5. Supply and Demand

5.1. Markets

A **Market** is a group of buyers and sellers of any particular good or service. The supply is controlled by the sellers, while the demand is controlled by the buyers. Markets can be found in many forms some are highly organized such as auctions, but the majority of markets are less organized.

Let's use for example, "poutine". This Quebecois goodness of French fries, cheese curds and gravy can be found in many fast-food chains and restaurants throughout the country and can be a good representative of what a less organized market looks like:

- Buyers of poutine do not meet at any point…unless they are at a *PoutineFest*.
- Sellers of poutine are also in different locations and offer different varieties.
- Each buyer makes the decision on how much poutine they are going to consume, and each seller decides their own price for a poutine.
- There is no auctioneer calling out the price of poutine as the price and quantity are not constant and are not dependent on a single buyer/seller.
- Each buyer and seller know that there are other sellers of the product.

5.2. Demand

The behavior of markets is governed by how buyers and sellers interact through **supply** and **demand**. To put it simply, Buyers determine **demand** and suppliers determine **supply**. In this section we will be discussing the determinants of the **quantity demanded** which is the amount of a good or service that buyers are willing and able to purchase.

5.2.1. Determinants of Demand

So, what determines the quantity an individual demands? Let's consider the previous example. How much Poutine are you willing to buy each month? What factors do you consider?

- **Price**
  - Assume the price of a small poutine (12oz.) is $20. Would you still buy the same amount? Of course not! On the other hand, if the price drops to $2, you would definitely buy more. This is because the quantity demanded is negatively related to the price.

Law of Demand: Other things being equal, the quantity demanded (Q_d) of a good falls when the price (P) of the good rises and vice versa.

- **Prices of Related Goods**
  - Let's assume the price of loaded fries falls. Based on **The Law of Demand**, you will buy more loaded fries and you may buy less poutine. Since both poutine and loaded fries have that nice savory flavor of cheese and fries, they satisfy similar desires.

- If the demand for a good decreases due to the price drop of another good, the two goods are considered **substitutes**.
- Alternatively, some goods do not have that same impact. For example, if the price of pop decreases, the demand for it will increase based on **The Law of Demand**. However, you may buy *more* poutine because these two pair together nicely. In this case these two goods are considered to be **complements.**

But as we have seen in our previous sections, many aspects of economic analysis can be subjective and imperfect. In the case of supply and demand analysis other complicating factors for the poutine example could include:

- **Income**
    - What would happen if you do not land that summer co-op you wanted and end up doing courses instead? You may try to save money by getting less poutine.
- **Tastes**
    - The most obvious factor in determining demand is your tastes since tastes depend on multiple factors that are either historical, cultural, or psychological.
- **Expectations**
    - General expectation of future events may affect your demand for a good. An example is if you are expecting a deal to start tomorrow that causes a drop in poutine prices, you may be less willing to buy it in today's prices.

5.2.2. Demand Curve

The Demand Curve is a graphical representation of the relationship between price and quantity demanded for a good. It takes into consideration all individuals in the market to determine market quantity demanded (Q_d) for several possible prices.

Table 1 - Demand Schedule for a Product

Price ($)	Person A's	Person B's	Person C's	Person D's	Market
10	12	28	5	5	50
20	10	20	5	5	40
30	8	12	5	5	30
40	6	9	5	0	20
50	3	7	0	0	10
60	0	0	0	0	0

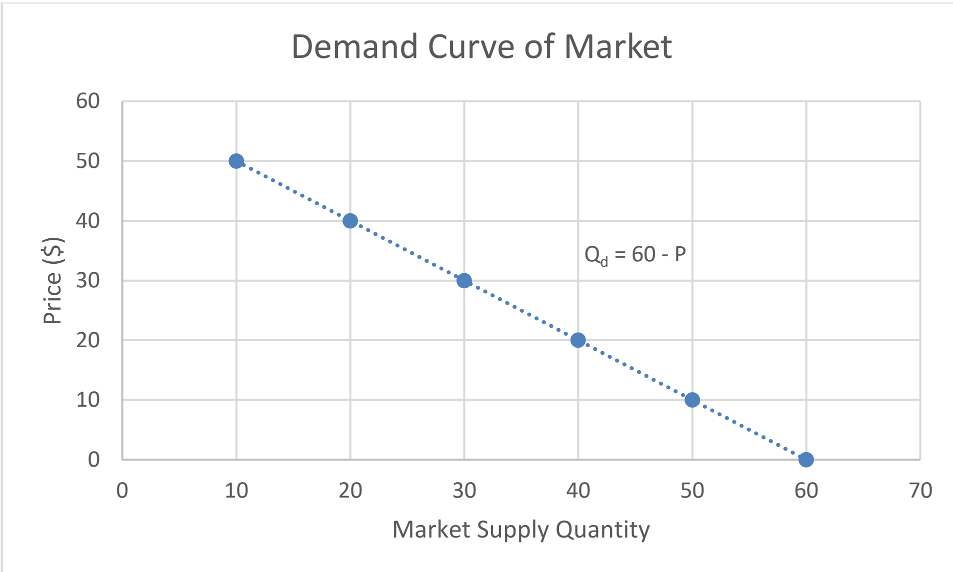


Figure 1 - Demand Curve of a Product

Note that price should always be on the **vertical** axis – an exception to typical mathematics.

Notice the Law of Demand in action. As the price increases, the quantity demanded decreases. As price changes, we can visually see how the corresponding quantity demanded changes by following the demand curve; the curve itself does not move.

Note also that individuals may have nonlinear & discontinuous demand functions (e.g., Person C wants 5 [per time, perhaps year, month, day, etc.] as long as the price is less than $45, otherwise they want 0), but the aggregate demand from considering all individuals tends to be continuous. A demand being linear in a region doesn't require that individuals have linear demand curves; it could also result from individuals having step demand curves that step at different prices - e.g., 5 people who all might buy 10 units of poutine per week, but due to taste, location, alternative foods available to them, etc. they have different price points where they'd buy these 10 units rather than none:

Table 2 – Alternate Demand Schedule for a Product

Price ($)	Person A's	Person B's	Person C's	Person D's	Person E's	Market
10	10	10	10	10	10	50
20	10	10	10	10	0	40
30	10	10	10	0	0	30
40	10	10	0	0	0	20
50	10	0	0	0	0	10
60	0	0	0	0	0	0

Since the market demand curve is a sum of the individual demand curves, those individual curves can change without always changing the market demand curve, as seen above.

Still, even considering aggregate impact of many buyers, the overall demand curve is not usually linear over the entire range of prices. Consider the demand curve for apartments. Most people would demand either 0 or 1 apartments depending on the price: there's some price point where this person would rent an apartment and if the price goes above that they won't (they'd live at home, live with a roommate, live in a different city entirely, etc.). Unless the price where each person would rent is evenly distributed across all people, the demand curve won't be linear; if there are some people who would rent regardless of the price and a minimum price below which almost everyone will rent it might look like this:

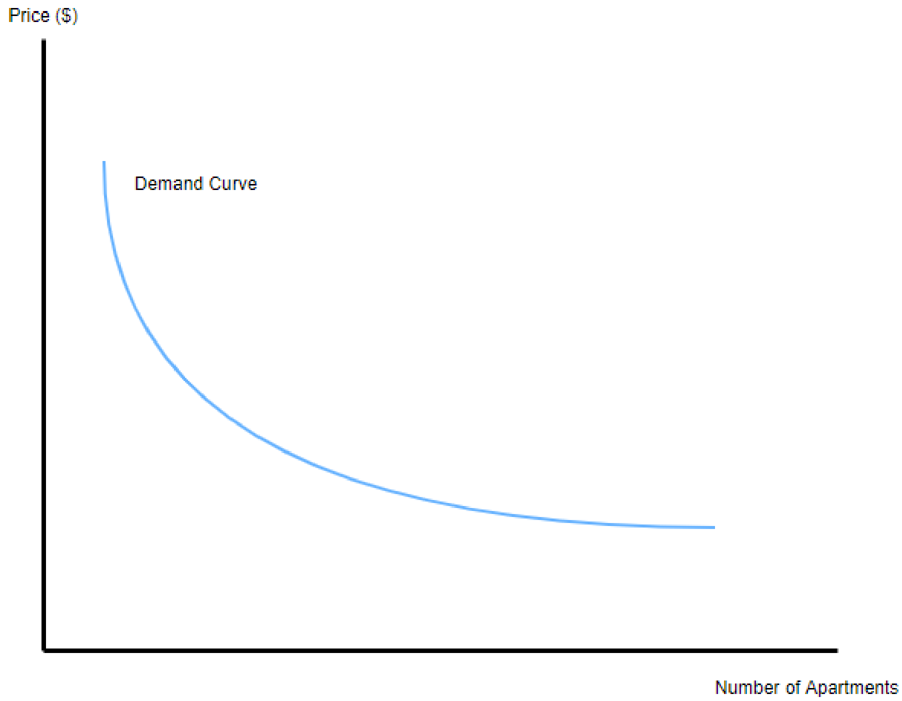


Figure 2 - Demand Curve of Apartments

5.3. Supply

A supply curve shows the quantity of a good that producers are willing to sell at a given price. Similar to demand, the vertical axis shows the price of a good while the horizontal axis shows the total quantity supplied. So, the supply curve is a relationship between the quantity supplied and the price – just like a demand curve is with quantity demanded. The basic model of both supply and demand is the workhorse of basic microeconomics.

In terms of engineering, many of us end up in jobs that focus on the supply dimensions as supply projects typically result in tasks such as design, analysis, production and efficiency. So, we will dig a little deeper into the supply aspect of the Supply-Demand relationship than we did for the demand aspect.

While a firm will incur certain expenses for start-up costs related to production (machinery, space, employees, etc.). The average cost of production will likely fall as more goods are produced, since marginal costs will decrease as the start-up costs are distributed across the increasing number of units made (and later sold). However, speaking in the short-term specifically, that marginal cost will begin to rise as the limits of the current production set-up are pushed. As the production space gets overcrowded, and the firm tries to still produce more units, additional costs will be incurred in the form of extra workers, machinery, materials, etc., leading to diminishing returns and an increase in marginal cost per unit. Eventually there would be a need for a new production space, adding another huge cost to be distributed across the number of produced units, etc.

For this reason, a supplier might only be able to produce *x* units at price *P*, since eventually the marginal costs will increase to the point where the firm is losing money for each successive unit. If that price *P* increased, the firm could cover the costs of additional units and make more while increasing profit. Additionally, *P* increasing will eventually allow new firms to enter the market, once they determine they can produce without losing money.

Just like demand curves, the market supply curve is an aggregate of all individual supply curves.

Table 3 – Supply Schedule of a Product

Price ($)	Firm A's	Firm B's	Firm C's	Firm D's	Market
10	10	0	0	0	10
20	15	5	0	0	20
30	30	10	5	0	45
40	45	15	15	10	85
50	50	20	25	15	110
60	55	25	35	20	135

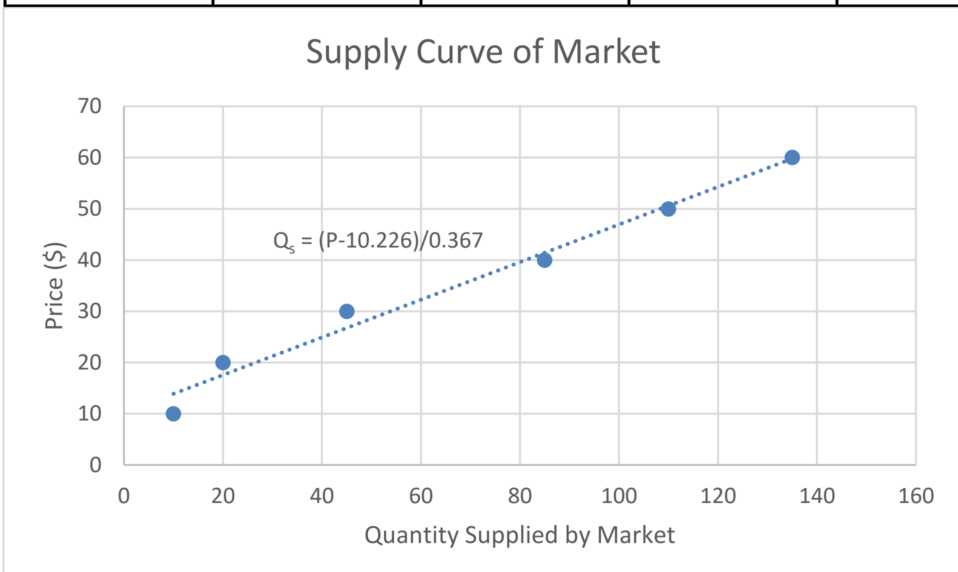


Figure 3 - Supply Curve of a Product

Different products/goods will have differently shaped supply curves, based on how people behave. Even the same product can have different supply curves based on the timeframe we're evaluating them on. Think back to the apartments example from earlier; what does the supply curve look like over the next month? It's more or less fixed: the supply of apartments will be constant at some level, no matter how much someone is willing to pay. There just isn't enough time to build more! If we were to evaluate several years instead, that could allow for the construction of additional units.

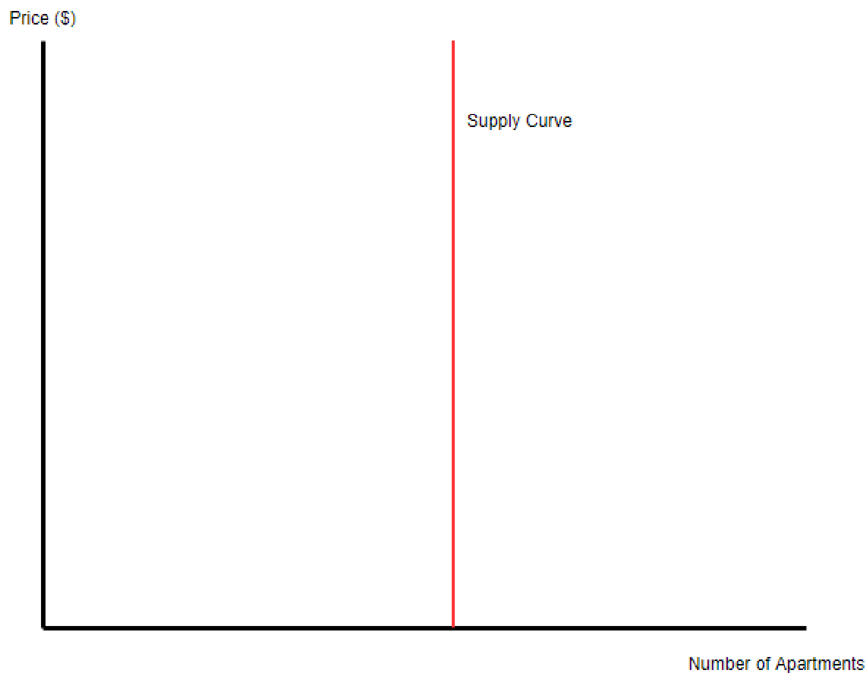


Figure 3 - Supply Curve of Apartments in Short-term

Overlaying the demand curve and the supply curve can give us an equilibrium point; the price at which the quantity demanded will equal the quantity sold. If you know the expression for both the demand and supply curves, you can calculate P* by setting the Qs = Qd and solving for P.

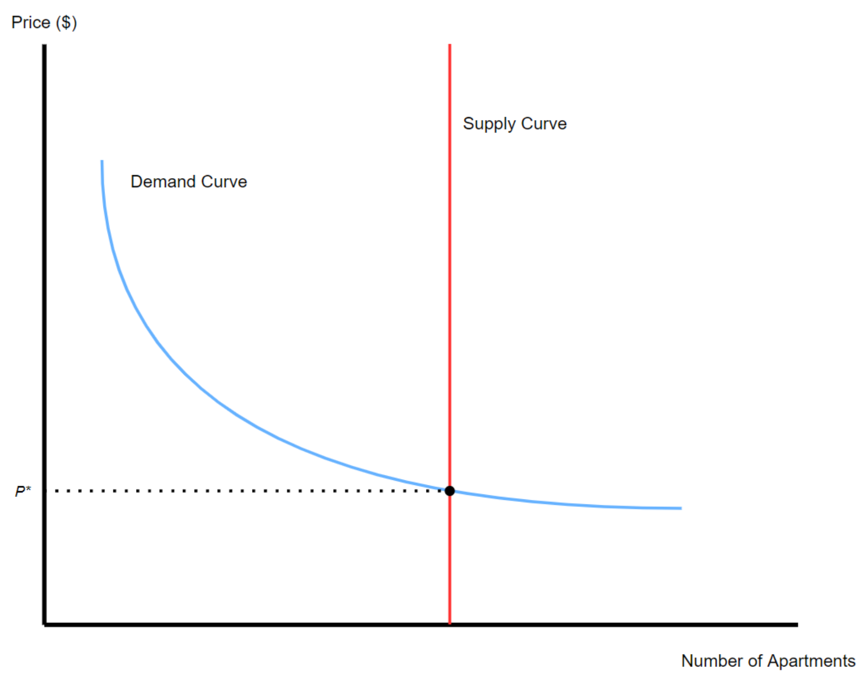
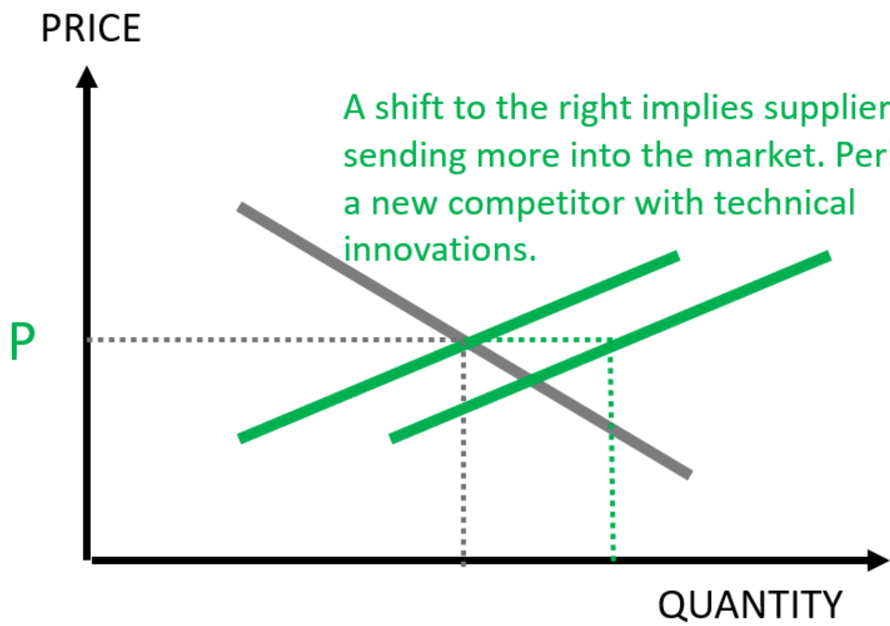


Figure 4 – Equilibrium Point of Apartments in Short-term

5.3.1. Determinants of Supply

Quantity producers are willing to supply at a given price depends on their production costs, including wages, interest charges, and cost of raw materials. If the goods a firm produces sell at a higher price, more current firms can expand production (hiring workers, affording overtime work, increasing plant size, etc.). Also, more newcomers can enter the market, as the previously prohibitive entry costs to beginning production are now massaged by higher expected revenues.

If the cost of production materials falls, production becomes more profitable, encouraging existing firms to expand production and enabling new firms to enter the market. The entire supply curve shifts rightward:



Whether this ultimately results in a price or quantity change also depends on the demand curve; we'll explore this interaction in section 5.4.

5.3.2. Shifts in The Supply Curve

Shifts in the supply curve can be typically influenced by many factors. This first set are typical of the kinds of issues that engineers have to deal with that will directly impact an organization's Supply strategies and perspectives:

- Technical Progress
  - New processes, machinery, or materials influence the technique of production (and therefore the volume of production)
- Change in Factor Prices
  - Land, labour, capital, and entrepreneurship
- Fiscal Policy, Taxes, and Regulations
  - Changes to import duties, changes to taxes on some categories of goods, and regulations that impact the production of a good (environmental, etc.)
- Transportation Improvements

    - Improvement in the means of transport reduces total costs. Can also impact the range of transport and thus the reach of the firm.

But as we have seen many times, economics can always have uncertainties and risks such as the following. Engineers are often called to teams involving colleagues with other specializations to respond to challenges posed by such influences.

- Natural Conditions
    - Floods, droughts, earthquakes, seasonal weather
- Calamities
    - War and famine cause shortages of supply and dislocation of production. These conditions can be significant enough that no price can bring about adequate supply as production simply cannot occur.
- Monopolies
    - Deliberate manipulation of supply as seen fit by the monopoly. The exercise of monopolistic power can increase or decrease supply on a whim. To a slightly less extreme extent, so can oligopolies, whom we see more often in the real world.
- Seller Expectations
    - Expectations of future market conditions affect today's production. If a change in political climate leads owners of oil supplying firms to believe the price of oil will rise in the future, then the owners may choose to wait to sell their supply until prices have been raised.
- Number of Sellers in an Industry
    - Having additional sellers increases the quantity available at each price of a good, thus changing supply.

5.4. Comprehensive Example: A,B Circuit Board Companies

Let's return to our circuit example from weeks ago and evaluate potential supplier A who generally sells predictably at $100 per board and supplier B who is less predictable and can deliver at an extremely low price of $60 or a very high price of $130.

The background of this example is that A is a well established and respected company with a strong reputation for quality and dependability. Currently, they sell some specialized circuit boards to a *niche* market at a price of $100 and for now, they are the only supplier of these boards. Cost to them for parts, labour, and processing of each board is $60 for the $100 priced board.

This particular product was actually released to the market by A, a few years prior. Then over the next years, they bounced around different pricing and experienced varying degrees of good and not so good sales and profit results as this table shows.

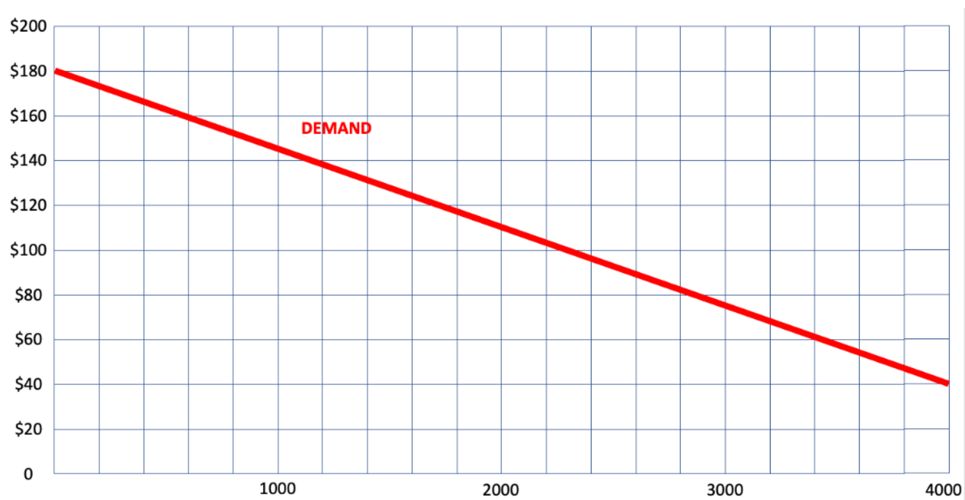
Year	Unit price	Unit cost of production	Total sales (units)	Total sales (revenue)	Total production costs	Profit
1	$150	$60	400	$60,000	$24,000	$36,000

2	$80	$60	1,500	$120,000	$90,000	$30,000
3	$100	$60	1,000	$100,000	$60,000	$40,000

In other words, they launched with a high ($150) price but then were not happy with the sales result. Then they dramatically cut the price ($80). Although they sold many more, their cost of production was so high that their profit actually dropped. In the third year, they pegged a middle price ($100) and found that their sales did well and their profit was acceptable.

5.4.1. Market demand

But senior management was not happy that they had to bounce around with different pricing. The business was too unpredictable. So, they commissioned some market research to get a clearer picture of the demand for this kind of product and the market's potential response to different pricing. Included in the final report was the following demand chart that estimates how much the market is willing to buy under certain pricing.



So, at the $100 mark, the research (and the chart) estimates that the market will be a little over 2,200 units.

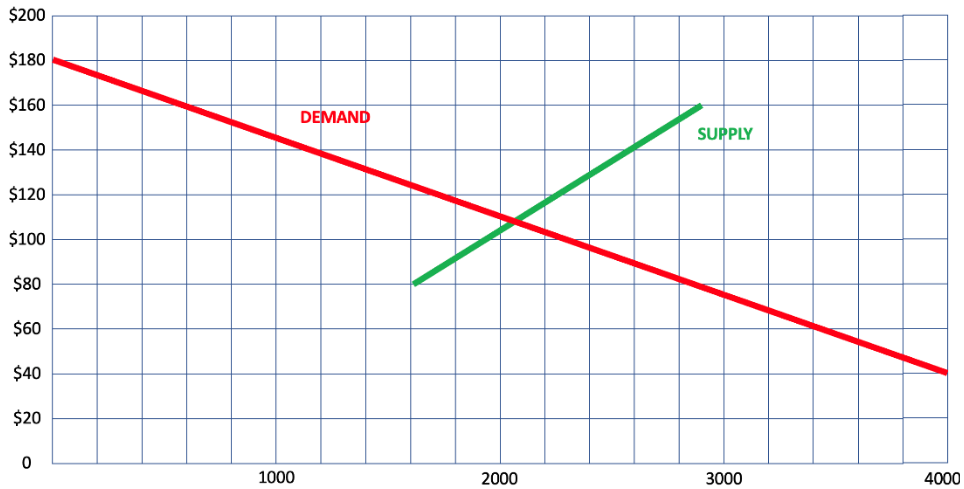
5.4.2. Supply strategy

The value of this chart is that the team can now begin planning for product and sales strategies. For example, we can now consider how much we are willing to supply to meet the market demand under various pricing. The engineering, production, and sales teams got together and produced the following projections for how much the company was willing to supply and the resulting profit benefit based on the assumption of $60 production costs per unit.

Price	Units	Sales	Profit
$ 80	1600	$128,000	$32,000
$ 100	1900	$190,000	$76,000
$ 120	2300	$276,000	$138,000
$ 140	2600	$364,000	$208,000
$ 160	2900	$464,000	$290,000

The production team then cautioned their management that if the number of units exceeded 2,000 they would have to retool and the new equipment would cost at least $200,000. Therefore, any price over $100 would incur this major additional investment. The engineering team was then tasked to do a cash flow and time value analysis! But that's a story for another day.

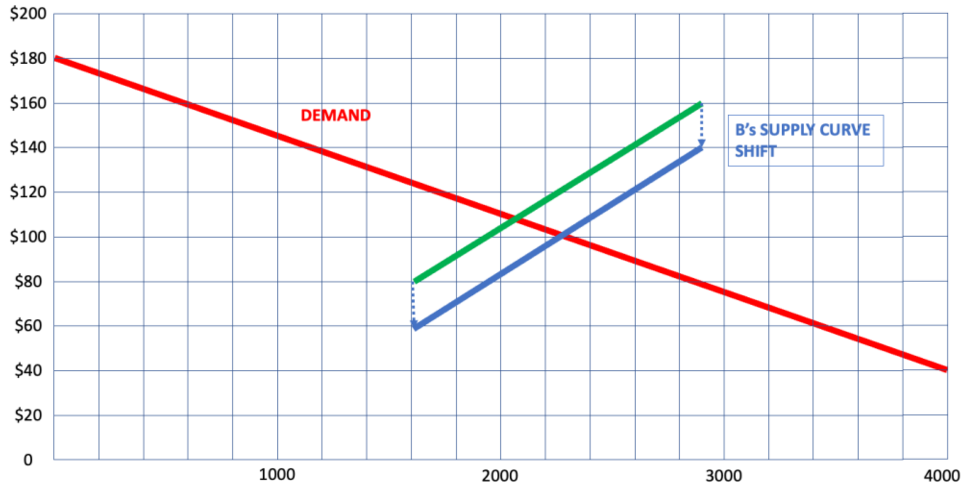
One clever engineering staff member took the initiative and plotted the supply projections onto the same demand graph to get the following:



This chart was presented to management as the basic model that will help the company's product planning – how many boards should they produce for various prices? From this chart, Company A was able to assess the various pricing options and how would adjust their production and sales processes to achieve good market acceptance. But a dark cloud was looming in the distance!

5.4.3. Supply and demand with competition

Company B is a new company that noticed the healthy business that A was developing and decided to enter the market. Through their own market research, they confirmed the data that A was using and managed to produce a similar Supply-Demand chart as A. In addition, B projected that they could produce a product of good comparable functionality but for lower production costs thereby allowing them to price their competitive product about $20 lower than A. From a chart perspective, this implies a shifting of the Supply curve downward by $20 based on the Price axis. This shift of the supply curve corresponds to B's willingness to supply comparable quantities to A but at a lower price.



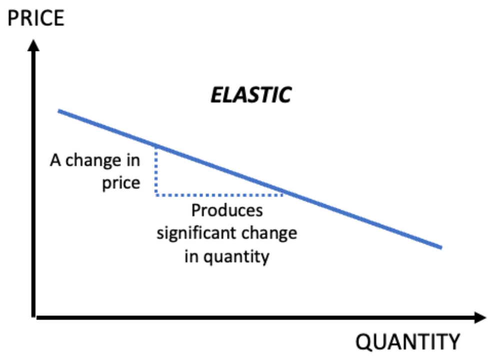
Part of the engineering effort under this strategy is to find ways to save the necessary $20 in the production while not sacrificing quality or functionality by using cheaper parts.

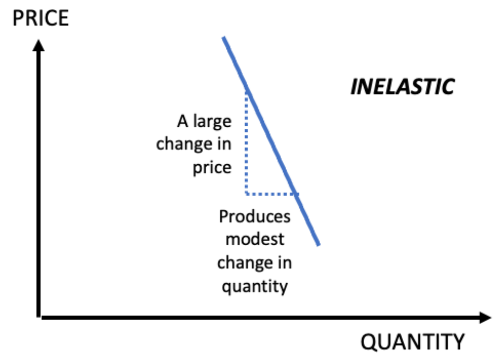
The typical work that engineers would do in situations like this could include:

- More clever designs that reduces total numbers of components
- Alternate suppliers of parts
- Efficiencies in assembly and testing
- Efficiencies in warehousing, logistics, and distribution
- Broad reduction of technical overhead

5.5. Elasticity

One way that we can add greater sophistication in our model is to introduce price elasticity which is a calculation for the amount that quantities change in the market when prices change -- I.e. how responsive is the market to the price change? A market is called "Elastic" if a modest change in price causes significant change in quantity. "Inelastic" refers to when even a large change in price produces only a modest change in quantity. Strictly speaking, if the *% change in quantity* divided by the *% change in price* is greater than 1, the supply or demand is considered elastic, or inelastic if this value is below 1 (and above 0). Graphically, we can envision it in the following way:





As these diagrams suggest, the mathematical formulas are of the form of a slope. Specifically, they are defined as,

$E_s = \left|\frac{(\frac{\Delta Q_S}{Q_S})}{(\frac{\Delta P}{P})}\right| = \left|\frac{P*\Delta Q_S}{Q_S*\Delta P}\right|$, where Q_S is the quantity supplied at price *P*.

This formula is for the supply elasticity – i.e., how the supply quantity responds to price change. There is a similar formula for demand elasticity (swap out instances of Q_S for Q_D). It's important to note that with demand elasticity, the result will always be negative (as increasing price means decreasing quantity, or vice versa, along the demand curve). To avoid confusion (mistakenly reading negative elasticity as referring to inelastic goods), we read elasticities as absolute values.

Engineers are often more involved in issues of supply. For example, if their company is producing products for a relatively elastic market then strong engineering efforts to reduce production and distribution costs could significantly improve sales. Or clever designs that reduces components while maintaining functionality can also reduce price and increase sales.

Any product that has lots of competition and choices for consumers is likely elastic. Canned soup, a standard laptop, a basic bike, etc. is considered elastic.

More exclusive or hard to source items such as specialty medications, gasoline, luxury items, etc., are considered inelastic as consumers may have very limited choice.

5.5.1. Elasticity Example

Suppose the supplied quantity and price of a particular good are linked by the equation, $P = 0.04Q + 300$, for 0 ≤ Q ≤ 15,000. What is the supply elasticity of this good?

First, let's rearrange for Q_S: $Q_S = \frac{P-300}{0.04} = 25P - 7500$. Next, for the elasticity formula, we'll need ΔQ_S, which can be found by taking the derivative of Q_S with respect to *P*:
$\Delta Q_S = \frac{dQ_S}{dP} = 25$, or in other words: for every ΔP of 1, we have a respective ΔQ of 25.

Now let's use the elasticity formula.

$$E_s = \left| \frac{\left(\frac{\Delta Q_S}{Q_S}\right)}{\left(\frac{\Delta P}{P}\right)} \right| = \left| \frac{P * \Delta Q_S}{Q_S * \Delta P} \right|$$

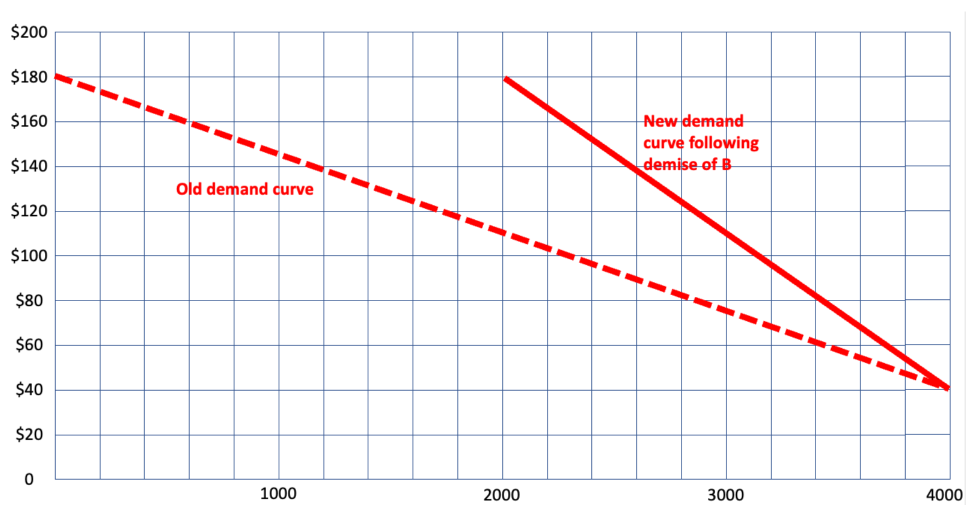
$$E_s = \left| \frac{P * 25}{(25P - 7500) * 1} \right| = \left| \frac{P}{P - 300} \right|$$

If we wanted to find the elasticity at a certain price – say, E(400), we'd use the above equation to figure that out. In this case, at a price of $400 per unit, the elasticity of this good is 3. By definition (elasticity being the change in % quantity divided by the change in % price), this means that for every 1% increase in price, there is a 4% increase in quantity supplied. We can double-check this. At P = 400, Q_S = 2500. At 1.01P, Qs* = 2600. 2500 to 2600 is a 4% increase – so this was done correctly.

5.5.2. Circuit Board example

Supposed that Company B did enter the market and as we know, from previous weeks, they struggled to provide dependable prices to the market. They needed a one-month lead time and they could not guarantee whether the final sale price would be the low $60 or the high $130. Because of this uncertainty, Company B sales never took off and within a year, they stopped production and left the market. Once again Company A was alone in the market.

But the turbulence that B caused with their unpredictable pricing really bothered potential customers who wanted stronger predictability in the supply chain. Company A once again commissioned a market study and to their delight, it discovered that the market turbulence had made this product much less elastic as the new curve shows.



From this curve, it is clear that even for a very high $180 price, there is a reasonable market size of 2,000 indicating that the departure of B removed a competitive choice and the market values stability and predictability of supply.

5.6. Economies of Scale

When engineers work on products that sell in relatively high quantities, one important factor they consider are economies of scale. When you buy one lemon, it may cost you one dollar but often, the same store will sell you a bag of six lemons for $3. We might call it bulk pricing but the reduction in price of the lemons is the same basic concept that we call economies of scale.

As companies plan to produce greater quantities of their products in response to increasing market demand, engineers are often called upon to refine designs and supply chain choices to help reduce production costs. An obvious use of economies of scale is to simply source your components and parts which may give the company a much better price as they are buying in higher quantities. But engineers can get cleverer. When quantity goes up, even if their parts pricing does not go down, they may be able to make design choices that produce same functionality for fewer or simpler design elements.

For example, if the circuit board used a particular set of three standard chips and an engineer sourced an alternate single chip that provided all of the functions as the three chips but at a lower cost than the combined three chip price, they would see significant savings when scaled to large quantities.

Hypothetically, one of the reasons that the Company B could have failed is because they could not figure out how to predictably scale their basic designs into high quantities by securing good suppliers of components and having elegant efficient designs.