

## **Getting Breakthrough Answers to Difficult Problems: TRIZ and ‘Mass Customization’**

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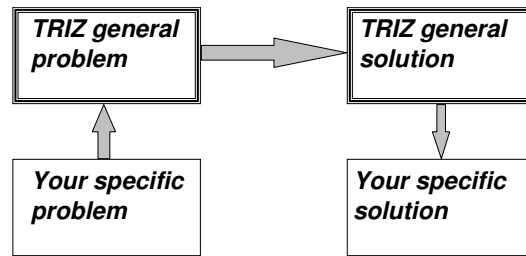
Technical risk is one leading threat to the cost and schedule targets of new product development projects. Whether the “product” is a physical product, a service, a business concept like ‘mass customization’, or a hybrid of these, the technical risks frequently become apparent late in development, when difficulties are encountered with prototypes, with scaling up to production, with developing support services, or in other areas that were difficult to analyze or simulate early in the project.

TRIZ is a problem solving method that accelerates the project team’s ability to solve these risk-creating problems (Tate and Domb 1997). “TRIZ” is the acronym in Russian for “Theory of Inventive Problem Solving.” The method was developed by G. Altshuller and his colleagues from the late 1940’s through the 1980’s in the former USSR. (Altshuller 1988, Salamatov 1999) It is now an international science of creativity that relies on the study of the patterns of problems and solutions, not on the spontaneous creativity of individuals or groups. Over 2.8 million patents have been analyzed to discover the patterns that predict breakthrough solutions to technical problems.

TRIZ research began with the hypothesis that there are universal principles of invention that are the basis for creative innovations that advance technology, and that if these principles could be identified and codified, they could be taught to people to make the process of invention more predictable. The research has proceeded in several stages over the last 50 years. The three primary findings of this research are as follows:

- 1. Problems and solutions were repeated across industries and sciences**
- 2. Patterns of technical evolution were repeated across industries and sciences**
- 3. Innovations used scientific effects outside the field where they were developed**

Much of the practice of TRIZ consists of learning these repeating patterns of problems-solutions and patterns of technical evolution, and methods of using scientific effects, and applying the general TRIZ patterns to the specific situation that confronts the developer. Exhibit 1 describes this process graphically.



**Exhibit 1. The TRIZ problem solving method. The arrows represent transformation from one formulation of the problem or solution to another.**

The “General TRIZ Solutions” referred to in Exhibit 1 have been developed over the course of the 50 years of TRIZ research, and have been organized in many different ways (Domb 1997, 2) (Frenklach, 1998). Some of these are analytic methods, such as

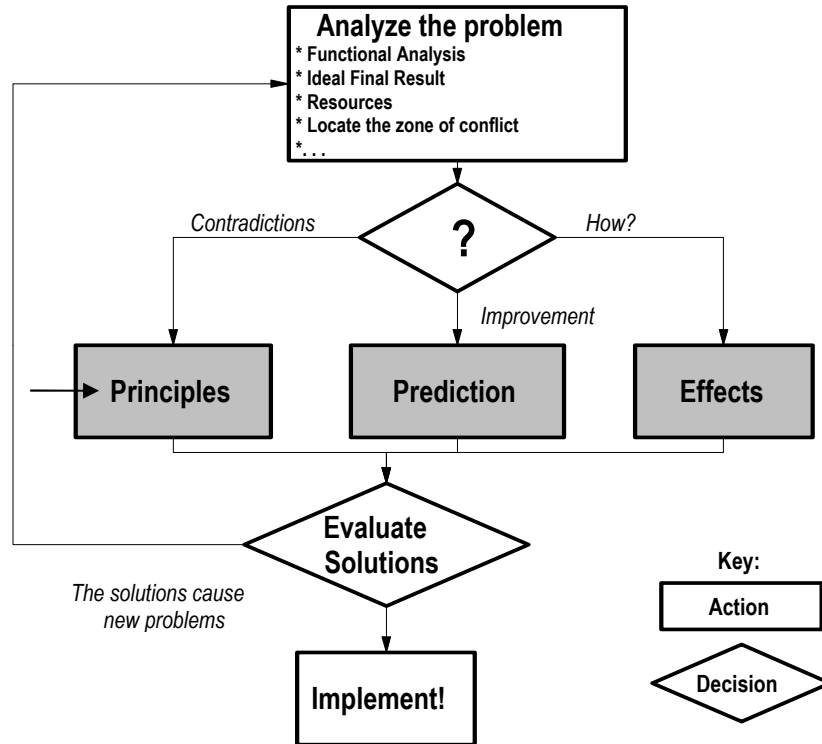
- The Ideal Final Result
- Functional Analysis and Trimming
- Locating the Zones of Conflict

Some are more prescriptive, such as

- The 40 Principles of Problem Solving
- The separation principles
- Su-field models and other models
- Laws of technical evolution and technology forecasting

In the course of solving any one technical problem, one tool or many can be used. A flow chart for problem solving is shown in Exhibit 2.

The 40 Principles of Problem Solving are the most accessible “tool” of TRIZ. (Tate and Domb 1997, Altshuller 1988, Domb 1997, Shulyak 1998) These are the principles that were found to repeat across many fields, as solutions to many general categories of problems. They are used to resolve contradictions, such as those that frequently put new product development projects at risk. (This is the grey box marked → in Exhibit 2.)



**Exhibit 2. Flowchart for the use of some of the tools and techniques of TRIZ**

TRIZ recognizes two categories of contradictions:

•**Technical contradictions** are the classical engineering “trade-offs.” The desired state can’t be reached because something else in the system prevents it. In other words, when something gets better, something else gets worse. Classical examples include

- \* The product gets stronger (good) but the weight increases (bad)
- \* The bandwidth increases (good) but requires more power (bad)
- \* Service is customized to each customer (good) but the service delivery system gets complicated (bad.)
- \* The automobile airbag should deploy very fast, to protect the occupant (good) but the faster it deploys, the more likely it is to injure or kill small people or out of position people (bad)

•**Physical contradictions** are situations where one object has contradictory, opposite requirements. Everyday examples abound:

- \* Surveillance aircraft should fly fast ( to get to the destination) but should fly slowly to collect data directly over the target for long time periods.
- \* Software should be easy to use, but should have many complex features and options.
- \* Coffee should be hot, for enjoyable drinking, but cold, to prevent burning the customer

- \* Training should be thorough and not take any time
- \* The automobile airbag should deploy quickly and slowly.
- \* The automobile airbag should deploy at high threshold and low threshold.

The TRIZ research has identified 40 principles that solve the **Technical contradictions** and four principles of separation that solve the **Physical contradictions**. Many problems can be stated as both physical and technical contradictions. When using the TRIZ research findings, in general the most comprehensive solutions come from using the physical contradiction formulation, and the most prescriptive solutions come from using the technical contradiction. In terms of learning, people usually learn to solve technical contradictions first, since the method is very concrete, then learn to solve physical contradictions, then learn to use both methods interchangeably, depending on the problem.

The TRIZ patent research classified 39 features for technical contradictions. Once a contradiction is expressed in the *technical contradiction* form (the trade-off) the next step is locate the features in the Contradiction Matrix. (Domb 1997, Mann and Domb, 1999) Exhibit 3 shows a piece of the matrix.

	Worsening Feature →	Volume of moving object	Speed	Force (Intensity)	Stress or pressure	Shape	Reliability	Object-generated harmful factors	Ease of operation	Ease of repair	Device complexity	Difficulty of detecting and measuring
	Improving Feature ↓	7	9	10	11	12	27	31	33	34	36	37
9	Speed	7, 29, 34	+	13, 28, 15, 19	6, 18, 38, 40	35, 15, 18, 34	11, 35, 27, 28	2, 24, 35, 21	32, 28, 13, 12	34, 2, 28, 27	10, 28, 4, 34	3, 34, 27, 16
10	Force (Intensity)	15, 9, 12, 37	13, 28, 15, 12	+	18, 21, 11	10, 35, 40, 34	3, 35, 13, 21	13, 3, 36, 24	1, 28, 3, 25	15, 1, 11	26, 35, 10, 18	36, 37, 10, 19
11	Stress or pressure	6, 35, 10	6, 35, 36	36, 35, 21	+	35, 4, 15, 10	10, 13, 19, 35	2, 33, 27, 18	11	2	19, 1, 35	2, 36, 37
12	Shape	14, 4, 15, 22	35, 15, 34, 18	35, 10, 37, 40	34, 15, 10, 14	+	10, 40, 16	35, 1, 16	32, 15, 26	2, 13, 1	16, 29, 1, 28	15, 13, 39
15	Duration of action of moving object	10, 2, 19, 30	3, 35, 5	19, 2, 16	19, 3, 27	14, 26, 28, 25	11, 2, 13	21, 39, 16, 22	12, 27	29, 10, 27	10, 4, 29, 15	19, 29, 39, 35
33	Ease of operation	1, 16, 35, 15	18, 13, 34	28, 13, 35	2, 32, 12	15, 34, 29, 28	17, 27, 8, 40		+	12, 26, 1, 32	32, 26, 12, 17	

**Exhibit 3. Selected rows and columns from the Contradiction Matrix. The numbers in the cell refer to the principles that have the highest probability of resolving the contradiction. A full version of the Matrix can be downloaded from the July 1997 issue of TRIZ Journal, along with articles on the 40 Inventive Principles. The 40 Inventive Management Principles article can be downloaded from the August 1999 issue.**

To use the Matrix, it is necessary to find the row that most closely matches the feature or parameter you are improving in your “trade-off” and the column that most closely matches the feature or parameter that degrades. The cell at the intersection of that row and column will have several numbers. These are the identifying numbers for the Principles of Invention that are most

likely, based on the TRIZ research, to solve the problem: that is, to lead to a *breakthrough* solution instead of a trade-off.

The work of B Joseph Pine II, and his discoveries surrounding the widespread business trend towards 'mass customization' (Pine, 93) offers a very good example of a contradiction-centred family of problems. The principle contradiction in mass customization involves the growing need for organizations to create large output of individual product solutions.

The discussion of TRIZ and Mass Customization here aims to answer three key questions:-

- 1) Is the Contradiction Matrix able to predict or reproduce the contradiction-eliminating solutions identified by Pine in his book?
- 2) Do Pine's solutions have anything to offer the TRIZ problem solving methods?
- 3) Does TRIZ have anything to offer organizations and researchers involved in Mass Customization projects above and beyond the solution strategies found in Pine's book?

Beyond these questions, a final section will examine the Mass Customization phenomenon in relation to a generic pattern of business evolution trends, and establish possible connections with Altshuller's discoveries concerning evolution of technical systems.

## MASS CUSTOMIZATION

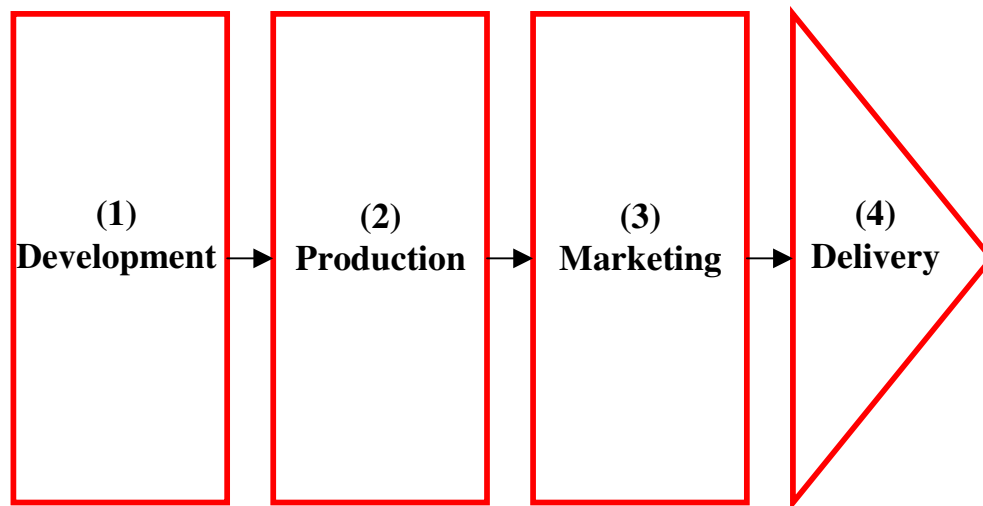
Mass Customization is all about the (economically viable) mass production of individually customized goods and services. In his book, Joe Pine describes five basic methods by which organizations can achieve mass customization:-

- 1) Customization of services around standardized products and services
- 2) Creation of customizable products and services
- 3) Provision of 'point of delivery' customization
- 4) High responsiveness throughout the value chain
- 5) Modularization of components to customize end products and services

Pine also discusses four innovations which further help to eliminate the 'mass' and 'customized' contradiction within an organization:-

- 1) Just-in-time (JIT) delivery
- 2) Reduction of set-up and change-over times
- 3) Reduction of cycle times throughout the value chain
- 4) Production based on *orders* and not *forecasts*

Each of the methods and innovations apply to different stages in what Pine describes as the key links in an organization's value chain (Exhibit 4):



**Exhibit 4: Key Links In An Organization's Value Chain (based on Pine, 93)**

Let us look at each of the methods and innovations from the perspective of their possible connection to TRIZ Inventive Principles.

Mass Customization Principle	Example	Equivalent TRIZ Inventive Principles
Customization of services around standardized products and services (3, 4) – <i>step number in value chain</i>	IBM System/360 Marriott hotel chains Flexible travel packages	(1) Segmentation (3) Local Quality (40) Composite Structures
Customizable products and services (1, 3)	Gillette Sensor razor Reebok Pump shoes Adjustable office furniture	(6) Universality (15) Dynamics (23) Feedback (35) Parameter Changes
'Point of delivery' customization (3, 2 added to 4)	Dealer-fit car accessories Lenscrafters/Eyelab/etc 1 hour photo-processing	(10) Preliminary Action (2) Taking Out (1) Segmentation
High responsiveness throughout the value chain (1, 2, 3, 4)	Benetton Peerless Saw Company Levi Strauss Nissan '3 Day Car'	(15) Dynamics (21) Skipping (38) Boosted Interactions
Modularization of components (1, 2, 3, 4)	Lutron Electronics Black & Decker Getaway Vacations	(5) Merging (17) Another Dimension (10) Preliminary Action (26) Copying
Just-in-time (JIT) delivery	Numerous horizontally integrated industries – e.g. automotive	(20) Continuity of Useful Action (35) Parameter Changes
Reduction of set-up and change-over times	Flexible Manufacturing Systems	(10) Preliminary Action (34) Discarding & Recovering (35) Parameter Changes (12) Equipotentiality (20) Continuity of Useful Action
Reduction of cycle times throughout the value chain	Most 'continuous improvement' initiatives	(15) Dynamics (3) Local Quality (2) Taking Out

Production based on <i>orders not forecasts</i>	Nissan '3 Day Car'	(19) Periodic Action (23) Feedback
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While concentrating only on the 'most likely' Inventive Principles (as opposed to 'all') in each case, it is clear that all of the techniques required to achieve 'Mass Customization' are to be found within the current set of 40 Inventive Principles.

## A TRIZ PERSPECTIVE

Having been derived specifically for use in solving technical problems, the 39 generic parameters which make up the Matrix will, likely as not, require considerable modification in order to be relevant to business-type problems. This modification looks set to require a fairly long and arduous period of research effort. In the meantime, however, 'Mass Customization' offers a contradiction which does appear to fit quite elegantly into the existing Matrix structure.

In TRIZ terms, then, 'Mass Customization' involves the search to improve the ADAPTABILITY & VERSATILITY of a product or service to suit the needs of a particular individual. As adaptability and versatility are improved, PRODUCTIVITY tends to get worse – i.e. as manufacture quantities tend towards one, it becomes progressively more difficult to achieve economically viable production.

According to the Contradiction Matrix, inventors working with technical problems have most commonly used the following Inventive Principles to solve ADAPTABILITY & VERSATILITY versus PRODUCTIVITY problems:-

- (35) Parameter Changes
- (28) Mechanics Substitution
- (6) Universality
- (37) Thermal Expansion

The list bears only occasional resemblance to the table of Inventive Principles suggested from Pine's work. 'Parameter Changes' (or rather the 'change consistency' or 'change degree of flexibility' parts of Parameter Changes) is used quite frequently, 'Universality' once, and 'Mechanics Substitution' and 'Thermal Expansion' not at all.

The discrepancy between current Matrix suggestions and the suggestions made in the Mass Customization text, suggests that a 'Business Contradiction Matrix' will be markedly different to the current Matrix, at least in terms of this one contradiction.

On the other hand, it is perhaps worthwhile in examining whether the Inventive Principles suggested by the current Matrix have anything of value to offer to the Mass Customization problem:

**Mechanics Substitution** – as interpreted in (Mann & Domb 1999) as the idea of replacing a mechanical entity with sensory means or a field, potentially has much to offer organisations interested in shifting to a Mass Customized method of doing business. At the most basic level, this is so because replacement of a physical entity with a sensory or field alternative means implies significant reductions in manufacture cost.

At a more detailed level, we might see the inbuilt user customizability of commercial word-processing software packages as an example of how substitution of a hard-wired system for user specifiable settings built into (no physical cost) software is an excellent means of achieving economically viable, mass-customized products. Similarly with the shift from mechanical to electronic based camera systems; let the software allow the customer to customize the camera operation to their own personal requirements.

Looking at ‘fields’ from the manufacturer perspective, as in Pine’s Levi Strauss case study, laser and ultrasonic measurement systems are much faster, more accurate, and measure a variety of parameters simultaneously, and return their results in digital form, relative to traditional mechanical methods of measuring. This makes mass customization of products such as clothing and contact lenses much faster and less expensive than traditional methods.

Mechanics Substitution may thus be seen to have much to offer in the context of Mass Customization.

**Thermal Expansion** – was interpreted in (Mann & Domb, 99) primarily as increasing the ‘excitation’ (heat) of people in an organisation. In this sense, there is a degree of overlap with the ‘Boosted Interactions’ Inventive Principle – which was shown in Pine’s book to be an important factor in achieving Mass Customization through high responsiveness through the value chain. The ‘differential expansion’ element of the Thermal Expansion Principle, perhaps suggests that the desired high responsiveness might be improved through due consideration of personality matching of the different individuals in the different parts of the chain.

Either way, Thermal Expansion is unlikely to feature in any ‘top 5’ Inventive Principles relevant to the achievement of effective Mass Customization.

While in all probability possible to make connections between **every one** of the Inventive Principles and the Mass Customization contradiction, based on Pine’s book, and the work described here, the Principles most likely to be beneficial in a Mass Customization context are felt to be, in approximate order of descending importance:-

- (1) Segmentation
- (15) Dynamics
- (17) Another Dimension
- (2) Taking Out
- (28) Mechanics Substitution
- (38) Boosted Interactions
- (3) Local Quality
- (40) Composite Structures
- (10) Preliminary Action
- (23) Feedback
- (35) Parameter Changes
- (21) Skipping
- (6) Universality
- (5) Merging
- (26) Copying

## RELATION TO TRENDS OF EVOLUTION

The Mass Customization phenomenon is consistent with several of the TRIZ trends of evolution. In fact, it is possible to see direct connections with just about all of the trends (Introduction of additives – user customizable features, Rhythm Co-ordination – systems which adapt to the way in which individual users utilise the product, Space Segmentation – evolution to active/adaptive pores, etc). We will concentrate here on just a few:-

- The trend towards increasing ideality
- Transition from macro to micro level, and
- Mono-Bi-Poly

**Ideality** – The trend towards increasing ideality (=benefits/(costs + harm)) is universal. Successful Mass Customization requires the recognition that different customers have different requirements; and that the benefits, costs and penalties for one may thus be completely different for another. The most significant change from traditional TRIZ practice is to shift the evaluation from the point of view of the manufacturer to the point of view of the customer.

<b>Ideality Element</b>	<b>Traditional TRIZ: the manufacturer's view</b>	<b>Mass Customization: the individual customer's view</b>
Benefits	What the typical customer wants	What I want, at the time that I want it
Cost	Materials, labor, design, distribution, packaging, sales, etc.	Costs to purchase, operate, maintain, and dispose of.
Harm	Undesirable side effects, legal liabilities, social impact	Undesirable features (Could be seen as benefits at a different

time!) Time to learn to use it.  
Undesirable side effects, legal  
liabilities, social impact.

Thus, Customer X's vision of the ideal video recorder as one which can be set to record a dozen different programmes, water the plants and feed the cat, is Customer Y's vision of an expensive product requiring a rocket-science degree to operate. The designer and manufacturer have the challenge of creating either one product where the complexity is hidden from Customer Y, and is inexpensive enough that she will still buy the product, or creating two products, where one is capable of all that Customer X wants and the other is limited to only what Customer Y wants. This sets up a physical contradiction, generally described in TRIZ as "I want A but I want 'not A'" which is solved at the general level by separation principles and at the operational level by the 40 principles. (We will return to the solving of physical contradictions in the business context in a future article.)

A successful Mass Customization shift is thus crucially dependent on the ability to first tap into the different customer views on benefit, cost and harm, and second to then translate that knowledge into products that can satisfy all the demands.

**Transition from macro to micro level** – while the increasing division of physical entities into smaller and smaller components is highly analogous to the idea of Mass Customization being focused on ever smaller customer groups, it is also worth noting that the TRIZ trend progresses beyond the small scale object through to powders, liquids, gas and ultimately fields. Whilst perhaps not immediately obvious in the context of 'customers' rather than 'things', the trend does continue to be applicable (and highly relevant) if an analogy is drawn between 'fields' and customer 'perceptions' and 'moods'.

A good example here comes from a recently opened London hotel. Recognising that not only do different occupants have different preferences as regards, say, the colour of the room they are staying in, but also that the same occupant might have different desires depending on the time of day (i.e. different moods), they have configured lighting and décor systems which allow customers to modify the apparent colour of the room at the flick of a switch.

**Mono-Bi-Poly** – the combination of similar and dis-similar objects into 'combined polysystems' is again highly consistent with the idea of mass customized goods: Lots of different elements combined into a system means increased likelihood that at least one will suit the particular requirements of a given individual customer.

The problem here is the common 'how poly is poly' issue, or, how far along the poly evolution path is it possible to go before the increased functionality benefits begin to be out-weighted by the increased costs and harms? Although there is no simple answer to this question, it appears clear – when thinking about mass customization through product modularization – that, at the very least, 'combined polysystems' need to incorporate the potential for additional components/functions to be added – e.g. cameras, modular hi-fi systems, dealer/user fit car accessories, etc.

## Another Perspective

Following on from this activity, we set out to look at whether Joe Pine's work had anything to add to the TRIZ trends of evolution. The initial answer – as shown in Exhibit 5 derived from (Pine, 99) – is that, yes it does. Integration of the economic evolution from Commodity to Product to Service to Experience based economic regimes with the technical trends of evolution then appears to offer considerable business performance benefit potential. That will be the subject of a future article.

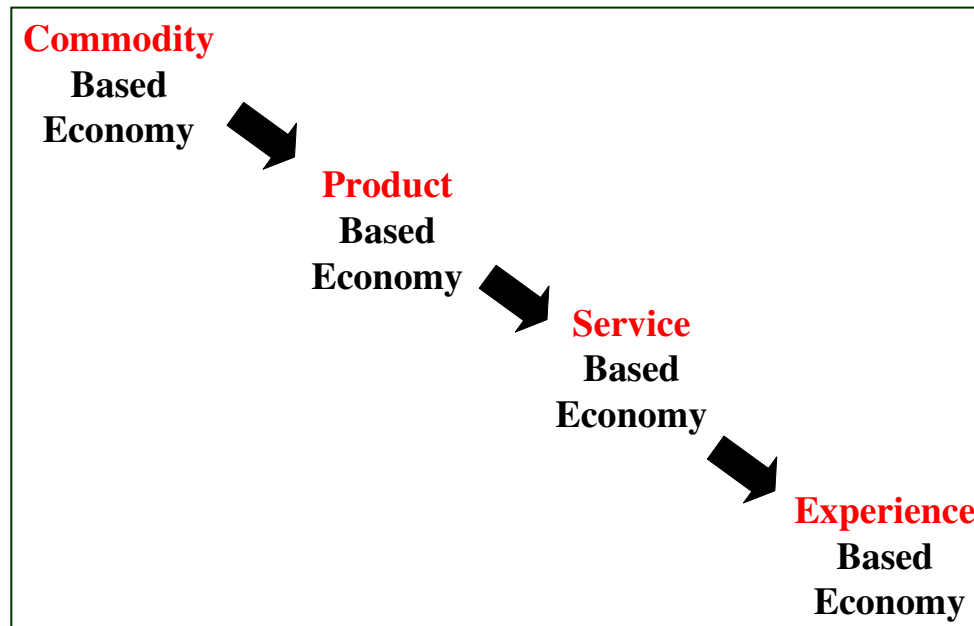


Exhibit 5: Global Economy Evolution Trend (based on Pine, 99)

## CONCLUSIONS

This article set out to answer three main questions:-

- 1) Is the Contradiction Matrix able to predict or reproduce the contradiction-eliminating solutions identified by Pine in his book?  
(Answer: in part.)
- 2) Do Pine's solutions have anything to offer the TRIZ problem solving methods?  
(Answer: The Mass Customization contradiction fits the current format of the Contradiction Matrix; the Inventive Principle solutions identified in Pine's book fit within the scope of the current Inventive Principles; they offer significant potential for populating a future 'Business Contradiction Matrix')
- 3) Does TRIZ have anything to offer organizations and researchers involved in Mass Customization projects above and beyond the solution strategies found in Pine's book?

(Answer: Yes in terms of both use of the Inventive Principles and the trends of evolution.)

A study of business evolution trends has shown that Mass Customization is highly consistent with and complementary to established TRIZ trends of technology evolution.

Mass Customization looks set to become a dominant business trend across many industry sectors. TRIZ may be expected to play a significant role in helping organizations to effectively and creatively enter or expand the Mass Customized marketplace.

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