Exponential Population and Economic Growth Versus Finite Scarce Resources = Boom or Bust?

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Contents

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Abstract

For many decades, the exponential growth in population, urbanization and technological advancements have provided the engines for economic growth and prosperity. However, the combination of exponential growth within a world with scarce and finite resources is increasingly resulting in growing gaps between demand and supply of especially food, water, energy, education, health care and other infrastructure resources. It is also increasingly resulting in shortages in raw materials and even in parts and finished goods within especially the commodity and consumer goods markets fuelled by the sustained economic growth in especially China and India that are driving up prices and jeopardizing economic and political stability around the world.

This paper provides insights into the underlying causes of both local (within organizations and industries) and global (countries) resource scarcity crises, the generic yet simple solutions to address these underlying causes and offers practical suggestions on how all of us - individuals, decision makers within organizations (from both the private and public sector) as well as governments - can help prevent the chaos that results from over- and / or under-supply and the common over- and under-reactions that follow.

The paper also shows through results achieved in recent global initiatives, that the same holistic, constraint focused improvement principles and methods, previously only applied to help organizations, can be applied at individual, department, company, supply chain, industry, city council and even country level to achieve more with less resources, in less time in a way that will not only help us all to survive the looming scarcity crises, but enable businesses and governments to flourish in the next few decades.

Introduction

Faster than expected economic recovery – good news or bad news?

The faster than expected recovery in economic growth in North America and Europe, and the ongoing growth in Asia, Africa and Latin America, point to comparatively positive challenges for supply chain and operations managers and other decision makers[1] over the next few years.

Other supply chain disruptions such as natural disasters, political unrest, scarcity crises and labour disputes will still need contingency plans, but after two years of recession, most of us may think that, "*faster than expected growth*" is a much "nicer" problem to deal with.

[1] All references are made considering both private and public sector organisations.

However not understanding the underlying causes and not having a contingency plan in place to cope with this faster than expected growth, can easily match the significant negative consequences of an unexpected market downturn or credit crisis.

Recent events again showed that during market downturn and / or credit crisis periods, decision makers at all levels tend to over-react due to fears of uncertainty and risk, cutting much of the assumed surplus or protective capacity necessary to cope with day-to-day fluctuations in demand and supply. In many cases, decision makers also delayed or even stopped much-needed capital and capacity expansion projects to deal with the increasing demands from the ongoing exponential population growth and urbanization.

What are the likely negative consequences of such (over-) reactions?

In consumer goods, manufacturers, distributors and retailers, unable to respond to the "faster than expected recovery", would not be able to meet demand, which can result in significant sales, profitability and market share losses. It is estimated for example that Apple has lost around 15-25% of their total potential sales for the iPad and iPad 2 due to their suppliers not being able to meet higher than expected demand (Neville, 2011). Apple customers are not the only ones facing long and frustrating queues and supply lead times. The same phenomena can be seen in many other private and public sector organizations that are struggling to meet demand growth that outstrips supply capacity.

This paper is not only about the impact of faster than expected recovery in consumer demand, but on the more generic problem of not being fully prepared for exponential growth in demand on any resources consumed or used by our exponentially growing human population.

The paper will argue that the mistakes made during the recession by supply chain managers and company owners alike, are very similar to the mistakes made by the decision makers in governments and other large global organizations responsible for allocating our scarce and sometimes finite resources when demand approaches and exceeds supply availability.

The paper will then present a set of recommendations to decision makers, based on common causes of – and simple yet practical solutions to resource scarcity crises identified in a number of global and local research projects to help better exploit and elevate scarce resources. These insights can be applied not only at the micro-economic level (by individuals and within organizations) but also at the macro-economic level (at city councils and regional or national governments) to significantly reduce the likelihood of avoidable resource scarcity crises or at least, allow decision makers to detect and correct for these faster to diminish their impact.

Increasing Reports Of Scarcity Crises

The material and consumer good shortages that resulted after the faster than expected recovery from the 2008 / 2009 recession (triggered by a credit crisis that turned into a financial crisis and resulted in the reaction by retailers, distributors and manufacturers to dramatically cut orders and reduce inventory and capacity), was simply a specific example of a more generic challenge.

When the demand for any resource approaches and exceeds the available supply of that resource, we will experience a resource scarcity. Any resource scarcity can turn into a crisis when stakeholders are not prepared for it and when there is no contingency plan in place to either find ways to get more out of the existing supply of this resource and / or to find viable alternatives or substitutes. Over the past few years, there have been increasing reports of "scarcity crises" around the globe related to many resources consumed or used by humans. These types of crises will make life very "interesting" for all decision makers, especially in the situations where these crises involve not only scarce but ***finite*** resources.

These crises include the most commonly reported such as scarcities in water, food, health services, housing and energy, and also crises involving capacity constraints in manufacturing and distribution networks and nodes such as airports, seaports and roads, already constrained due to the unprecedented and sustained economic growth and urbanization in developing countries.

The impact of these scarcity crises varies from minor consumer irritation and frustration, to loss of business, business bankruptcies, political instability, irreversible environmental damage and more and more will lead to more and more avoidable deaths (from avoidable illness, extreme poverty and mal-nourishment as well as political instability related deaths).

Types Of Resource Constraints

A resource constraint is defined as any resource where ***the demand placed on the resource, exceeds the current availability of that resource***. Most resource constraints are temporary by nature due to opportunities to unlock hidden potential through better exploitation, elevation or reduction in demand using methods such as Dr. Eli Goldratt's Theory of Constraints, LEAN and 6 Sigma.

A "finite scarce resource" is a special and more consequential type of resource constraint. It is defined as ***a resource where the demand exceeds available supply, and which, for practical purposes, has a finite capacity with no viable short-term accessible substitutes or alternatives***.

In most cases, alternatives can be found for finite non-renewable resources but frequently, these come at a much greater cost and / or with significant transition delays and barriers. A good example would be the supply of oil. It is finite and to a large degree non-renewable, but there are many (albeit more expensive and not short-term viable) alternatives available.

Consequences Of Resource Constraints

The consequences of resource constraints within any system, whether finite, renewable or temporary, are similar in a number of important aspects. These include:

1. Resource constraints cause scarcity. Scarcity tends to drive up prices (and competition) for any product or service that requires that scarce resource, since the perceived value of something that is scarce is more than for something that is abundant.
2. Even before scarcity is experienced, resource constraints cause the queue time or supply lead-time for these resources to grow exponentially as demand approaches 100% of the available resource capacity.
3. When supply lead-time grows exponentially due to resource constraints, the reliability of supply (that is, due date performance) will decay exponentially as demand approaches 100% of the available resource capacity.

4. Without sufficient "catch-up" capacity (or available substitutes), it can take a long time to recover from the above-mentioned consequences of resource constraints in any system.

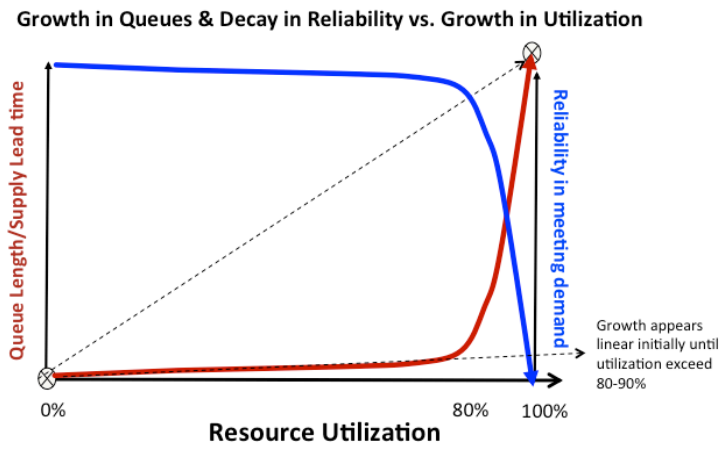


Figure 1: Queue Growth And Reliability Decay With Growth In Resource Utilization
Source: Barnard, A. "How To Identify And Unlock Inherent Potential Within Any Organization", PhD Thesis, 2009

Those familiar with queuing theory, will recognize **Figure 1** as the graph showing the surprising relationship between the exponential growth in queue length and / or supply lead-time for those waiting for the resource as the resource utilization (demand versus available capacity) approaches the 80 to 90% "tipping point" where growth goes from linear to exponential. It also shows the exponential decay in reliability in meeting demand when resource utilization approaches 80 to 90%.

This can, and frequently does trigger a ***vicious cycle***. As the reliability decays, there is more uncertainty about how much and when you will get the resources, products or services you require. If the last time, you only got 50% of the resource you required, you might be tempted to order double as much as you need the next time, and / or ordering earlier than you need to, causing additional and "unnatural" peak load on the already constrained system which will cause lead-time of supply and reliability to deteriorate even further and frequently prices and especially speculation driven market prices to escalate.

These types of resource scarcity driven vicious cycles also occur within the public sector. If there is a growing gap between demand and supply within any government provided service or infrastructure, it will result in congestion, long (and very frustrating) service delivery or supply lead times and delays as well as unpredictable and worsening service delivery performance (not meeting promises to citizens despite the best intent). When service delivery becomes consequentially bad, many citizens will stop payment. Less revenue means governments can't afford to invest in improving service delivery and / or infrastructure which will force governments to raise the cost of these services to those that do pay, causing even more dissatisfied citizens, which in turn will increase the number refusing to pay, triggering a vicious cycle difficult for any government to break out of.

The impact of lack of "catch-up" capacity in any resource constrained environment is best illustrated with a "Cumulative Flow Diagram" (CFD) showing the cumulative "flows" over time in demand (arrivals of customers requiring a specific resource, product or service) versus supply (shipments or delivery of those resources, products or services).

Fig 2a Fig 2b Fig 2c

Figure 2: Cumulative Flow Diagram Showing Impact Of No Catch-Up Capacity

Source: Barnard A., "Using Cumulative Flow Diagrams to early detect and correct for supply-demand imbalances", 2003

The first CFD in **Figure 2** shows that when we graph the cumulative demand for any resource, product or service over time, versus the cumulative supply of that resource, product or service, we should see a "balance of supply vs. demand flows". The graph is very useful, since regardless of whether the Y-axis is used to define the value of the flows (e.g. cumulative demand vs. supply in US$) or the units of flow (e.g. cumulative demand vs. supply in tons), we can just read from this graph the average supply lead time (SLT) and average work-in-process (WIP) in the system.

CFDs provide a practical way to illustrate the very useful "***Little's Law***" which states that:

The average work-in-process in any system is equal to the average flow rate through that system (supply throughput or delivery rate) multiplied by the average flow time (the average lead-time it takes for demand to be satisfied).

If you know two of these variables, Little's Law allows you to simply calculate the third regardless of how complex the internal processes are for converting inputs into output. For example, if we know how many parking bays there are at an airport (the maximum WIP of the system) and we know the turn-around time per aircraft, we can calculate what throughput rate of departing aircraft will be. In the same way, if we know the desired throughput rate in tons or value to make a farm economically viable and we know the average lead-time from say planting to harvesting, we can calculate the average WIP or farming land needed for the farm to achieve the desired throughput rate. We can then also calculate the reduction in farming land needed if we can increase the average yield through better farming techniques or the impact shorter farming cycle times will have on throughput.

In the context of better understanding the underlying causes of resource scarcity and its consequences, CFDs are very useful in that they clearly illustrate what will happen to SLT (queue or waiting times) and WIP when there is either an increase in the rate of demand and or a disruption in the supply as shown by the second and third CFD in Figure 2. Even if these changes are only temporary (that is, demand or supply return to previous rates), the increase in SLT and WIP will be permanent unless there is sufficient "catch-up" capacity.

By definition, when a system is capacity constrained, there is not any "catch-up" capacity at that time, which explains why it takes so long for supply lead times and inventories to reduce back to original levels when there is a spike in demand or disruption in supply. When demand keeps on growing while supply capacity is constrained, it means supply lead times will continue to grow and do so exponentially, as illustrated in Figure 1 and proven with queuing theory.

Almost every organization has and will continue to face the consequences related to the demand for their products, services or the resources approaching or exceeding their supply capacity. The early warning signs of supply constraints are normally clear and (in the case of macro-economic growth constraints and / or resource scarcity crises) frequently well reported on in the media - undesirable effects such as longer lead times, higher work-in-process, supply shortages, frustrated customers, longer and longer times to recover from shortages, fire-fighting to decide who and what to supply and upward pressure on prices.

So why is it that the decision makers in so many organizations take such a long time to react to these early warning signs? Alternatively, once they do take action, why do these actions so frequently exacerbate rather than remedy the situation?

Causes And Direction Of Solution Of Scarcity Crises

Since the late 1970s, Dr Eli Goldratt, creator of Theory of Constraints (TOC), together with TOC experts and practitioners from around the world have been actively researching the common causes and developing practical and simple solutions for all types of resource scarcities and other constraints to growth and stability. This research shows that the majority of the scarcity crises (whether it involves input materials, supply capacity / skills, market demand or cash) stem not from actual resource constraints (where the available capacity is really less than the current demand), but quite counter-intuitively, from three fundamental and avoidable causes.

1. A generally poor understanding of why any set of resources, necessary to produce an end product, project or service, on average will always produce significantly less than the inherent capacity of the slowest resource or bottleneck of that production, distribution, project or service delivery process and take significantly longer than the sum of the cycle times (touch time) of each process. [2]
2. A generally poor understanding of the consequences of exponential growth in demand and particularly how best to allocate and prioritize scarce resources when demand approaches and exceeds supply or vice versa to fully capitalize on either scenario.
3. An assumption that the best way to protect (against uncertainty and fluctuations in supply and / or demand) and improve any “system” is to protect and improve each part of the system

[2] This is caused by the effect of statistical fluctuations and interdependencies as well as inappropriate release mechanisms that cause either too much or too little to be released and/or bad multi-tasking which reduces flow rates and increases flow time and WIP through a system.

The result of these three fundamental causes is that important decisions, which could prevent or at least diminish most of the avoidable scarcity crisis and / or organization failures, are not taken in time or that the wrong (local optima) decisions are taken.

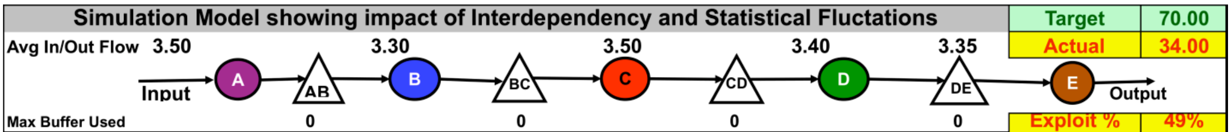
When these causes are addressed through implementing Theory of Constraints' based "constraint focused solutions" (especially when supported by continuous improvement methods such as Lean and Six Sigma) to improve and better protect the whole system - rather than improving and protecting each part - it is common that organizations from both the private and public sector report results of being able to achieve between 10 to 100% more goal units, with the same or less resources in typically 25 to 75% less time than the previous norm[3].

It is these types of results that can provide any organization, any city council and even country with the protective capacity needed to prevent or at least significantly reduce the impact of a market downturn or resource scarcity crisis that can limit or delay the much needed economic growth and stability desired by all.

How Interdependency And Fluctuations Cause Scarcity

There is a simple reason why most processes (and supply chains) can't produce output that is close to its design capacity (the capacity of its capacity constraint or bottleneck). The secret lies in the impact of dependency and statistical fluctuations, which causes delays at upstream processes / links to cause starvation of downstream processes / links and delays at downstream processes / links causing blockage of upstream processes / links.

We can use a simple process flow example that can be easily simulated in a spreadsheet to illustrate the point illustrated in **Figure 3** below.



	Output A [units/hr]	Buffer AB [units]	B [units/hr	Buffer BC [units]	[units/hr]	Buffer CD [units]	Output D [units/hr]	DE [units]	Output E [units/hr]	Prob [%]
Average	3.5		3.5		3.5		3.5		3.5	
Minimum	1	0	1	0	1	0	1	0	1	
Maximum	6	0	6	0	6	0	6	0	6	
Starting WIP		0		0		0		0		

Figure 3: Simulation Model Showing Impact Of Statistical Fluctuations And Interdependency
Source: Barnard, A. "How to identify and unlock inherent potential within any organization", PhD Thesis, 2009

How much will a system produce in say twenty days, if system output is produced with five processes working in series (interdependency), and each of these has a potential output of 3.5

[3] The World of Theory of Constraints, an international survey of 80 companies that implemented TOC, reported a mean increase in throughput of 68% and a reduction in lead-time of 69%. Similar results can be viewed in hundreds of other TOC case studies available on www.toc-goldratt.com and www.realization.com.

units / day with fluctuations of between one and six units / day (for example, the statistical fluctuations can be represented by the throw of dice)?

This "system" can represent any system where work flows from one resource to another such as in manufacturing, distribution, education, hospitals, banking, airport passenger flow etc.

The common assumption is that since on average, each process / link can produce 3.5 units per day, after twenty days, the system should be able to produce 70 units.

However, this is not possible, since due to the interdependencies, when the first process produces only one, only one will go through the system that day, regardless of whether all four other processes were capable of producing six that day. The net impact of this starvation (when a process gets less than it is capable of processing) or blockage (when there is no more space to produce into or the next resource is not yet ready to receive) is that if we simulate such a system with the simple throw of dice, the system will produce between 30 to 40 units, with the mean around 35 (Figure 1 shows the results of one such simulation with an output of 34). This is 50% less than what we assumed to be the installed capacity.

Most people know that the system can never produce more than the capacity constraint (weakest link or bottleneck) can produce in a day. However, what is frequently ignored, is that the capacity constraint loses capacity due to starvation and blockage by non-constraints or other capacity constraints. The more resources required in series to produce a product or service, the more significant this impact is. The "50%" true utilization of the process flow bottleneck is commonly seen. This explains why, if a mechanism can be found to reduce or significantly prevent the impact of starvation and blockage, system throughput can be increased by up to 100% with the same resources.

There are only three ways to improve the output of the system above.

1. Add capacity at each link until the real output is close to 70. This is normally a very costly and time-consuming option.
2. Reduce process time variation from between one to six per day, to be very close to 3.5 per day, every day. This is also normally a very costly and time-consuming option.
3. To select one process to be the "bottleneck" and ensure, by buffering it properly, that it is never starved or blocked.

Although this third solution is normally fast to implement and can be done with no or small investment, it requires quite a counter-intuitive solution which involves buffering only the bottleneck and choking the release of flow to only release what is needed now. Although this significantly improves output and reduces variation in output, it will cause many of the resources to be idle from time to time– something few have the courage to attempt since there is an assumption that "an idle resource is a major waste". The more common approach is (1) – demanding more capacity to cope with more demand and (2) – creating variation reduction projects for each of the processes involved that frequently takes a long time to deliver substantial results.

How Bad Multi-tasking causes long supply lead-times and Scarcity

Most of us believe that the best or even the only way to get many things done as soon as possible, involves the ability to multi-task. We believe the sooner we start something, the sooner it will be finished. But is this really true? Recent research, validated by experiments completed on a large number of Theory of Constraints Critical Chain Project Management projects have proven that the opposite is true. It proves that the more we multi-task, the fewer things actually get done and the longer everything takes to get done. This frequently results in resource constraints and scarcity related crises that could have been avoided if the practice of bad multi-tasking could be reduced or eliminated.

Figure 4 below shows how bad multitasking causes lead-times to be much longer, and throughput to be much lower than expected whenever we work on more than one task or project at a time. In the 1st scenario, a resource completes all three tasks on Project A before switching to the three tasks for Project B and then the three tasks for Project C. In the second scenario, the same resource is multi-tasking, switching between the tasks on Project A, Project B and Project C, resulting in A being completed much later, B later and C at the same time as before. The 3rd scenario shows what happens in reality, when the resource not only loses time in the "Setup" (time to figure out where you were) when switching between tasks on different projects, but also actually takes longer to complete exactly the same tasks due to the distractions that causes work to take longer than in a uninterrupted or fully focused state.

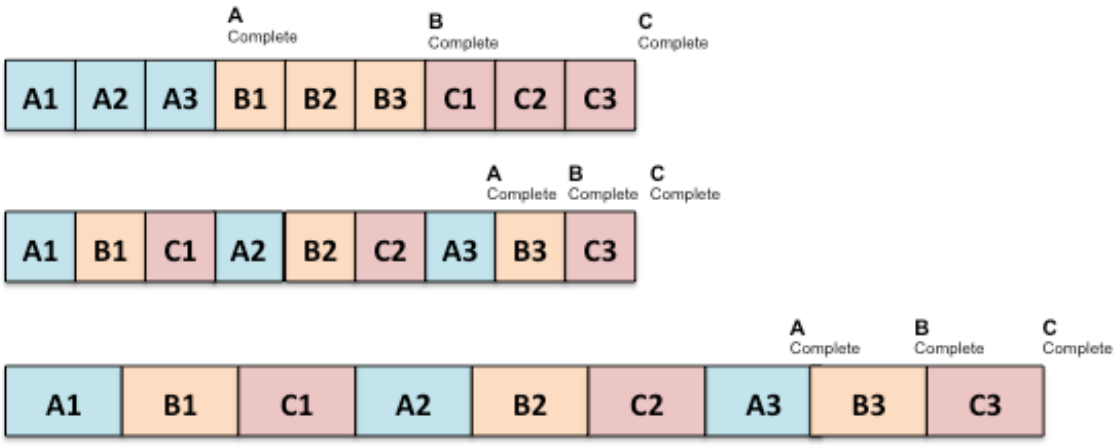


Figure 4: Simulation Model Showing Impact Of Bad Multi-tasking on Lead-time and Throughput
Source: Barnard, A. "How to identify and unlock inherent potential within any organization", PhD Thesis, 2009

Figure 4 shows therefor that the assumption that pushes us all to bad multi-task - "the sooner we start, the sooner we finish" is simply not true when we have more than one thing to do. Research has shown that when bad multi-tasking can be eliminated to allow resources to be in a fully focused (no distractions) state when working on tasks, that "touch time" to complete a task can be cut by up to 90% and that total project lead times and throughput rates can be improved by 25 to 50% with the same or even less resources at much higher due date performance.

The worst bad multi-tasking (in terms of consequences) in any organization happens at management level. Since most organizations are actually constrained by top management time/attention (***the bottleneck is always at the top of the bottle***), reducing bad multi-tasking can have a dramatic effect on the goal units of the whole organization. This means that "***achieving more from the same or less resources in less time***" should be a realistic expectation when the distractions from bad multi-tasking can be eliminated or at least significantly reduced at all levels of management. The potential to unlock such performance improvements is especially important when demand outstrips supply capacity due to exponential demand growth. Unfortunately, when demand grows at even a low but steady annual growth rate, demand will grow exponentially which can result in a real disaster when managers delay critical supply decisions because they (incorrectly) assume "***we still have plenty of time***".

How Exponential Growth And Local Optima Causes Scarcity

In the past, humanity has always been able to innovate themselves out of scarcity crises caused by an exponentially growing population within a finite environment. Each of these major innovations (e.g. agricultural, industrial and information revolutions) resulted in a new era of growth and prosperity. A number of scientists have since the early 1970s given warnings that exponential growth of human population will soon reach "limits to growth". The consequences of crashing up against such limits to growth can be catastrophic if it involves "finite" resources that are non-renewable and / or if viable alternatives cannot be created within the remaining time of that resource.

In 1972, four young MIT scientists, under the supervision of Professor Jay Forester, the father of System Dynamics, wrote "Limits to Growth", which shocked the world and became an international best seller. Using the "World3" computer model, the authors looked towards the future, for the first time showing the consequences of unchecked growth on the finite planet and humanity. **Figure 5** below shows the outcome of their "World3" predictions on what will happen to natural resources, world oil production, life expectancy, food, industrial output and pollution as population continues to grow until the limits to growth is reached that will cause either, at best a stop to growth or, at worst, a collapse in human population (massive starvation).

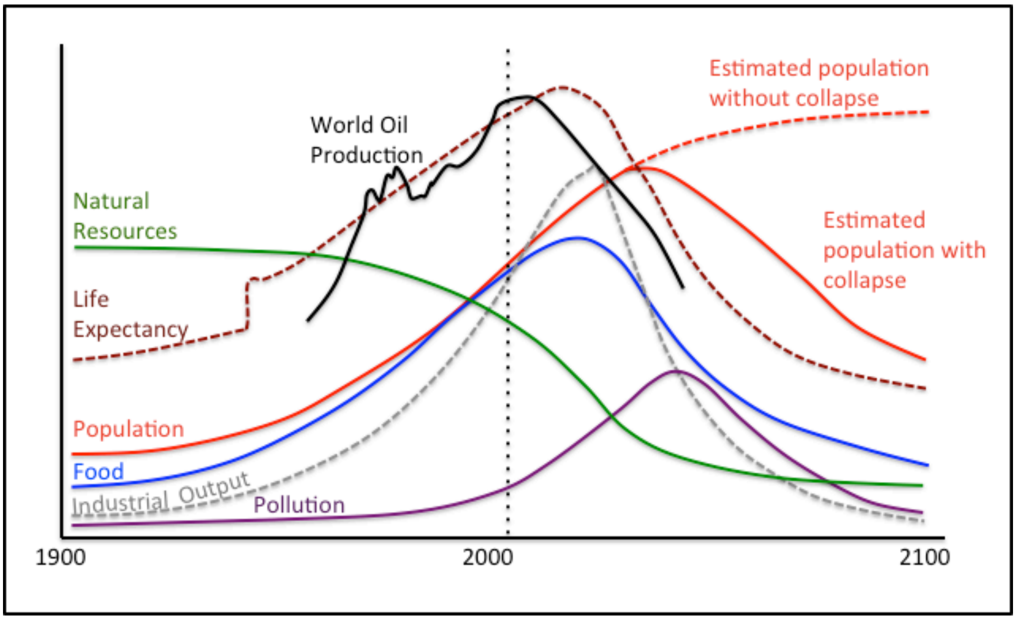


Figure 5: "World3" Simulation Resource Decay Predictions Published In "Limits To Growth"
Source: "Limits to Growth – the 30 year update", Meadows et al, Chelsea Green Publishing 2004,

The second of the most notable of these studies was produced by Professor Albert Bartlett, Professor of Physics at the University of Colorado, who claimed[4] that those that assume we can innovate ourselves out of a looming resource and energy scarcity crisis don't understand the simple arithmetic of the exponential function. He famously said that:

> ***The greatest shortcoming of the human race is our inability to understand the exponential function."* – Professor Al Bartlett**

Professor Bartlett used very simple examples to illustrate the almost inevitable resource scarcity crises from exponential population growth and why most decision makers will likely wait too long before taking action and / or take the wrong actions.

For example, he asked us to imagine that we are bacteria living in a bottle. We grow by division (1 bacterium becomes 2, the 2 divide to become 4 etc) and as a result, the growth is exponential. Our specific strain of bacteria has a division or doubling time of one minute. From the outside, it can be observed that if one bacterium is placed in the bottle at 11am, by 12 noon, just 60 minutes later, the whole bottle will be full (with about 576 quadrillion fellow bacteria or 2^{59} - the result of just 60 "doublings").

This is a simple example of exponential growth within a finite environment, which shows how we can get very, very large values very quickly if we keep doubling even a small number. It is important to note for our exploration later that this simple example is mathematically identical to exponentially growing consumption of many finite resources such as fossil fuels, food and water consumption or the exponential growth (as per Moore's Law) in the number of transistors per chip that are only now reaching physical limits. Keep this in mind as you consider a few important questions related on our world in a bottle as bacteria:

Question 1: When (at what time) will we still have 75% of the available volume in the bottle left? **Answer**: Most people will answer something like "around 11:15am since 75% of 60min is 45min). Of course, this is not the correct answer. It is simple to calculate it even without a calculator if we just work backwards from 12 noon when the bottle is full. At 11:59am, the bottle is 50% full, which mean we still have 50% space left. At 11:58am the bottle is only 25% full (1/2 x 50%) so we still have 75% left. The right answer therefore is not 11:15am, but 11:58am. Quite a difference!

Question 2: If you were an average bacterium in the bottle, at what time would you first realize that you were running out of space? **Answer:** There is no definitive answer here, but can you imagine that at time 11:55am, when the bottle is only 3% full and you have still 97% open space, that anyone will raise the alarm yet? And even if someone did, maybe someone that was actually carefully tracking the accelerated consumption of space, what is the probability that anyone will listen to them? Answer: Real life experience shows they might have a really tough time to convince others that will simply argue, "***we still have plenty of time – no need to panic now***". Sounds familiar?

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4 Bartlett, Albert A., "Forgotten Fundamentals of the Energy Crisis", *American Journal of Physics, Volume 46, Issue 9, pp. 876-888 (1978)*

Question 3: Now suppose that some far-sighted bacteria realize that they are running out of space, and through patient but very deliberate means using scientific evidence of a looming crisis, successfully convince their leadership to invest the effort and funds to search for new bottles. After an extensive search, they return just in time; at time 11:59am, with wonderful news. All the cost and efforts were worth it, since they discovered three more empty bottles. Of course, there will be great sighs of relief from all worried bacteria who by probably 11:58 and definitely by 11:59 realized that there was going to be a major catastrophe at 12:00 noon unless more empty bottles can be found. Can you picture the panic just before noon? The discovery quadruples the total space resource known to the bacteria. Surely this will solve the problem for the bacteria? The question is how long can the bacterial growth continue with the three new empty bottles? **Answer:** Those that don't take the time to do the simple arithmetic might be tempted to answer 180 minutes (since the first bottle lasted 60min). Of-course the correct answer is the 3 new bottles will last only two more doubling times. At time 12:01pm the first new empty bottle will be consumed, and by 12:02, the remaining two empty bottles are full. Unless many, many more empty bottles are discovered, or unless the bacteria take a decision to stop all further growth, a catastrophe is unavoidable.

This simple example and the underlying simple (but frequently poorly understood) arithmetic is one of the keys in helping us understand not only why we have already seen so many resource scarcity crises (just like the space availability crisis faced by bacteria) but also why a major catastrophe is almost unavoidable unless we can figure out how to further reduce our exponentially growing population. At the same time, we have to identify and apply best practices for utilizing and allocating the scarce and finite resources we have much better and also find ways to accelerate finding alternatives much faster, especially when we can see we are reaching the limits to support further growth?

Simple Mathematics Of Exponential Growth And Decay

When a quantity such as the rate of consumption of a resource is growing at a fixed or steady percent per year, the growth is said to be exponential (regardless of how small the fixed percent growth is). The important property of such "steady" growth is that the time required for the growing quantity to double its size remains constant. This time is called the doubling time T_2, and it is related to P, the percent growth per unit time by a very simple approximation that should be a central part of the educational repertoire of every person. It is called the "rule of 70"[5] and it states that:

$$\text{Doubling Time (in years) } T_2 = 70 / P$$

As an example, a growth rate of 7 % / year will result in the doubling of the size of the growing quantity in a time $T_2 = 70 / 7 = 10$ years. Exponential growth is characterized by this doubling,

[5] The notion of doubling time dates to interest on loans in Babylonian mathematics. The "rule of 70", like the "rule of 72" used in finance, is an approximation of $T_2 = \text{Ln } 2 / \text{Ln } (1+r) \approx 0.69 / r$ or approximated by 70 / P where P = r x 100.

and as shown earlier, just a few doublings can lead quickly to enormous numbers. **Table 1** below shows the approximated doubling times for different percentages of annual growth.

Annual Growth Rate	%	1%	2%	3%	4%	5%	6%	7%	10%	15%	20%
Doubling Time	Years	70.0	35.0	23.3	17.5	14.0	11.7	10.0	7.0	4.7	3.5

Table 1: Doubling Time For Various Annual Growth Rates Ranging From 1 To 20% Per Annum

Another important characteristic of any exponential growth in consumption is that the quantity consumed within the next doubling time, is almost equal to the total quantity consumed since the beginning of when the consumption started.

To prove this, let's return to the bacteria world example. Bacteria divide once every minute (its doubling time). In the 1st minute, there is 1, which consumes say 1 unit of food resource. In the 2nd minute there are 2 bacteria, consuming 2 units of food. In the 3rd minute, there are now 4 bacteria, consuming 4 units of food. These 4 units, consumed in minute 3, is 1 more than the total food resource consumed in the previous 2 minutes (4 is one larger than 1+2). In the 4th minute, the bacteria population will grow after the 3rd doubling to 2 to the power of 3 (2^3) or 8 bacteria, consuming in that 4th minute, 8 units of food. This 8, is one more than the sum of the total food resource consumed since the beginning of time 1 (8 is one larger > 1 + 2 + 4)

We can now apply these concepts to the exponential growth of the human population within a finite resource environment (at least until alternative resources are found). Appendix 1 includes details on how the "***Rule of 70***" was derived as well as how it can be used to calculate the "Life time remaining" of any finite resource. It is included as this calculation is frequently done incorrectly even by experts who erroneously assume linearity in growth or no growth in consumption when "***life time remaining***" is calculated perpetuating an erroneous assumption that "***we still have plenty of time***".

Consequences of Exponential Population Growth

Anyone who examines world population growth over especially the past two centuries certainly must be astounded, and quite possibly alarmed. **Figure 6** below shows the "J-curve" in growth since the beginning of time. The global population reached one billion around 1800. In 1930, some 130 years later, it passed two billion. By 1960 it reached three billion and four billion by 1975. In 1987, the world population was five billion, and twelve years later, in 1999, it passed six billion. Early this year (2011), just twelve years later, it passed seven billion. This growth is in line with the results of applying the rule of 70 to human population growth. In 1960, at a population of three billion, the growth rate was around 1.8%. The rule of 70 would have predicted a doubling time of 39 years, which accurately matched the reality of reaching six billion (doubling the three billion) in 1999.

Most of this growth has occurred and will continue to occur in developing nations. The world's growth rate peaked in the 1960s at 2% and a doubling time of 35 years. Although the actual population grow rates vary quite significantly between countries (the highest is 4.5% for Liberia and -2.25% for the Republic of the Cook Islands), the current global average population growth rate is approximately 1.14%. This gives a doubling time of around 61 years, which means that if the population continues to grow at an average of "only" 1.14% per annum, we will reach 14 billion by 2072 and 28 billion by around 2133.

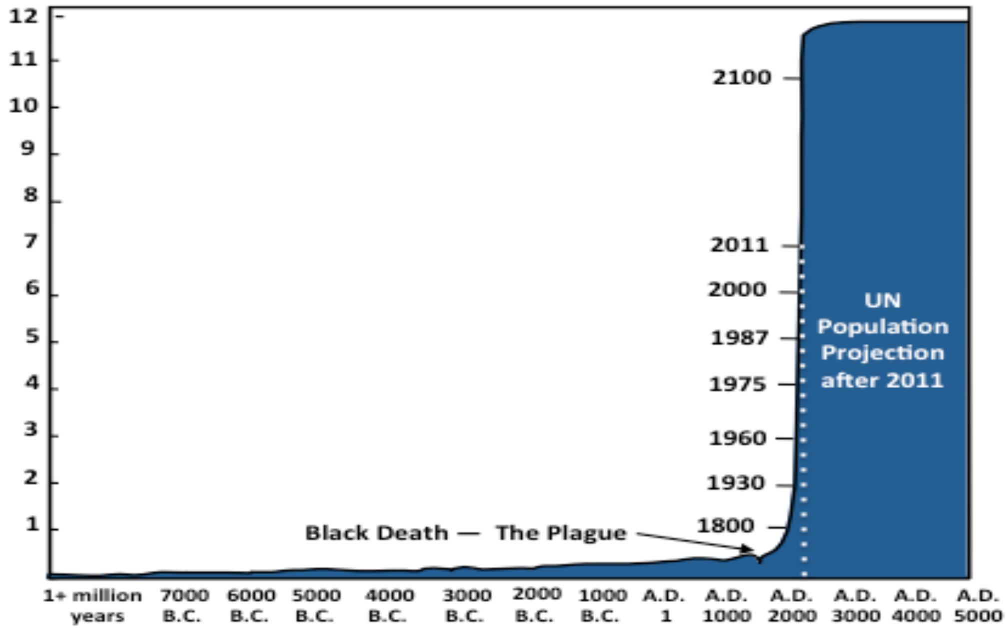

Figure 6 The "J-Curve" Of Exponential Growth In Human Population
Source: Population Reference Bureau; and United Nations, *World Population Projections to 2100*

The UN is projecting that the global population growth rate will come down to below 1%, which translates, into a UN projection of reaching eleven billion by 2100, mainly due to:

- Urbanization (people choosing to have smaller families)
- Increasing mortality rates in sub-Saharan Africa and parts of the Indian subcontinent (that is, due to HIV/AIDS, which is spreading much faster than previously anticipated).

However, even at these lower growth rates, because of the large base on which the growth is taking place, we can see from Table 2 we are still adding approximately 80 million more people every year or almost a quarter million every day to our human population.

Population Increase per	World	More Developed Countries	Less Developed Countries	Less Developed Countries (excluding China)
Year	80,794,218	1,234,907	79,559,311	71,906,587

Table 2: Absolute Population Increase – Developed Versus Less Developed Regions
Source: Population Reference Bureau, 2005 World Population Data Sheet

Most of this growth will be in the less developed countries and especially cities within these regions that are already facing major difficulties in providing access to all citizens to basic services such as food, water, sanitation and electricity. **Appendix 2** includes additional details on the likely impact of exponential growth in consumption on scarce resources such as coal and food, while **Appendix 3** includes additional details on, especially the exponential growth in urbanization in Africa and the consequences of this on already strained infrastructure, food and water resources.

Take a moment to think about how:

- Congested the roads and airports are already.
- Strained many of our utilities such as electricity, water and waste management infrastructure are currently
- Strained our educational, health and justice systems are.
- Most African and middle-eastern countries are already not able to produce enough food, don't always have the foreign currency to import the difference, and in many cases, productive land is turned into unproductive land due to environmental damage and “land reform” policies.

Now imagine what will happen to these in just one more doubling time, around 60 years, for the human population.

Considering all the recent reports of food, water, oil and other resource scarcity crises, what time do you think we are at (like the bacteria in their bottle) as humans on a finite planet?

Is there a carrying capacity for homo-sapiens on planet earth?

As we have seen, the human population growth curve is currently following an exponential curve or a "J-shape" in **Figure 6**. Even for those without scientific knowledge in this field, common sense tells us that such growth cannot continue – otherwise, at the current growth rate of around 1.2%, within just 830 years, every square meter[6] of the Earth's surface would be taken up by a human being, not leaving any land for food production.

Experience with other species tells us that, long before then, real resource limitations and / or habitat degradation or disease will force the human population curves to approach an upper limit or asymptote - the ***carrying capacity***, often symbolized as " K" by ecologists, or worst case, cause a collapse of mass extinction. Limits to growth such as carrying capacity turns exponential growth curves into ***sigmoidal growth*** curves. S-curves start off life as exponential growth curves by as it approaches some limiting condition; it first starts decelerating and then flattens at the top. Under certain conditions, they can then start declining as can be seen in the typical S-curves of the market life of a product or as shown in “Limits to growth” when the population collapse due to increased scarcity of finite resources.

How many people can the Earth actually support?

This question has interested scientists for many years. In the 17th century, Dutch microbiologist Anton van Leeuwenhook (1673-1723) estimated that the Earth could support a maximum of 13.4 billion people. In the mid-19th century, German chemist Justus von Liebig (1803-1873) formulated his Law of the Minimum, based on the realization that the addition of

[6]. The earth’s land surface is estimated at just over 148 million km^2. At the current growth rate of around 1.2%, it will take just over 830 years for the population to reach 148 trillion, giving every person only one square meter of land.

a single fertilizer will increase crop yield only if a particular soil can deliver all the other necessary nutrients. Any of the essential minerals, such as nitrates, phosphates, potassium, etc, could become the controlling factor in plant growth. Liebig's Law of the Minimum has been applied not only to the study of animal populations but also population of humans, will be constrained by whatever survival resource is in shortest supply.

Using Liebig's approach, modern estimates for human carrying capacity have ranged from ten to twelve billion people living in relative prosperity, to thirty three billion people fed on minimum rations and using all suitable land for high-intensity food production. The UN, supported by the views of many scientists based on the latest research on the impact of new technological innovations and alternative water and energy sources believe that the human carrying capacity of Earth may be approximately twelve billion.

Exponential Population Growth – The Good News

As shown in Table 2, at a growth rate of just less than 1.2%, we are adding over 80 million people to the economy each year. Each of these will not only be a consumer and user of products and services, but can also potentially be an innovator of a technology that can save us from the devastating exponential growth spiral we are trapped in.

Since most of the "new arrivals" will be in the emerging economies, it is great news for any company that manufactures, distributes and / or sells consumer goods products or services to these markets. It can also be a major advantage for these economies if they are careful in how they capitalize on this population growth.

China and India have shown how a country can capitalize on its human capital growth to provide the country with a decisive competitive edge and in turn, improve the lives of most of its citizens.

How can a country capitalize on exponential population growth?

China's economy has maintained an average growth rate of 10% per annum since 1970. This means a doubling time for GDP of only seven years. In 1970, China's GDP was only 1% of the world economy. In 2011, China took the second place from Japan as the world's second largest economy after the United States. China is not only the largest exporter in the world now, but also the second largest importer and took the place in 2011 from the USA as the world's top manufacturer.

China has succeeded in moving up the ladder of development through rapid growth in just three decades. The pace of China's growth is not what is unique — Korea, Singapore and other economies in East Asia grew as fast in the 1970s and 1980s. What is unprecedented historically is its scale. The size of China's population, market and geography, and the dynamism that flowed from economic reform and transformation are what define its impact on the rest of the world.

The dynamics unleashed by Deng's reform of China towards a market economy (letting the market determine prices rather than the state), combined with other important economic policy and institutional changes have propelled continuous capital accumulation, productivity gains, trade and income growth on a scale the world has never seen before. China, by many measures still a developing country, became the world's largest international trader in 2009.

A central question now is whether this exceptional Chinese growth can be sustained over the next 20 to 30 years, given the significant impact it will have on the domestic as well as global economic and politics. The consensus amongst economist is that the Chinese economy will continue to expand, albeit at a slower rate of probably around six to eight per cent per annum[7] for at least the next twenty years (2010 to 2030). There are other more bullish, and of course more conservative projections. But even growth at the consensus rate over the next twenty years would make China the largest economy in the world with per capita incomes perhaps four or five times as large as they are currently. China's nearly 1.5 billion people on this trajectory are set to join the richer people in the world very soon. Already companies such as Bentley and other luxury goods manufacturers report that China is already their number one region in annual sales.

Can African countries and other emerging economies learn from the success of China or will they continue the trend of a widening gap in per capita income versus the rest of the world?[8]

An interesting correlation to support the above point can be found when we compare the growth rate of the human population with the average GDP (Gross Domestic Product) per capita in the world. **Figure 7** below shows how the GDP per capita has continued to exponentially grow with population in those countries where the right conditions are put in place by their governments to enable continuous improvements in productivity and yields.

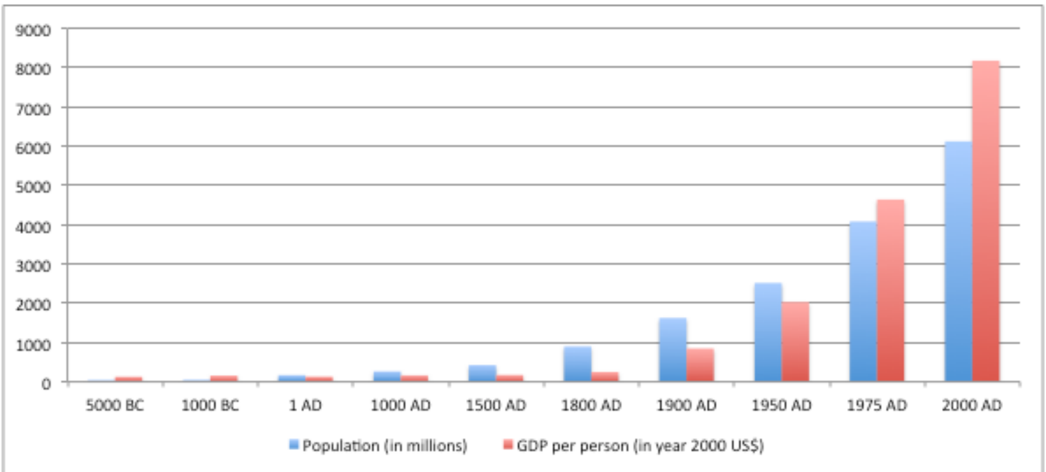

Figure 7: Correlation between Human Population growth vs. GDP growth per capita over time.

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7 Important to note that due to their large contribution to the world economy, a 1% growth in China contributes to a 0.4% growth globally and vice versa.

8 One of the common causes of not benefiting from generic best practices is arguing, "we are different" or "they will never agree". As long as African political and business leaders claim, "we are different" they are unlikely to benefit from the important lessons that can be learned from China.

How can companies capitalize on exponential population growth?

Many claim that once a company reaches a certain size, its growth rate will start slowing down. However, considering the J-curve in population growth, surely, as long as you are supplying products and services that are ultimately linked to the exponential growth of consumption by people, surely the minimum expectation should be to grow at least as fast as the population is growing. Of course, shareholders expect companies to grow faster than the overall market growth, which is only possible if a company has a decisive competitive edge to ensure the market never constrains their growth.

Many of the world's largest companies such as Walmart (founded in 1962 by Sam Walton and still controlled by the Walton Family) and Berkshire Hathaway (taken over by Warren Buffet in 1966) have shown that with a decisive competitive edge in markets driven by exponential growth in consumer driven consumption, increasing returns, can and should be the norm.

Since 1970, Walmart has grown from $44 million in revenues from 38 stores and 1300 employees to over $400 billion in revenues from close to 9000 stores and with 2.1 million employees in 2010. This is an annual growth rate of 26.3% per annum or a doubling time of around only 2.6 years.

Since 1970, Berkshire Hathaway has grown its market capitalization (value of the company) from $25 million to over $188 billion in 2010. This is an annual growth rate of 25.7% per annum or a doubling time again of 2.7 years.

For those that were not born yet in 1970, a more interesting example might be Google's exceptional growth. Google has grown their revenues from only $86 million in 2001, to over $29 billion in 2010. This is an annual growth rate of 107%, more than doubling sales on average every single year for the past ten years. If they can maintain this growth rate, they will over-take Walmart within the next five years. However, Google has grown so quickly that in many markets they have a market share so large that growth has "slowed" to around 26% per annum in 2010. Probably the most important lesson to learn here is that rather than blame the market downturn or large market share, they are capitalizing on the fact that even at 26% growth, they are doubling every 2.5 years in size and in cash reserves. Rather than complain or blame, they are applying their very innovative minds to find additional opportunities for growth and it seems they are succeeding.

What is the cost of delay when the growth rate can be exponential?

The "cost of delay" can be categorized in one of two types. The first is where the "cost of delay" will result in a company / new technology not being able to capitalize on a window of opportunity and missing out completely on it. But what is the cost of a delay when the opportunity remains the same and provides exactly the same exponential growth, just realized later in time? Doing this calculation on any of the above companies really provides insights into the value of compound growth, and the cost of delay.

For example, as shown in **Figure 8** below, if Warren Buffet took just an additional five years in taking over Berkshire, the market capitalization of the company in 2010 would be "only" $60 billion, not $188 billion. Therefore, the cost of just a five-year delay would be $128 billion!

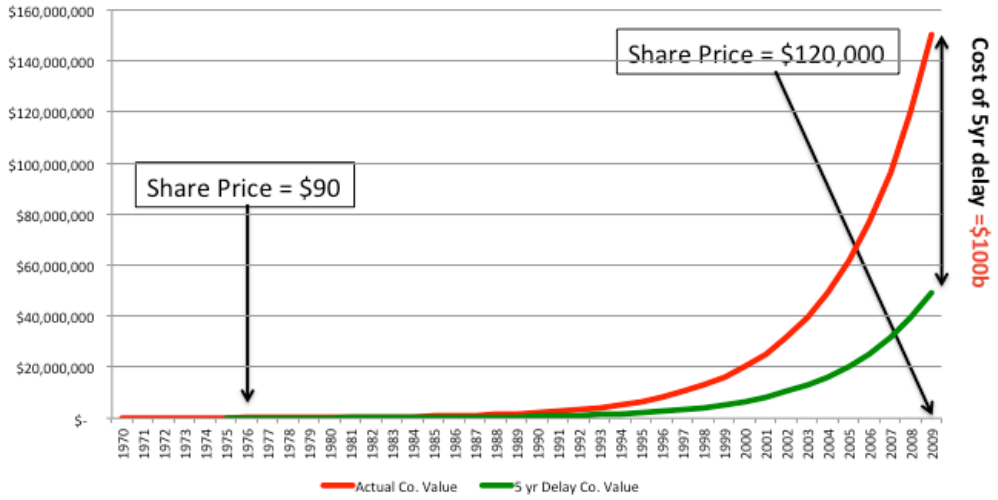

Figure 8: Cost Of Five Years Delay In Taking Over Berkshire Hathaway

This is an important lesson for any company whose sales are expected to grow by a steady percentage each year (for example, 10 or 20% per annum). This expected growth will be exponential, and as a result, the "cost of delay" of any decision that delays capitalizing on opportunities to build and sustain a competitive edge should be quantified in the same way as the above example. Considering that profitable companies contribute significantly to the tax income of the country, the cost of this delay is not only to shareholders, but also to all citizens in that region. This is one of the major reasons why China decided to make it easier for entrepreneurs to start new businesses and support these by making it much easier for foreign companies to invest and trade with China.

How can individuals capitalize on exponential population growth?

Any investment that provides steady growth over a long period of time can create a tremendous amount of wealth even after discounting for inflation. It does require the discipline to select carefully, based on good effect-cause-effect thinking (rather than advice from "experts" that get paid commissions on the initial investment).

This is the advice Warren Buffet has given for years. Select investments that are easy enough to understand how and why it will grow over time. For example, if you invested $10,000 in Walmart in 1980, today, just 30 years later, your investment would be worth $6.4 million at an annual growth rate of 25%. Even at a growth rate of 15%, your shares today would be worth $575,000 (if you had the discipline to leave it alone and not be tempted to react to the typical market fluctuations).

What does "***good effect-cause-effect thinking***" mean? It simply means that you carefully observe an effect, speculate a cause and then predict effects as if the cause is true and validate whether these predicted effects do exist or are starting to appear (to validate or invalidate the speculated cause). For example, we observe an effect of exponential population growth within a finite environment that drives up prices of these finite resources such as oil and gold. We speculate that the cause is that scarce resources without viable (short-term) alternatives are valued more than abundant resources and therefore should be a good investment.

Based on this we predict that any finite resource without a viable short-term alternative will likely gain in value, at a faster rate than inflation. This makes companies that supply this type of product / service and which have a decisive competitive edge within this market (validated by checking if they are growing faster than the competition), a very good investment (as long as you are patient and are not distracted with short-term market fluctuations).

Exponential Growth In Population – The Bad News

There is no doubt that exponential growth in population within a finite environment is a doubled edged sword for all stakeholders. The world economy needs a continuous supply of more (young and productive) people to provide the economic engine to generate new demand to allow companies to grow and countries to increase tax revenues and to cover the medical and retirement costs of an increasingly older population in especially the West.

At the same time, an increasing population will further strain infrastructure within especially developing countries and also further accelerate consumption of already scarce and / or finite natural resources, which will drive up prices making food and other basic necessities more and more unaffordable.

Critical Scarce Resource Crisis

Oil and natural gas, water, food, and minerals are critical to ensuring our wellbeing and prosperity. The mismatch between future demand and supply is crystallizing into one of the most complex and urgent issues policymakers will face in the twenty first century. Unless the challenges arising from these scarcities are confronted in a comprehensive and proactive manner, our economies will stagnate and more regions will be threatened with the associated political instability due to an inability to deliver on the "***better life of all***" promise that politicians make during election time.

While resource scarcity is a global challenge, as no single country is self-sufficient in resources needed to power one's economy, its effects are not equal across countries/regions. This is attributed to the uneven distribution of and variations in demand for resources by countries / regions. Thus, given that countries do not suffer or benefit from resource scarcity in equal terms, asymmetric dependence across resources can be an important driver for cooperation or conflict in the international system.

Under conditions of resource scarcity, the realist thinking renders the future of world politics as conflict prone and raises the likelihood of wars among major powers. This gloomy interpretation of international relations is particularly worrisome, given that major powers are all resource hungry. These states regard access to resources as vital to their national security and do not exclude the use of military force to protect their interests. On the other hand, scarcity can also fuel greater cooperation between countries and organizations, as asymmetry in resource distribution does not always translate into a power source.

Against this backdrop, it is important to review a few of the more critical resource scarcity related crises to identify how the generic causes and solutions can possibly be applied for the benefit of all.

Rising Commodity Prices Crisis

At the time of writing this article (May 2011), the Oil price is up over 40%, Corn is up 49%, Wheat is up 41%, and Sugar is up 32% in just the last year.

Many blame the greed of intermediaries for the escalation in prices of commodities in especially the last few years. However, Thomas Malthus already warned in 1800, that the prevailing notion of the time (and in many cases still today) that greed of intermediaries was the primary cause of high prices of commodities was not correct.

Instead, Malthus argued that the high prices stem most likely from government policies (and later practices by traders on commodity markets) interfering with the "natural laws of supply and demand". He argued that especially during times of scarcity, it was the responsibility of governments and large organizations to ensure that the longer-term stability of the economy should be placed above short-term expediency.

Two of the major reasons for price increases as mentioned before are speculation and scarcity. Scarcity can be reduced by applying best practices such as those of Theory of Constraints, proven to increase yields and throughput, reduce fluctuations in throughput and reduce wasteful practices such as over-production (which results in surpluses in one part or region while there are shortages in others). Speculation has a much larger influence when there are significant fluctuations in availability. So, if we can find ways to reduce the variation and uncertainty, we will reduce significantly the impact of speculators on commodity pricing.

Growing "Haves" Versus "Have-Nots" Gap Crisis

The fantastic economic growth experienced over the past 200 years was uneven in geographic as well as time terms. For example, the rise in life expectation and income has been most rapid in Western Europe, North America, Australasia and Japan. By 1820, this group had forged ahead to an income level twice that in the rest of the world.

By 1998, the gap was 7:1. Between the United States and Africa the gap is now 20:1. This gap is still widening. In the past half-century, resurgent Asian countries have demonstrated that an important degree of catch-up is possible, but only through governments with the courage and conviction to make decisions that will really ensure a "better life for all" than simply to make decisions based on staying in power and enriching a few.

Figure 9 below shows how this 20:1 gap came about and why it is likely to widen rather than shrink unless major changes are made in macro and micro-economic decisions within Africa. It shows that around 1820, there was not a significant difference the per capita income of residents of USA / Europe versus Africa. However, the USA / Europe managed to grow their economies by an average annual growth rate of 1.7% while Africa, despite its abundance of natural and human resources could only manage 0.7%. The result is that today, the gap is around 20:1 and widening rapidly over time.

What a difference 1% makes over 200 hundred years….

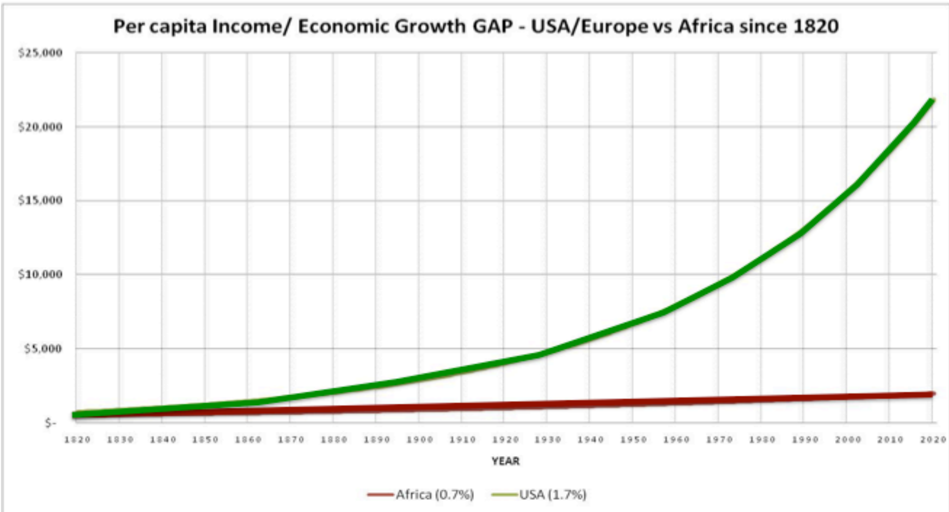

Figure 9: Growth Comparison In Per Capita Income – USA / Europe Versus Africa Since 1820
Source: ***"The END of POVERTY – How can we make it happen in our life time"*** by Jeffrey Sachs

According to Bourguignon and Morrison (2002), in 1820, the percentage of the poor (living below US$2 per day) in world population was 94.4% and that of the very poor (living below US$1.25 per day) 83.9 %. Since then it has consistently decreased year-on-year, down to 39% and 21% in 2005. Thus, the fundamental reason why there are so many poor people in the world is that world population has dramatically increased. The reality is that as long as there is a large base of poor and extremely poor, especially in environments where the gap between the "haves" and "have-nots" is growing, economic and political stability will be at risk.

China and others have shown that these large and widening gaps can be closed within a relatively short period of time if entrepreneurs are supported properly in starting up business, citizens are provided with safety and security and access to basic services. In parallel, the government takes responsibility to ensure that exponential population growth can be curtailed to be no more than 1% per annum (for example, through China's "one-child" policy) and also that there are sufficient win-win; public / private partnerships to expand and maintain the necessary infrastructure to ensure neither infrastructure nor government policies ever constrain the inherent economic growth potential of the region.

Airport And Other Transportation Infrastructure Congestion Crisis

The only way to sustain economic growth in a region is to ensure no industry or skill-set within that economy and / or no transportation infrastructure necessary to move goods and skilled people becomes a bottleneck or constraint to the growth.

It should be inexcusable that sea- or airports or even road-networks start constraining the inherent economic growth potential. Unfortunately, this is already happening in some regions due to a combination of a faster than expected recovery and generally a poor understanding of the consequences of exponential population growth on the demand on finite and scarce resources.

To understand why this is already happening, let's take as an example of traffic flow of passengers through an airport that grows at "only" 7% per annum. From the Rule of 70, we immediately can estimate the doubling time to be around ten years. We now know this means that if today, the number of passengers going through the airport is one million per month, then, in ten years, it will be two million per month. It also means that in the next ten years, there will be more passengers going through the airport, than the total number of passengers that have ever gone through the airport since it opened.

Considering that capacity is designed normally with a 10 to 15% safety factor, it is quite alarming to note that if the growth estimate on which the capacity calculation was based on, are only marginally out, the implications could be catastrophic. For example, if the growth was 10%, not 7%, it means we will reach the doubling time in only seven years, rather than ten years. From queuing theory we know that once we start approaching 80 to 90% of the available capacity, queues will start growing exponentially, reliability will start decaying exponentially and the costs to deal with these could escalate to a level where either airports and or airlines are no longer economically viable or whether prices would have to be raised to a level that will make it unaffordable to many.

The conventional approaches to cope with this unreliability are to allocate more buffer time and / or to add capacity. But adding capacity takes a long time and frequently encounters land availability constraints. Adding buffer time will mean that passengers will have to arrive even earlier to ensure they don't delay or miss their flights and planes having to stay longer in parking bays to ensure passengers don't miss connecting flights. The latter consumes scarce parking bay capacity, which means the airport has to raise prices for parking time and airlines having to raise prices to recover these increases. What is needed is a simple way to significantly reduce all the avoidable causes of capacity losses and delays by eliminating the three causes mentioned earlier in this paper.

The good news is that we already have the proven solutions for these types of problems. All that is missing is the political will and support from leaders within government and private industry to work together to identify how to implement these in a win-win way for each of the specific resource constrained areas that can limit economic growth. Unfortunately, despite good intentions, the major focus by all stakeholders is still mainly towards optimizing their own interests and / or putting in place incentives or penalties that frequently drive local optima. Past experience shows that only a real crisis will change this.

Recommendations on how to prevent resource scarcity crises

Need For A Holistic Focusing Process

The scarcest resource in any organization is top management time and attention. There will always be more demand on their time and attention than the available capacity. If their limited time and attention is applied to allocate the organizations' scarce resource in a productive manner, the organization will flourish and vice versa. But how do top management and other decision makers differentiate between all the MANY parts (processes, policies, skills, capacity) that CAN be improved, from the FEW that MUST be improved in order to achieve more goal units for their organization, their supply chain partners and for their country now and in the future?

In the 1980s, an Israeli physicist, Dr Eli Goldratt, started applying the mind-sets and methods of the hard sciences to the "soft" science of managing and improving organizations. He realized that the performance of organizations are limited by it's system constraint (the weakest link) and that this (insight) can provide the necessary focusing mechanism for all levels of management to differentiate between the MANY parts within their area of responsibility that CAN be improved from the FEW that MUST be improved to help the organization achieve more goal units for all stakeholders.

This focusing process should enable each part of an organization to identify not only what that part must START doing to contribute to the improvement of the whole organization but also (more importantly) what that part must STOP doing that is not contributing to or in some cases, in conflict and therefore damaging the performance of the organization as a whole.

Dr Goldratt called this new body of knowledge the "Theory of Constraints" or TOC. TOC's five focusing steps to analyze and improve any organization holistically included:

Step 1: Identify the System Constraint or most scarce resource (to achieving more goal units for the organization)

Step 2: Decide how to exploit (not waste) the system constraint (by removing causes of avoidable starvation, blockage, over-production and other forms of local optima)

Step 3: Subordinate everything to the above decision (by changing any policy, process or measurements that drive local optima behaviour)

Step 4: Elevate the System Constraint (by increasing the capacity of that resource or finding viable alternatives faster and at lower cost and investment)

Step 5: If in a previous step a constraint was broken, don't let inertia become the system constraint, go back to step 1.

Over the past 30 years, Dr Eli Goldratt, together with an increasing number of TOC practitioners, implementers and academics have created a vast body of knowledge of how to apply the five focusing steps to different types of organizations from different industries and to different parts of the organization (operations, finance, supply chain, projects, sales, marketing and managing people), and also developed a holistic decision support framework (Throughput Accounting) and a set of logical Thinking Processes and Management Skills that can be applied when organizations are stuck on one or more of the above steps.

The five focusing steps can be applied to a function within an organization (for example, managing operations, sales, finance, logistic etc), to a total organization or even to a whole supply chain, industry and / or economic region. Recently, more and more public sector organizations and even countries have started applying Theory of Constraints to help them achieve more with the same or less resources in less time. Remarkably, the same simple constraint focused solutions that work within the private sector, turns out to work equally well and sometimes with even better results in the public sector[9].

Need For A New Business Model Between Supply Chain Partners

As long as there is one or more links in a supply chain that are not viable, the whole chain is at risk. But how do we ensure that all the links in a chain is viable and share fairly in the exponential growth in demand supplied by such a supply chain.

As long as the consumer has not bought, no link in the supply chain has actually sold…

Dr Eli Goldratt

In this quote, Goldratt warns that as long as each link is "pushing" based on unreliable forecasts to get the next link to buy as much as possible (typically in return for a significant discount), every link's profitability and ability to respond and capitalize on changes in demand will be compromised. "Push" modes of production results in surpluses in some areas and shortages in others, which not only wastes scarce - and sometimes finite resources, but also can turn viable links into non-viable links. Non-viable links combined with stock surpluses and shortages can create supply and price instability that is a lose for all over the long run. To solve this problem, we need to find a way, not only to share actual consumption by consumers/users to all links in the chain (to reduce over-production and waste), but also to align the incentives to not create shortages or surpluses and/or exploit price increase opportunities.

The non-viability of one or more links and the risks this holds for the whole chain, have pushed some industries to consider a new business model where each link gets paid immediately for their units shipped (that is, they are paid for their actual variable input cost as well as direct Operating Expenses) and, in a fair manner share in the Throughput made by the final link selling to the end-user. The Throughput is the difference of the Selling Price to end-consumer / user – Totally Variable Cost of the last link). This type of model could go a long way to ensuring aligned objectives and significantly reduce the risks of large excess inventories and price fluctuations that cause so much damage and contribute to avoidable scarcity crises.

There is currently a number of global initiatives to apply this type of win:win:win business model within agriculture as well as other scarce resource based industries to validate whether it really does provide a more sustainable and profitable solution for all stakeholders.

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9 A number of these case studies can be found at www.tocico.org, www.toc-goldratt.com, www.goldrattresearchlabs.com and www.realization.com including how the government of Japan has used TOC to accelerate infrastructure repair and expansion projects and how the UN DP and Donor organizations are using TOC to help city councils achieve more with less in less time

Can We "Innovate" Ourselves Out Of This Crisis?

There are a number of new technologies that can make a real difference in each of the important scarcity crises described in this paper. Many of these technologies have benefited from the exponential growth in developments that increases their effectiveness while reducing prices. They include:

New Sources Of Energy

Despite all the technological breakthroughs, we are still "level 0" in civilization sophistication (that is, status = primitive) as we are still getting the majority of our energy from dead plants (fossil fuels like oil and coal) rather than using existing energy sources or creating our own. Fossil fuels are so scarce that it has, for ages, triggered wars between nations and neighbours.

There are other sources of available energy (clean energy) that is for all practical purposes infinite. For example, fusion reactors that can and hopefully will replace nuclear power plants. They are both safe and cheap. We know how to reach self-sustaining fusion energy phase, but have not allocated enough resources to overcome technical challenges. The expectation is that we will have large-scale fusion reactors by the end of this century.

The development of solar panel technology is on an exponential curve with each new generation offering lower costs and higher conversion efficiencies. Although it still makes up less than 1% of the total energy supply, its usages has a doubling time of two to three years, which means we are only a five to six doubling times away from a significant amount of fossil fuel usage viably replaced by solar technology.

Nano Technology

Nano technology, another technology on an exponential growth curve with a doubling time of around 18 - 24 months, already allows us to build the equivalent of Nano-machines (only a few hundred atoms in size) that can be created to complete complex tasks and will soon be sophisticated enough to find and destroy tumours in the body. In the future, Nano-robots will permanently patrol our blood streams and keep us healthy like clearing the brain of gummed up proteins in the brain that causes Parkinson's or something as simple as finding and destroying unnecessary fat cells.

Also, Nano technology will likely replace silicon-based solar panels. Essentially it will copy the protein molecules "living machines" in flowers that convert sun energy into chemical energy. Of course, as with any new technology, there are some negatives of this Nano-technology. Increased life expectancy will make it difficult to reduce population growth rates.

There are risks involved as by design, the Nano-bots will be self-replicating. When anything is self-replicating you better know where the "off-switch" is else they can quickly grow to a level (through their exponential growth) to consume all the energy on the planet. This could happen by "accident" or by design as a new sophisticated weapon system. Despite these risks, Nano-technology will impact all aspects of our lives and can have a dramatic impact on the looming energy, health, food and even water crises.[10]

Personal Fabricators

This is a technology that can change **EVERYTHING,** as it is the holy grail of Nano-technology - being able to manipulate matter by manipulating patterns of atoms and molecules to literally create anything out of almost nothing. Imagine having a "personal fabricator" (PF) in your home that can create almost anything you need. MIT professor Neil Gershenfeld claim that PF's could have the most profound impact in the history of mankind in closing the gap between the rich and the poor. What will become "scarce" and valuable is not the "goods" itself but the recipe / information to create almost anything from almost nothing. Also, just imagine the impact this will have on manufacturers and distributors worldwide when single unit production machines in your home can compete with mass production methods.

When will it be here? We already have the first versions available in the form of 3D printers. These 3D printers can already print very complex assembled items in one-go. At the Massachusetts Institute of Technology (MIT), Peter Schmitt, a PhD student, has been printing something that resembles the fully assembled workings of a grandfather clock. It took him a few attempts to get right, but eventually he removed the plastic clock from a 3D printer, hung it on the wall and pulled down the counterweight and It started ticking. 3D printers by themselves can already have a major impact on reducing waste in raw materials as it cuts waste in two ways; no "off-cuts" and only producing what the market needs, when they need it (no over-production).

Simple versions that can manipulate matter will be available likely within the next twenty years and more powerful versions probably by mid to late twenty first century.

Super Computers

Moore's law[11] describes a long-term trend in the history of computing hardware. The number of transistors that can be placed inexpensively on an integrated circuit doubles approximately every eighteen months. This trend has continued for more than half a century and is expected to continue until 2015 or 2020 or later. The capabilities of many digital electronic devices are strongly linked to Moore's law: processing speed, memory capacity, sensors and even the

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[10] NANOFRONTIERS: VISIONS FOR THE FUTURE OF NANOTECHNOLOGY, Karen F. Schmidt, 6 MARCH 2007.

[11] Moore's Law is named after Intel co-founder Gordon E Moore, who described the trend in his 1965 paper. The paper noted that the number of components in integrated circuits had doubled every year from the invention of the integrated circuit in 1958 until 1965 and predicted that the trend would continue "for at least ten years".[10] His prediction has proved to be uncannily accurate, in part because the law is now used in the semiconductor industry to guide long-term planning and to set targets for research and development

number and size of pixels in digital cameras. All of these are improving at (roughly) exponential rates as well. This exponential improvement has dramatically enhanced the impact of digital electronics in = every segment of the world economy.

It is expected that once the laws of physics will start limiting the doubling of the transistors per silicon chip, new molecule-based transistors will help continue and even accelerate the exponential growth in computing power. This continued exponential growth in power of super computers will help us discover the secrets of everything around us including how to manipulate and even create life.

The Internet and the World Wide Web

One of the most quoted examples of exponential growth is the growth in Internet traffic, especially since the invention of the World Wide Web (www) by Sir Timothy John Berners-Lee in 1991. Initially Internet traffic grew with a doubling time of just 3 months but more recently "slowed down" to a doubling time of around 12 months. Internet traffic grows in three dimensions – number of users that go online, the time they spend online and also the volume of data downloaded or uploaded. It is estimated that already 25% of the total population has access to the internet.

Access to the Internet via the www by an exponentially number of users (and consumers) has played probably the most significant role in accelerating in globalization - making it possible for people right across the world to communicate and collaborate with each other effortlessly and relatively cheaply. It has accelerated development and research in all technologies, but most likely its most profound impact will be through the social networking platforms such as Facebook, Youtube and Twitter and new ones to follow.

The power and simplicity of the www and specifically the social networking platforms which enable anyone to broadcast messages to a global audience have already been proven to achieve objectives varying from reducing the time and effectiveness to respond to natural disasters to toppling regimes. More and more, the true power of the internet and www will be used to bring scarce resources such as education, health care, access to capital and other resources to those that need it most in a very affordable way right on their mobile phones.

Call For Action

You might think, "*Well these are all macro-economic issues*", so what can we do. A good starting place is to first define what the potential solutions are that can contribute significantly to the problems described in this paper. When dealing with accelerating demand on finite and scarce resources, there are really only three possible (and complimentary) solutions:

1. Slow down population growth rate to ensure resources will last longer and more people can improve their quality of life and life expectancy
2. Find ways to reduce the current wasteful practices of especially scarce and finite resources
3. Accelerate the search or development of viable alternatives / substitutes.

Is it possible for individuals and even organizations to contribute to these?

Well, I think we can all help in a significant way.

Here are some suggestions on how each of us can help:

Contribute To Achieving Zero Population Growth And Surplus Wealth

Any further significant increases in the population will make all the problems described in this paper much worse. Of course, the choice of how many babies a family should have is a very personal and sometimes very emotional decision, but, like in production best practice, to maintain constant WIP in the system, we would have to find a way to apply a rule of "one-in one-out".

Unless there is self-governance, governments would be under increasing pressure to create incentives for families to have fewer children, or in critical cases where the base population is already very large, have a policy like that in China of "One-child per family". China introduced this controversial policy to alleviate social, economic, and environmental problems in China in the most adversely affected regions (the policy covers approximately 37% of Chinese families). Since its introduction, authorities claim its impact, reduced births by around 300 - 400 million from 1979 to 2011. The policy is enforced at the provincial level through fines which means families still have the choice, but are heavily fined if they do chose to have more than one child.

Unfortunately, governments of other developing countries like South Africa, have, unintentionally, through child support grants, given an incentive for especially the extremely poor, to have more children in order to get more child support as one of the few ways of increasing the income of the family in economies with large scale unemployment. One can imagine that it places policy makers in a terrible dilemma but there must be a better way for solving both problems without the same damaging consequences.

One of the other consequences of large families, price increases and an increasingly wasteful lifestyle is the reductions globally in percentage of income invested in savings. Prosperity does not come from growth, but comes from surplus. Savings can be invested in education, starting small business and / or invested into the stock market to help other companies grow and improve productivity. Individuals should save and invest more to capitalize on what Einstein is reported to have called "***the most powerful force in the universe – compound interest"*** and Governments should consider giving real incentives for savings and investing in initiatives that contribute to creating surplus, not just growth.

Turn Every Crisis Into An Opportunity To Learn and Innovate

One of the consequences of the recent earthquake in Japan was major shortages in electronic and automotive parts around the world normally produced in Japanese factories that were affected by the earthquake. Since capacity is now in such short supply, it gave a major incentive to all stakeholders to ensure only those parts with critical shortages were being produced and in turn, taking a significant part of the excess inventories out of the system. When there is a crisis, we tend to break the rules to cope with the scarcity, but typically go back to "the way we always do things" once the crisis is over. Maybe we should consider why the rules that worked so well during the crisis, should not be the standard "best practice. A similar thing hopefully would happen after the recent credit crisis to ensure we do not waste scarce capital.

We can all help therefore to use every resource scarcity crisis, whether involving materials, products, cash or skills to re-evaluate whether there is not a better way to allocate scarce resources, to better exploit the capacity we have and to develop better and faster feedback or early warning systems to always maintain sufficient protective capacity to prevent the exponential growth in supply lead times and decay in reliability of supply.

Help Identify And Abolish Any Form Of Local Optima And / Or Supply-Demand Imbalance

There are two forms of insubordination. Not following the (right) rules and following the rule even when you know it damages the system. A good example of this is spending a remaining budget just to ensure you get it next year when a much better policy would have been to allocate the remaining budget to parts of the system that had a real shortage. There are many such examples within organizations where at least some people know that one or more of the current "rules" (policies, procedures and or measurements) is causing local optima at the expense of global optima.

With regards to supply-demand imbalances, there are normally clear early warnings that one or more resources are becoming constraints that will limit growth and jeopardize stability. Individuals, organizations and governments should put in place early warning systems such as Cumulative Flow diagrams that track the balance (or imbalance) between demand and supply as well as to monitor WIP and supply lead times. These can provide critical early warnings to help reduce the time to detect and time to correct for the frequently devastating consequences of the over- and under-reactions triggered by resource scarcity and market downturns or upturns.

Ask Not What This Country (World) Can Do For You, But What You Can Do For It...

As supply chain management practitioners, we have been trained to deal with day-to-day resource scarcity crises and understand principles and best practices for dealing with market upturns and downturns due to exponential growth or decay within capacity constrained environments. We should volunteer our services to help governments apply these principles and best practices to help them help all "do more with the same in less time".

Results from thousands of implementation case studies in Theory of Constraints, Lean and Six Sigma shows that it is normally possible to get 25 to 50% more goal units with the same or even less resources in 25 to 50% less time. Just imagine the impact if we can achieve this type of results at the macro-economic level. Just imagine the consequences of such results in providing the "catch-up" capacity necessary to help cut backlogs in health, justice, education, housing, food supply and other basic services

Find More Time To Help By Focusing On What Really Matters

Most probably, many of you will say "I'm already too busy"...where will I find the time.

The history of humanity shows that the only real constraint to growth and stability is our time / attention. We waste it by ***doing things we know we should not***, and ***not doing what we know we should***. The best place to start to “find more time / attention” is to simply make a list of all the things you are currently spending time on that you know you should not and also, those things you know you should be doing, that you are not.

It is not uncommon that we lose anything from 25 to 75% of our most scarce resource – time / attention – by doing what we know we should not, and by wasting time justifying to ourselves and others why we are not doing what we know we should. Once you have your list, make a simple decision. Just STOP doing the things you know you should not, and use the time released, to START doing those things you know you should.

Releasing the time to contribute to the greater good of mankind is a necessary but not sufficient condition. There must also be a commitment to do what is good for all and a willingness to be held accountable if we don't. Maybe we should consider the equivalent of the Hippocratic oath that doctors take for all professionals. **Appendix 4** contains the modern version of the Hippocratic Oath that provides a great framework on how all professionals should act, especially in a world with finite and scarce resources with exponential growth in demand on these resources leaving no room for error or local optimization.

Conclusion

In my lifetime, I’ve seen the world population double from 3.5 billion in 1969 to 7 billion in 2011. This is a doubling time of just 42 years. If the human population maintains its growth rate of just less than 1.2%, it means it will double again to 14 billion within 58 years. When we look at the GDP growth per capita, we see the same exponential growth following the population trend. Since the 1800’s, GDP per capita increased with higher population only in the developed countries, but more and more in the developing countries we are now seeing the same trends when public and private sectors find collaborate to turn surplus human capital into a better life for all. For those that are still to recover from the recent recession, it is important to note that when we look at the GDP growth over time, the recent recession of 2008/2009 and even the great depression of the 1930’s seem insignificant “minor corrections”.

The relentless and quite predictable exponential growth in population and GDP will continue to accelerate over especially the next few decades and will bring with it unprecedented opportunities (boom) for any manufacturer, distributor, service provider or retailer than supply goods to the consumer market. When anything grows exponentially, whether it is savings from compound interest, the value of a company or even the GDP of a country, acting earlier rather than later has huge pay-offs.

However, the same engine of exponential growth in population, has put humans on a collision course (bust) when the demand from the growing population crashes up against the limitations of finite and scare resources such as food, water, energy, housing, education and health.

Unless we can find a way to close the gap in demand vs. supply of housing, education and health; and unless we can find a way to dramatically increase productivity and yields from industries such as agriculture and mining; and unless we can find viable alternatives soon enough for the unhealthy dependency on fossil fuels, we will have to live with the (horrible) consequences of more and more raw material, food, water, energy and other key resource shortages, escalating prices and the political and economic instability that result from these.

The good news is that there are already proven ways to dramatically increase yields and productivity from especially finite and scarce resources, there are already "pockets of excellence" that have applied these methods to show what's possible when we all stakeholders work towards win:win:win and that there are exciting technologies, that with the right public and private sector support, can save us from ourselves.

Our biggest obstacles are the assumptions that "*we still have plenty of time*", "*we are different and therefore cannot learn from the pockets of excellence we see all around u*s" and "*the best way to improve and protect a system is by improving and protecting each part of the system - local optima*". Once again it appears as if "*the bottleneck is always at the TOP of the bottle*".

The first step to ensuring exponential growth within an environment of finite and scarce resource results in a boom rather than bust is to understand the simple yet powerful governing principles, causes and consequence of exponential growth and scarce resources. Understanding these better not only will help us more accurately predict the likely growth in demand and or "***life time remaining***" of scarce and finite resource, but also can provide the early warnings (e.g. cumulative flow diagrams) we need to know when there are imbalances in supply vs. demand and more specifically, which resources are starting to constrain economic growth and prosperity and how best to overcome these at both micro and macro-economic scale.

The only way out is to realize that we must focus our scarcest resource (our limited time and attention) on only those few parts of the system (the weakest links) that is currently limiting further improvement and growth - the system constraint(s). Better exploiting and or elevating a system constraint will always improve the performance of the whole system, to the good of all - whether this system is an organization, supply chain or even a country.

More than 30 years of success stories within both the private and increasing the public sector has shown that Theory of Constraints (TOC) can provide the focusing process and proven logistical solutions and thinking processes to help differentiate between all the parts that can be improved and those few that must be improved to achieve more with less in less time. TOC, together with other continuous improvement methods such as LEAN and 6 Sigma, also helps us with a systematic way to analyse systems holistically using "good effect-cause-effect" logic, to develop and to test hypothesis (rather than acting on opinions) to develop innovative solutions. More and more, the application of these methods has shown that it can deliver equal and sometimes even better and faster results when applied in public sector organizations and even industries.

Each of these success stories has shown that when management tried previously to improve all parts of their organizations or larger system the possible became impossible. When they started focusing (not bad multitasking) their time on identifying and improving only those parts that currently constrain performance (the highest leverage points), suddenly the impossible becomes possible – enabling achievement of more with less in less time.

However, to apply best practices such as TOC not only at a micro - but also macro-economic level, we need to understand the world of exponential growth within a finite environment. The powerful combination of exponential population growth and human innovation within a finite environment can bring about two scenarios:

1. BOOM - Peace, harmony and prosperity that will be a win-win for all people
2. BUST - War, chaos and poverty for the majority that will be a lose-lose for all people.

If we chose (2), by our non-actions through typical excuses such as “it’s not my problem” or “what can I do”, we are all in deep trouble.

If we chose (1), we can all help. As Supply Chain practitioners we have most of the knowledge and experience needed to help our organizations, city councils and even governments make better decisions related to how to better utilize (and not waste) our scarcest resources and also how to better allocate scarce resources and accelerate development of viable alternatives for rapidly depleting finite resources - based on global rather than local considerations.

It is our choice.

But we have to decide soon. We are literally running out of time as all things exponential are accelerating towards the finite carrying capacity of our current resources with dire consequence for all if enough of us do not make the right choice.

Appendices

1. Life Time Remaining Calculations

Professor Albert Bartlett developed the concept of "Life Time Remaining" to show the impact of even small errors or changes in annual consumption growth rates on the lifetime of a finite resource.

As an example, a resource with a life time of 100 years at 0% growth on today's consumption levels, will have a life time of only 30 years at a mere 7% growth.

		Life Time Remaining for Resource in Years				
Consumption Growth Rate per year	0	10.0	50	100	1000	10000
	1%	9.5	41	69	240	462
	2%	9.1	35	55	152	265
	3%	8.7	31	46	114	190
	4%	8.4	27	40	93	150
	5%	8.1	25	36	79	124
	6%	7.8	23	32	69	107
	7%	7.6	21	30	61	94
	8%	7.3	20	27	55	84
	9%	7.1	19	26	50	76
	10%	6.9	18	24	46	69
	11%	6.7	17	23	43	64
	12%	6.6	16	21	40	59
	13%	6.4	15	20	38	55
	14%	6.3	15	19	35	52
	15%	6.1	14	18	33	49

The way to calculate "Life Time Remaining" is illustrated below.

When a quantity such as the rate $r(t)$ of consumption of a resource grows a fixed percent per year, the growth is exponential:

$$r(t) = r_0 e^{kt} = r_0 2^{t/T2} \qquad (1)$$

Where r_0 is the current rate of consumption at $t = 0$, e is the base of natural logarithms, k is the fractional growth per year, and t is the time in years. The growing quantity will increase to twice its initial size in the doubling time $T_2$where: T_2(yr) = (ln 2) / k » 70 / P (2)

and where P, the percent growth per year, is 100k. The total consumption of a resource between the present ($t = 0$) and a future time T is:

$$C = \{T \text{ to } 0\} \quad r(t)\, dt \qquad (3)$$

The consumption in a steady period of growth is:

$$C = r_0\{T \text{ to } 0\} \quad e^{kt} dt = (r_0 / k)(e^{kt} - 1) \qquad (4)$$

If the known size of the resource is R tons, then we can determine the exponential expiration time (EET) by finding the time T_e at which the total consumption C is equal to R:

$$R = (r_0 / k)(e^{kTe} - 1) \qquad (5)$$

We may solve this for the exponential expiration time T_e where:

$$\text{EET} = T_e = (1/k) \ln(k R / r_0 + 1) \qquad (6)$$

This equation is valid for all positive values of k and for those negative values of k for which the argument of the logarithm is positive.

2. Additional Information On Scarce And Finite Resources

Coal

Coal is the most abundant and burned fossil fuel. This was the fuel that launched the industrial revolution and has continued to grow in use. China, which already has many of the world's most polluted cities, was in 2007 building about two coal fired power plants every week. Coal is the fastest growing fossil fuel and its large reserves would make it a popular candidate to meet the energy demand of the global community, short of global warming concerns and other pollutants.

According to the International Energy Agency the proven reserves of coal are around 909 billion tonnes, which could sustain the current production and consumption rate for 155 years. However at a 5% growth per annum this would be reduced to 45 years, or until 2051. In the United States, 49% of electricity generation comes from burning coal. In South Africa, 88% of electricity generation comes from burning coal. In South Africa, electricity generation consumes around 53% of the total coal production each year. At current consumption levels, coal reserves will last around 134 years. At the current growth rate of 5% per annum, this is reduced to only 55 years (even on the assumption that 100% of the remaining coal reserves is allocated to electricity generation).

Special Note On South African Coal Reserves

If we assume total SA coal reserves of around 30 billion tons, it means at current coal consumption for electricity of around 118 million tons per annum, coal should last another 134 years. You can imagine someone doing this calculation in 1970 and thinking we have plenty of time left to find an economically and environmentally viable alternative. However, with just a 5% growth in electricity consumption per year, the coal would only last 52 years. This means it will last only until 2022….not until 2104!

Food Crisis

Food prices worldwide were up by a whopping 25% in 2010, according to the UN's Food and Agriculture Organisation, and February marked the eighth consecutive month of rising global food prices. Within the past two months, food riots helped to trigger the ousting of ruling regimes in Tunisia and Egypt. (It is noteworthy that food prices increased 17% last year in Egypt, and the price of wheat, a critical staple there, soared by more than 50%.) For poor countries that are net importers of food, even small increases in food prices can be catastrophic, and recent bumps have been anything but small.

There are several causes of rising prices. First, large-scale disasters have precipitated localized crop failures, some of which have had broad ripple effects – for example, Russia's ban on grain exports through at least the end of this calendar year resulted from fires and drought. Second, deadly strains of an evolving wheat pathogen (a rust) named Ug99 are increasingly threatening yields in the major wheat-growing areas.

The global food situation doesn't look too promising, as floods in Australia and excessively hot weather in Latin America harm harvests; upward pressure is mounting on prices. The only way out is to find ways to significantly increase yields on especially the small non-commercial farms by helping apply best practices in farming in fertilization and to address the credit constraint that blocks these farmers accessing the required capital to scale up operations to produce surplus.

3. Impact Of Urbanization On Africa

While the world's urban population grew very rapidly (from 220 million to 2.8 billion) over the twentieth century, the twenty first century and especially the next few decades will see an unprecedented scale of urban growth in the developing world. This will be particularly notable in Africa and Asia where the urban population will double between 2000 and 2030: That is, the accumulated urban growth of these two regions during the whole span of history will be duplicated in a single generation. By 2030, the towns and cities of the developing world will make up 81 per cent of urban humanity.

Economic growth, more efficient ways of producing food as well as urbanization, has had a major impact on the percentage of population living in poverty since 1820. As per the table below, in 1820, 94.4% of all people were living in poverty (on $2 per day or below adjusted for inflation) and 83.9% were living in extreme poverty (below $1.25 per day). From then to 2010, these numbers have dramatically improved to only 36% and 13.1%. However, since the world population has grown exponentially from 1820, the absolute number of people living in poverty and extreme poverty has actually risen and will continue to do so unless the growth rate can be slowed down. In 1820, 83.9% of one billion was 839 million people. In 2010, 13.1% of seven billion people mean 917 million now living in extreme poverty despite all our technological and agricultural improvements.

Year	% Population living in poverty	% Population living in extreme poverty (<$1.25/day per person)
1820	94.4	83.9
1850	92.5	81.5
1870	89.6	75.4
1890	85.7	71.7
1910	82.4	65.6
1930	75.9	56.3
1950	71.9	54.8
1960	64.3	44.0
1970	60.1	35.6
1980	55.0	31.5
1990	51.3	23.7
2001	44.0	18.0
2010	36.0	13.1

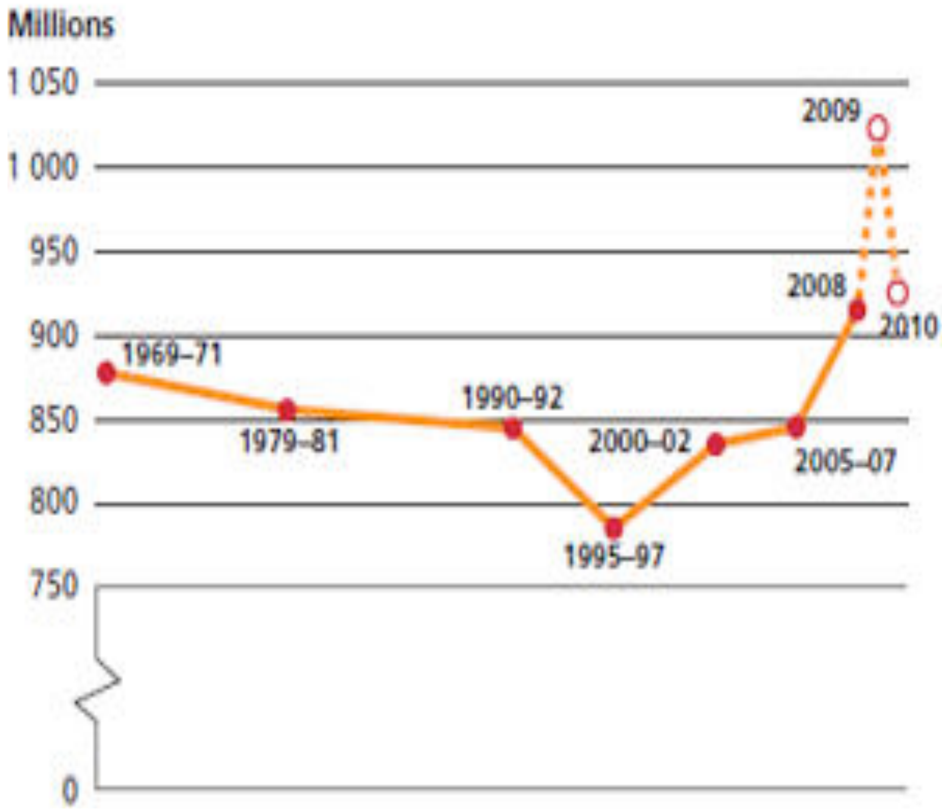
According to the UN-HABITAT's new report, The State of African Cities 2010: Governance, Inequalities and Urban Land Markets, African city populations will more than triple over the next 40 years. For the first time, in 2009, Africa's total population exceeded one billion, of which 395 million, almost 40 per cent, lived in urban areas. This urban population will grow to one billion in 2040, and to 1.23 billion in 2050, by which time 60 per cent of all Africans will be living in cities.

> ***"No African government can afford to ignore the ongoing rapid urban transition taking place across the continent. Cities must become priority areas for public policies, with hugely increased investments to build adequate governance capacities, equitable services delivery, affordable housing provision and better wealth distribution,"* Joan Clos, the Executive Director of UN-HABITAT.**

According to the report, with an urban growth rate of 3.41 per cent, Africa is the fastest urbanizing continent in the world and will in 2030 cease being predominantly rural. The increase in urban populations will lead to an exponential increase in the demand for shelter and services. But as the authors point out African cities are already inundated with slums; a tripling of urban populations could spell disaster, unless urgent action is initiated today.

No one really knows how many people are malnourished. The statistic most frequently cited is that of the United Nations Food and Agriculture Organization, which measures 'under-nutrition'. The most recent estimate, released in October 2010 by FAO, says that 925 million people are undernourished. As the figure below shows, the number of hungry people has increased since 1995 to 1997, though the number is down from last year. The increase has been due to three factors:

1. Neglect of agriculture relevant to very poor people by governments and international agencies;
2. The current worldwide economic crisis, and
3. The significant increase of food prices in the last several years, which has been devastating to those with only a few dollars a day to spend.



Number Of Hungry People, 1969 to 2010
Source: FAO

In round numbers there are seven billion people in the world. Thus, with an estimated 925 million hungry people in the world, 13.1 percent, or almost one in seven people are hungry.

4. Hippocratic Oath – Modern Version

A widely used modern version of the traditional oath was penned in 1964 by Dr Louis Lasagna, former Principal of the Sackler School of Graduate Biomedical Sciences and Academic Dean of the School of Medicine at Tufts University. It states:

I swear to fulfill, to the best of my ability and judgment, this covenant:

I will respect the hard-won scientific gains of those physicians in whose steps I walk, and gladly share such knowledge as is mine with those who are to follow.

I will apply, for the benefit of the sick; all measures [that] are required, avoiding those twin traps of overtreatment and therapeutic nihilism.

I will remember that there is art to medicine as well as science, and that warmth, sympathy, and understanding may outweigh the surgeon's knife or the chemist's drug.

I will not be ashamed to say "I know not," nor will I fail to call in my colleagues when the skills of another are needed for a patient's recovery.

I will respect the privacy of my patients, for their problems are not disclosed to me that the world may know. Most especially must I tread with care in matters of life and death. If it is given to me to save a life, all thanks. But it may also be within my power to take a life; this awesome responsibility must be faced with great humbleness and awareness of my own frailty. Above all, I must not play at God.

I will remember that I do not treat a fever chart, a cancerous growth, but a sick human being, whose illness may affect the person's family and economic stability. My responsibility includes these related problems, if I am to care adequately for the sick.

I will prevent disease whenever I can, for prevention is preferable to cure.

I will remember that I remain a member of society, with special obligations to all my fellow human beings, those sound of mind and body as well as the infirm.

If I do not violate this oath, may I enjoy life and art, respected while I live and remembered with affection thereafter. May I always act so as to preserve the finest traditions of my calling and may I long experience the joy of healing those who seek my help.

Considering the contribution all professionals can and should make and the risks and consequences of local optimization within a finite environment facing exponential growth, should we not consider drafting and applying such an oath for all professionals?

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About The Author

Dr Alan Barnard is considered one of the leading experts in the world in Theory of Constraints (TOC) frequently working with Dr Eli Goldratt, creator of Theory of Constraints on large and complex projects around the world. Alan is CEO of Goldratt Research Labs (USA), Director of Goldratt Group Africa (RSA), Chairman of Realization Africa (RSA) and Chairman of The Odyssey Institute (USA).

In 2009, Alan was awarded a PhD in Management of Technology & Innovation, from the Da Vinci Institute with a thesis titled "*How to identify and unlock inherent potential within organizations (private and public) and individuals*?" Alan is certified at the "implementer" level in all Theory of Constraints (TOC) applications (Operations, Finance, Projects, Supply Chain, Thinking Processes and Holistic Business Strategy) by the "Theory of Constraints International Certification Organization (TOCICO)

Alan is a past-President of SAPICS (2000 to 2002) and past-President of TOCICO (2003 to 2005) and received the TOCICO Lifetime Achievement award in 2006. He has worked with companies such as ABB, BHP, Cisco, Seagate, SAP, Random House Publishing, BC Rail, Tata, Larsen & Toubro, Adidas and SABMiller in the private sector and with UN DP, UN WFP and

InWent on applying TOC to city councils in developing countries in the public sector to help them identify and unlock inherent potential through application of TOC and Systems Thinking.

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