consequently tools, techniques and strategies are defined differently in various scenarios.

5-6 WHAT ABOUT ALTERNATIVES (DIFFERENT SCENARIOS)?

Agility is a concept that cannot be squeezed in a limited certain definition and specification-borders. Consequently, scenario of how-to-become-agile can’t be formulated into a clear prescription or a step-by-step instruction. Even if somewhere by theories or papers it shows the same route for two or more cases, how-to-become-agile varies practically according to the industry, type of change, probability, severity, current status of the department or organization, in-time restrictions and possibilities, preferred infrastructural enabler tool.

Also, how-to-become-agile process may need to be agile itself, to response properly to changes alongside the implementation timeline. It may vary during the time of implementation if the type of change, the severity or probability changes. So, the ideal how-to-become-agile process should think and bring such provision and consideration into account.

Different tools (infrastructural enabler) offer different possibilities to define alternative scenarios and consequently ways to evaluate those. For example, as mentioned before, Plant Simulation tool has a feature called Experiment Management. By such feature we can design, run and evaluate different possible scenarios based on the input data and our criteria.

But this paper believes that how-to-become-agile problem/question, structure wise, could always be formulated into an OR (Operation Research) problem. Then restrictions and assumptions, as an output of analysis phase, can be input for the problem and lead it to an optimized answer in time. Such claim is easy to be validated based on the nature of the problem, however to narrow down this paper to its objectives, such validation and detailed description will be left up to further studies.
There could be different level of breakdown for the processes when it comes to investigation among alternative scenarios. Such level of breakdown can be defined based on the need and the tool precision. But, this paper believes the best level of breakdown of a process to evaluate different scenarios is “operation” level.

Counting operations as micro-processes or the tiniest part of a process which still has the nature of a process, an organization may think that a kind of micro-management at such level of details is inevitable. Such assumption may seem to be a bit scary, time consuming and costly to most of the managers. But by narrowing down the scenario/s being experimented to the area/process which are more problematic or detected by analyzing tools as a point to improve, a temporary micromanagement can be implemented at such detailed level on a limited domain and affordable cost.

By breaking down the process to high level of operations at least, an organization can have flexibility to play with alternative scenarios and even revise a process by nature if necessary. Such necessity will be revealed during the analysis, evaluation or even sometimes validation of the scenario if it goes that far.

“Operations strategy is the integrator of all change initiatives within the organization, as operations progressively learn how to dominate market rules and create new ones in hyper-competition” (Gagnon, 1999, pp 133). As mentioned before, he concludes: investment on the organizational infrastructure is both supportive and generative for operating excellence. (Gagnon, 1999, pp 134)

5-7 HOW TO ACT (STEP INTO ACTION)?

Now that it comes to action, it’s better to review practical steps one by one.

Based on above descriptions, the best is to define the process of how-to-become-agile as a modular process itself, to let it agile enough, flexible to change the path, strategy and requirements based on necessities at any time.
Aligned with the mindset, the infrastructural strategy is planned based on the data analysis, selected designs and tools which are the outcome of previous phases and predecessor for all further activities. So, scope of the project and the framework for activities are already defined.

Strengthen effective weak-points is a good start to step in if the effect can’t be compensated alternatively by other abilities or strong points. Customization fittings should have been designed before execution; otherwise the practice of stationing concepts/tools will face challenges and complications on its way.

When it comes to planning and execution, the WBS (Work Breakdown Structure) which is defined in former phase, will prioritize activities, and successors and predecessors on critical path as well as milestones and deliverables at each phase are detected. Project Management Office will define, manage and control the structure of PM, project team, resource allocation, budgeting, etc. based on PMBOK standards and other principle and methods of a standard Project Management process.

The only difference between a standard PM process and such agility PM process (in higher level the same known Agile PM) is that the latter is dynamic i.e. the schedules, resource lay-out and even WBS itself may change during the life cycle of the project. So, PM phases such as control, monitoring and documentation is much more critical for such projects. Also, a combination of change management, knowledge management and people management is a key factor for such dynamic process, especially in terms of training and using tools and techniques which should be carefully planned and considered in a format of learning curves.

Therefore, it’s much important that the Project Manager is sticking to the final target which is being agile, rather than the structure of the project which is defined at the beginning. S/he needs to have live-communication with decision making committee to change the way as soon as needed, just to keep the process agile and efficient enough. Through such live communication, s/he informs about the need for any change or gets informed about any new change which was not existing or considered from the beginning.
It’s important that what the project manager at such agile process will deliver finally as the product/output, is a fundamental system for the organization which will give it abilities and will form its further behaviors and identity, not a defined product with determined features and dimensions. So, quality of the system should also be defined by dynamic indicators.

Therefore, the Project Manager at such agile processes will not be only a performer, controller and coordinator, but also more a change manager and a system analyzer and designer, who needs to have live communication with main designers as well.

At the phase of budgeting and planning, it’s important not to define an agile project “open”, but “dynamic”. If as an “open” project, restrictions of deadlines, cost limits and quality/scope borders are removed from the scope, while other ongoing production processes and projects which lead to produce the main product are affected anyhow, then no framework will remain to control measures and efficiency of the project. An “open” project for any project else than a small short-term-defined project, normally goes to continues improvement processes arena/category.

But by keeping it “dynamic”, the project will have flexibility to change during the life cycle in a limited triangle of cost, time and scope. A dynamic project is like an OR (operation research) problem which can get optimized during the path at any time and based on strategic priorities. Therefore, it’s important to define such project in a way to affect ongoing production and processes not to stop and just change smoothly, and it’s much easier in a dynamic project.

5-8 HOW LONG DOES IT TAKE?

To-become-agile is a never-ending process, as mentioned earlier, it can count a part of continues improvement projects. But of course, phase to phase it can have a deadline in its project scope. Also depending on urgency, time can affect the scope or vice versa.

By getting agiler, the company may change its place on the Agility Filed Model and so based on new severity and probability of changes, the scope of the project and the time frame may change. It’s common on the Project Delivery path, at any milestones deviations will be evaluated and new deadlines are defined if it makes the life cycle shorter.
Projects defined based on hardware or people, may depend on budget as well and so they’ll be flexible time-wise. But scopes defined based on software, IT & design, may be more plannable through a rough schedule.

5-9 HOW MUCH DOES IT COST?

Breaking down the process of “becoming agile” into several projects, each sub-project varies in terms of cost and expenses imposing to the company. But the quality of the process and the correctness of implementation are very critical to keep the costs of the project within the limits; especially when it comes to infrastructure customization or organizational build-ups, for example distributive modules, factory-in-a-box, Obeya Room.

In such cases, the entity of the company is facing a kind of evolution, so normally wrong implementation is not easily reversible and may lead the company to go on a wrong track for long term.

Also, the company, on its way of such evolution to make up an agile body and mind, is normally more vulnerable against changes. Furthermore, usually a part of the present system is resisting against such evolution and is skeptical to its success and reluctant to support. Therefore, mistakes in practical implementation can lead to provoke misunderstandings and misinterpretations, and so one of the main pillars, i.e. people, will be difficult to be drawn back to the track of support.

It’s recommended to perform a risk management and estimate such risks costs into the overall project cost as well. But generally, a breakdown of costs, which is normally defined at budgeting/initiation phase of a project, for each sub project or even for each milestone, should be defined in a scale that could be estimated realistically enough.

5-10 HOW FAR TO BECOME AGILE?

This question can be answered through “Methodology to become agile” presented by Sharifi and Zhang 1999, and their scoring model for determining agility need level (Fig. 1. Sharifi and Zhang 1999, Page 22). By using Agility Field model (Fig. 2. Page 66), a company can analyze its need level
of agility for specific changes, and accordingly define related projects; or for ongoing processes, to speed up or to slow down.

When the characteristics of the gap between “current level of agility” and “need level of agility” is analyzed, Agility Field model (Fig. 2. Page 66) helps for a specific change not to go long farther than its need. However still agility, as an attribute and a general capability, involves continues improvement and becoming-agile counts an endless process.

Milestones of the Project’s delivery also could be defined in a way to review and revise at each milestone where the company is standing on Agility Field Model.

Always budget limits for a certain project, time limits for a certain change, and scope limits imposed by the solution’s complications, technologies involved, and political or partner restrictions can also affect to stop or extend a project in terms of reaching the agility level it needs.

5-11 HOW TO MEASURE IT (OR ITS EFFICIENCY)?

How to measure agility is itself a topic for a separate study which could not be squeezed into a sub-chapter of this paper. So, at such scale, we could not go through methods, tools and details of different perspective through which each metrics will look at agility.

But as an introduction, we can look briefly at the title of some of these metrics which can be used as a keyword for further studies.

For agility in practice, there are some metrics developed or formulated by qualitative or quantitative measurements. However most of the Project Management metrics, such as OTD (on-time delivery), OBD (on-budget delivery), and quality metrics, are valid and applicable for agility-project cases.

But still some other metrics such as “transparency”, “speed/velocity”, “efficiency”, “chaos report”, “sprint”, or some other predictability metrics such as “iteration” are utilized in different case studies.
Time-to-value metrics is one of those indicators and measuring concepts which reflects the value chain measures specifically and is recently used as an effective indicator to measure agility.

Among metrics which are recently presented and discussed, “Triple T” or Time-To-Transform is also a time metrics which has been recognized as an effective measuring indicator.

Despite the importance of measuring metrics for such important concept in industry since 1991 in that Agility concept was presented for the first time, still there are few studies and papers which have dealt with its measurement, tools and methods. One of those recent one which counts an effort to form “A Comprehensive Agility Measurement Tool (CAMT)”, by Erande and Verma (2008), is trying to measure agility on a scale of 1 to 5 (1 for least agile - 5 for most agile). Although this tool takes only ten enablers being used by agility and so other areas shown as lacking agility. Analytic Hierarchy Process (AHP) is used by this tool which claims it solves “the problem of changing priorities of agility enablers from enterprise to enterprise.”

5-12 HOW TO INTEGRATE, MAINTAIN AND MANAGE IT?

As discussed formerly, implementation of agility elements, enablers and systems can be defined as an individual project characterized by duration and deadline in a limited scope. Although the scope can develop and extend in further steps and phases of a bigger project. While “Agility” concept, based on dynamism of the above definition, has no limit to start from or to end up to.

By finding conceptual and physical connections between agility infrastructural enablers, tools, techniques and strategies with other ongoing projects’ facilitators, agility project can be a sub project of another bigger infrastructural project or integrator of some production sub-projects.

What is important here is that focusing on agility should not lead to forgetting other projects’ targets, scopes and limitations. There is no verse to prove: the more number of projects to bundle together, the more complication! Sometimes combining two or more projects will lead to a simplified overview, integrated budget, levelled resources and more efficient management. But we have to admit that the only complicated phase which needs more attention and precise calculation is “planning” phase. By a proper planning, the more projects with interfaces which can be integrated into one, the better, both cost wise, time wise and resource wise.
Such aim can only happen through a holistic mind and a proper tool used by trained and skilled operators. Tools such as Primavera Professional Project Management Software is an effective planning tool used for high-performance project management. It can handle large-scale, highly sophisticated and multifaceted projects. It has ability to organize projects of up to 100,000 activities with unlimited resources and an unlimited number of target plans.

Regardless that where on the Agility Field model (Fig. 2. Page 66) the organization is standing, as mentioned before taking action to become agile or agiler can count as a part of continues improvement project; so organizationally categorized in Quality Management System and Production wise, applied by Manufacturing Engineering.

Agility, also as a critical concept for the current market, is to be monitored, measured, audited and evaluated continually and periodically; each time with an action plan for improving or keeping the level. Such analysis shall be handled by a group of experts including production and manufacturing engineers, to comment on manufacturing technologies, sequencing, capacity, layout, people strategies, IT infrastructures, tools and machineries, etc. while they’re trained to apply agility tools and techniques effectively. Also, the expert group shall have been including organizational leaders and QA managers for quick and basic decision making.

The group has to supervise and analyze continually the status, potential external and internal changes, trend of changes, probabilities, weak-points and potential points to improve, and other factors and variables defining the level of agility and level of the need to be agile.

To equip the group by tools, reports and up-to-date knowledge (gained by trainings or benchmarking) a fundamental knowledge management and people management seems necessary. No need to emphasize on comprehensive trainings when it comes to professional tools, applications and high-tech device.

5-13 HOW TO MAKE IT SUSTAINABLE?

At section 3 of chapter 3, DESIGN, SUPPORT AND SUSTAINABILITY, some approaches are reviewed which help to think of a proper design and layout of agility elements to ensure its sustainability and to keep alive those competitive advantages derived from a flexible body.
Approaches referred to, such as Kusiak 1998, Gagnon 1999, Varnedat 1999, Browne and Zhang 1999 and Christopher and Towill 2001, by focusing respectively on Modular System Design, Operation Management, Enterprise Integration, Total Product Value Chain, and Agile Supply Chain, have described advantageous output which can lead an agile design to a sustainable structure. (See Table 2, page 45)

This topic is not studied more detailed at this brief literature review, but some openings to this topic is discussed under other topics such as infrastructural enablers which most of them provide the organization with production analyzers and methods to design the best possibility at time.

In some cases, even the importance is highlighted, and related strategies or system designs are reviewed in detail by introducing enablers and supporters.

Also, at the next sub-section, “How to update/upgrade it”, it’s pointed out how to monitor agility in an organization to keep the level of agility under control continually and keep To-Become-Agile process itself agile forever.

5-14 HOW TO UPDATE/UPGRADE IT?

Agility concept as a part of continues improvement trend, should have been under continual monitoring and maintenance. However, it can be updated or upgraded in different occasions when an immediate change necessitates or when the technology applied into the agility system is upgraded. Similar occasions are when IT tools, design concepts or people knowledge are upgraded.

By monitoring the level of agility through the Agility Field Model, we can keep the level of agility and upcoming or probable changes under control.

Therefore, anytime an upgrade is needed, or probable to be needed, through a quick gap analysis an organization can step into a calculation/estimation by answering the questions presented at this paper as Problem Statement. Combination of answers to such questions, using the methodologies described at this paper as Result and Analysis, could be the main guideline to upgrade agility and stand updated all the time.
6-SUMMARY & CONCLUSION

To survive in the turbulent competitive environment and to successfully develop and implement the next generation of products and services, industries should be successful in generating new strategic and systematic ideas as well as having the ability to quickly realize these into successful products and competitive production systems.

As either researchers described, or experience told us, business was used to be like a game such as chess. Moves often were better to be slow enough and calculated. Before making a move, you had to spend a lot of time to think. But today, business is turned into be more like a video game. An enterprise does not know when or where from the competition will come through or how the competitors may attack. These days, time is too short to make proper decisions quickly or to make the best strategy work out properly.

No doubt the emerging paradigm as a resolution for such situation is agility. Agility is the concept needs to come into practice to response to a growing need for flexible, reconfigurable and responsive manufacturing systems brought up of uncertainty in markets and rapid introduction of new products.

Jackson (2000) looks at the necessity of Agility through a broader perspective. He believes the only point that manufacturing industries need to be aware of is the ongoing and dynamic “change”. Based on such awareness, they can prepare, adapt and develop on proper time. Therefore, at any time, they will be able to anticipate change instead of just reacting to it.

But some others such as Bill Adams, president of Agile Web Inc., does not believe that there is sufficient potential, embedded into such general broad definition for agility, that can lead to make a practical instruction out of it. He believes that being agile, at the first step involves defining core competencies/capacities. On further steps, to reconfigure the business practices will lead to a dynamic organization which is formed within a company.

Although there are lots of contradictory points of view in presenting definitions and practical solutions, still companies who want to acquire abilities of being agile and are trying to become
equipped by its tools, have to set their objectives into a practical framework, and do a kind of engineering based on a dynamic analysis and an advanced customization.

When it comes to practice, Litsikas (1997) points at a keen point: though most of enterprises are not ready for agility and agile manufacturing, and consequently they cannot pass the “readiness” gage, there is another approach, as a kind of weapon in the arsenal, that enterprises can use when they go to compete in the global marketplace. “Times are changing and when that happens everyone go back to zero”. That obviously means that successes belonging to yesterday may be virtually irrelevant tomorrow.

This paper tried to collect different approaches to agility and in particular agile manufacturing systems in a classified way as well as to do synthesis an integrated practical solution in four classified phases: 1) a literature review of agile manufacturing definition, its enablers and strategies, as well as approaches, theories and practices of those who worked on the basics of this concept, 2) offering a methodology to become agile by defining a step-by-step guideline to design, support and sustain an agile manufacturing system, 3) its implementation and practical confrontations by introducing tools and purposefully designed tools, 4) tips for how to keep the organization/manufacturing system agile all the time by monitoring and upgrading as well as by seeing the process of Getting Agile itself as a process to be agile!

Beside a few tools and technics usable in different phases of agility implementation, a new model is introduced in this paper which is developed in format of a mathematical function. The function is defined by some agility factors as its variables, where each factor’s probability is also a variable influencing the function behavior. The illustration of the function plays a helpful role for companies to find out their need level of agility.

Further in this paper, an integrated practical guideline is presented by answering fundamental questions that any company may ask at beginning of Getting Agile journey. To answer these question, many theories, tools, methods, technics and strategies, design principles, and practical ideas are combined.
All approaches, which are addressed in this paper, are converging towards “how to become agile”. The collection of ideas offered through this paper is beyond “what agility is” or “why or where agility is needed”. Through this paper a collective view could be achieved from different researches and papers that “in the long run, their integration into building blocks would allow more diversity and flexibility in operations strategies, and would guarantee that firms are getting the maximum returns from various initiatives”. (Flynn et al., 1995)
7-FURTHER STUDIES

An important step, to be taken by an extended collective approach, is to get a comprehensive picture of the market requirements and opportunities for agile manufacturing systems. A more detailed study among more companies within the engineering manufacturing industry should be executed interactively with other components narrowed in particular market. Some ideas conducted in this paper to implement agility need to be confirmed and validated in practice.

Also, an interesting area for further studies is to develop a decision model for setting up a framework for implementing the agile manufacturing concept. To optimize and upgrade a handful of existing agile enterprises could be interesting and useful.

The model, whose basics are developed and introduced in this paper as a part of methodology to become agile, can be improved in terms of simulation details and measures. It has to be validated in practice however most of the indicators are practically applicable and not restricted to theoretical concepts.

Referring to Jackson’s (2000) believes, there is an ongoing trend to focus on differentiation to achieve competitive advantage among manufacturing industries. “The consequence of this is a growth of knowledge intensive areas within industry.”

From organizational points of view, to study the structure and architecture of an agile enterprise, the interaction between different organizational components/units with a goal of creating a harmonic movement for the whole body of organization should be an important area to cover. Through a close-up, the interaction between the organizational components, the employees, and the technical aspects of the system has big impact on the overall performance, development, and improvement of the system. The hierarchy between manufacturing and production is also important to be discussed.

As this paper claims, how-to-become-agile problem/question can always be formulated into an OR (Operation Research) problem. Then restrictions and assumptions, as an output of analysis phase, can be input for the problem and lead it to an optimized answer in time. Such claim is easy
to be validated, however to narrow down this paper to its objectives, such validation and detailed description is left up to further studies.

“How to measure agility” and proper metrics to measure it, is also an almost untouched arena. Developing some mathematical models and numeric quantitative models can play a very helpful role in providing a tangible sense of what is discussed in this paper.
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