Operational Analysis of the Knife Manufacturing Industry

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Introduction

Steel

The steel industry is one of the largest manufacturing industries in the world. It is also one of the most energy and greenhouse gas intense industries and contributes to around 8% of global emissions across all industries. Steel is also very reusable and has a global recycling rate of over 60%. Some of the largest crude steel producers include China, Japan, the United States, India, Russia, and South Korea (Wikipedia: Steel). Steel is made from naturally occurring minerals like iron ore and oxygen. The raw materials are mined and then transformed into steel through a complex process with many significant players focused on improving the manufacturing efficiency and sustainability of the process. The first step in the process is ironmaking, where iron ore and other raw materials are cooked. The second is the steelmaking phase, where the iron and recycled steel scraps are melted and purified. There can also be a third step for high-grade steel products (Horiba: Iron and Steel Production, n.d.). A review from ScienceDirect analyzes the role of material stocks in economic development, especially concerning steel, because of its overpowering use in all physical services. It discusses how China's unparalleled expansion, combined with the economic disparities across the country, serves as a good indicator for assessing growth in both developing and developed countries (How Material Stocks Sustain Economic Growth).

Kitchen Knife Niche

MarketWatch classifies the kitchen knife market “in terms of market size, market coverage, market exchange rate, segmentation, and market share” (MarketWatch, 2022). It also discusses how the market is projected to grow significantly over the next few years, especially in revenue. Similarly, Fortune Business Insights outlines key market projections over the next five years and related industry drivers and restraints moving forward. The functionality of the kitchen knife is unmatched compared to other cooking appliances. Thus, developing new food or dining establishments like hotels, restaurants, and other related service outlets drives the market. On the other hand, the study identifies the increasing costs of resources needed for manufacturing processes as a deterrent to market growth (Kitchen Knife Market Size…, 2022).

Industry Overview

Cross Chain Issues

Currently, steel prices are down almost 20% since the beginning of 2022 and following historic highs in late 2021. For back-to-back Quarter 2s, steel was the third most sourced product due to companies working to rebuild supply channels following the pandemic and closure of major trade routes. As a result, there are common challenges and trends across all industries and supply chains. The steel industry has experienced material shortages, increased prices, and a struggle to meet demand with the disruption of trade routes. Manufacturers also face similar issues associated with stalled supply chains, rising costs of inputs, and labor shortages. Lastly, in the distribution and retail channels, supply chains struggle with labor shortages (specifically for truckers), lack of warehouse space, and growing online consumer demand. An article in Shopify's blog notes, "global supply chain disruptions have become common amid the pandemic, with shortages, rising import costs, and delays interrupting the normal flow of goods. The impact has been felt by the world's biggest companies and small businesses trying to secure the materials they need in a timely manner" (Strapagiel, 2022). The rising prices of inputs and declining selling prices of products due to consistently high demand have made streamlining manufacturing processes and stabilizing operations a priority to maintain profitability.

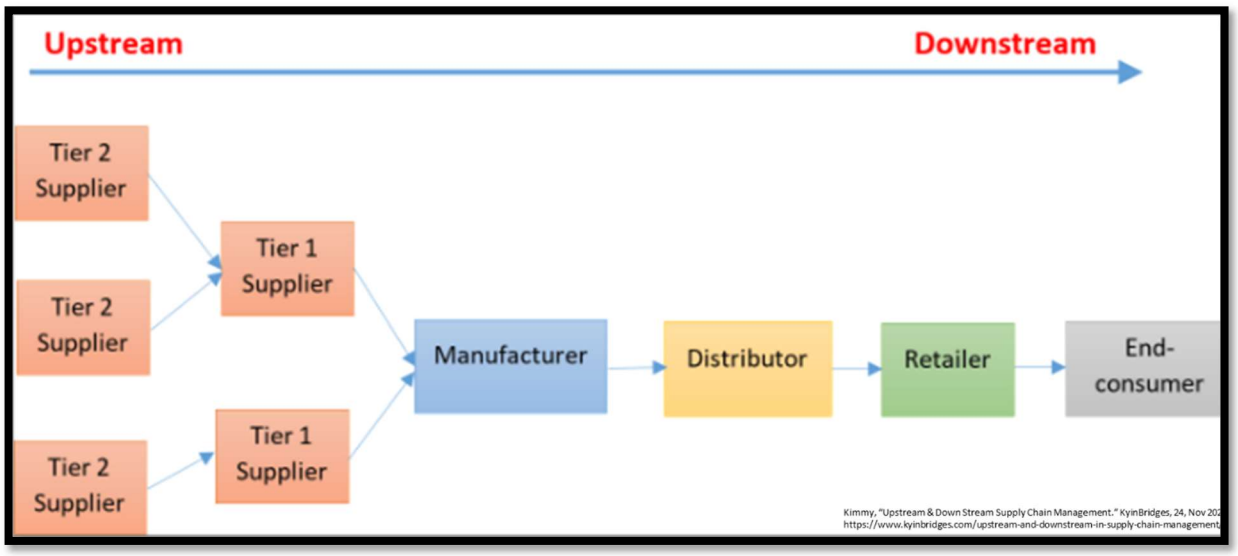
Typical Process Flow

Description

The typical process flow for steel or other manufacturers that source raw materials or commodity goods can be seen in the chart below. "Steel touches every part of the supply chain, from sourcing the raw material, to manufacturing products, to building the trucks and ships that transport goods to consumers" (Kaplan, 2018). The tier 2 boxes represent the raw material suppliers that extract these natural resources and include materials like iron ore and gold. The tier 1 suppliers include the refineries that source these natural resources and transform them into usable commodity goods. For example, how steel manufacturers derive steel from iron ores, or silver is derived from lead and copper ores. Next, we have the manufacturers that will then use these refined materials, like the automobile

manufacturers or construction companies that produce usable products for consumers. After manufacturing, finished products like cars, housing appliances, buildings, or knives move to the distributors before reaching the end-user.

Typical Process Map



Hypothetical Case

Hypothetical Case

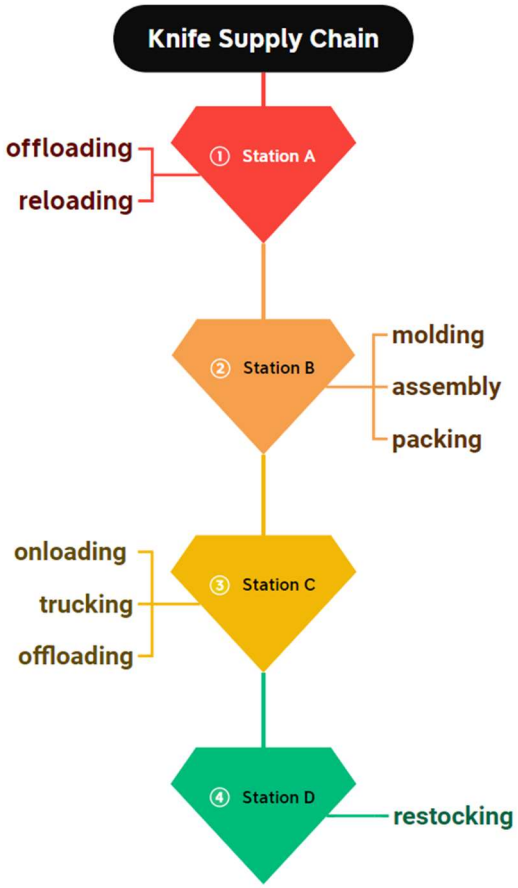
This knife manufacturing supply chain consists of tier 1 & 2 suppliers, a knife manufacturing and distribution plant (joined operations), and a retailer. The tier 1 & 2 suppliers provide the manufacturing plant with resources (plastic, steel, packaging materials) each day. The manufacturing and distribution plant produces a variety of knives, including kitchen, utility, hunting, and even collectible. Finally, we have a Retailer, an all-purpose home goods chain with five physical wholesale locations equally dispersed around the manufacturing plant. The manufacturer has recently partnered with an AI robot manufacturer to conduct pilot programs for supply chains operating under the Just-in-Time (JIT) inventory management method. With AI implementation, this program aims to alleviate truck drivers' workload and allow these JIT distribution channels to operate more efficiently. The pilot program also offers scalable production opportunities by reducing costs associated with human interaction in supply chains.

These may include but are not limited to costs related to wages, human error, quality assurance, theft, and unpredictability.

Process Map

This process map is a little more descriptive regarding the specifics of the manufacturing, distribution, and retail activities of the situation outlined in the hypothetical case. It outlines the sequential process of the manufacturing, distribution, and retail supply chain phases of the knife manufacturer. It is organized and oriented on production flexibility, efficiency, output quality, and costs. It is a process that requires total employee accountability and participation for continual improvement of manufacturing performance.

Station A highlights when the tier 1 and 2 suppliers arrive at the manufacturing plant and offloaders begin unloading the resources (steel, plastic, and packaging materials). This process activity is followed by reloading each assembly line with the required knife production resources. Station B includes knife molding, final product assembly, and packaging activities for the ten assembly lines and different styles produced on any given day. After products are assembled, packers at each line organize the final products by the quantity demanded by each wholesaler and conveniently place the shipping boxes for loading. Station C outlines the distribution processes that begin at the manufacturing plant. These activities include loading the final products, transporting the cargo, and then offloading at each wholesale location. Finally, station D begins at the end of each day with employees restocking the shelves and small inventory reserves at each site. The process activities section contains more information regarding the individual resource responsibilities and system caveats.



Identifying the Problem

Process Activities

The process starts each day at the same time when the tier 1 and 2 suppliers arrive at the manufacturing plant, and the offloaders can begin their activity. Knives are functional products and generally experience consistent demand, so it is assumed the manufacturer's quantity of inputs (from tier 1 and 2 suppliers) and outputs (finished products) remain constant. Again, this is a sequential process, so once one step completes, the next begins. The process activities for the hypothetical case described above are listed in depth below:

1. **Offloaders** – Offload the resources from the tier 1 and 2 suppliers' trucks. There are twenty resources and five trucks, so four are utilized per truck. Once the offloaders finish, they begin reloading.

2. **Reloaders** – Reload the ten molding machines with the steel and plastic resources. These workers also reload the cardboard shipping boxes for the packing activities.
    a) Human error includes incorrectly reloading material pallets or calculating the quantity needed at each line.
3. **Engineers** - Oversee the molding process for two hours and spend an additional hour servicing the machine. The machines must be serviced right before use and reprogrammed if demand changes, or new styles are introduced.
    a) The molding machines are reliable and only malfunction due to human error during reloading. Otherwise, the process has no unexpected or costly malfunctions if engineers keep up with daily service requirements.
4. **Assemblers** – There are two assemblers for each assembly line. One of the workers stencils a logo on the handle while the other checks the quality of each knife.
    a) Human errors include stencil misplacement. Final assembly activities generally remain consistent; however, if new styles or models begin experiencing heightened demand, the carvers must quickly learn a new pattern, increasing the chances of human error.
5. **Packers** - Once the final assembly completes, packers fill shipping boxes according to the quantity demanded at each wholesale location. There's no storage at the manufacturing plant so final products are packaged and placed for onloading at the same time each day.
6. **Onloaders** – Ten onloaders (two per truck) begin their activities and load the shipping boxes onto the truck. These resources are also utilized until activity step #8.
7. **Truckers** – Trucking routes to the
8. **Offloaders** - Offload shipping boxes at each of the wholesale locations.
9. **Stockers** - Employees at the five wholesale locations are required to handle unpacking products, restocking shelves, and the small reserves. Each retail store has an inventory reserve if shipments are delayed, or demand predictions fluctuate.
    a) Human error consists of inventory miscalculations, product misplacement, and employee theft.

Utilization Calculations

**Note – Please see the data analysis section for more details. Hourly activity time calculations can also be found in Appendix A.

Station	#	Activity	# Resources	Job Desc	
A	1	offloading	**20**	offloader - offload materials from tier 1 & 2 suppliers	4 per truck
	2	reloading		reloader - reload molding machines w/ resources	2 per line
B	3	molding	**2**	engineer - program/ service machines, oversee molding/ blade carving	2 per plant
	4	assembly	**20**	assembler - stenciling & quality check	2 per line
	5	packing	**50**	packer - pack final products & place for onloading	5 per line (1 per loc)
C	6	onloading	**10**	onloader - load final products at manufacturing plant	2 per loc or truck
	7	trucking		trucker - route to physical store location	2 per loc or truck
	8	offloading		offloader - unload final products at physical stores	2 per loc or truck
D	9	restocking	**25**	stocker - unpacking, restocking shelves & store reserves	5 per store
		total	**127**		

Utilization by Station

Station	# Resources	Activity Time (mins)									Workload	Capacity	Utilization
		1	2	3	4	5	6	7	8	9			
A	40	120	120								240	0.1667	42.86%
B	72			180	240	60					480	0.1500	47.62%
C	30						120	180	120		420	0.0714	100.00%
D	25									180	180	0.1389	51.43%
	167										**1320**	**0.0714**	
											22	**hrs**	

**Note – Disclaimer, these numbers are entirely made up and do not represent a real knife manufacturing supply chain. They are to illustrate my findings of the key issues of supply chains in the steel manufacturing industry and knife manufacturing supply chains alike.

Data Analysis

The chart at the top outlines the required number of individual resources to complete the supply chain processes daily. It provides information on each activity's job description and organizes the resources and activity steps by station (A, B, C, or D). The process requires 127 individual resources to complete in 22 hours each day. It is important to note that Stations A and C utilize the same resources at each activity step in their immediate station. The charts on the bottom calculate the utilization of each station. The trucking and loading activities in station C are overutilized due to reuse at each activity step. Station C has the second longest processing time and is also the bottleneck. Stations A and B are underutilized, with a large number of resources required for the process's

execution. The result is additional slack between the activities, increased work required due to excess resources, and a higher likelihood of human error.

Assumptions

Notable Implementations

Today, there are many examples of successful AI implementations throughout supply chains. In addition, there is a breadth of supporting research indicating these AI implementations can improve the efficiency of these supply chains and will become increasingly important in the next few years. In the human-focused approach, the system utilizes molding or carving machines to ensure the quality of the knives is consistent. Despite this version being very dependent on human labor, the molding machine eliminates some variability of the outputs. It allows the process to operate efficiently and significantly reduces human error compared to systems using traditional grinding methods.

One noteworthy example in the knife manufacturing industru is KUKA Robotics & Automation, which demonstrates how automated implementations produce higher-quality knives than traditional grinding methods (Robots produce knives of higher quality than the traditional grinding method does, 2022). Another example is Locus Robotics which develops automated warehousing robots, a crucial aspect of the supply chain. Geodis, a global warehousing and logistics firm, has experienced continued improvements since 2018, following their expanded partnership in 2020. Automated mobile robots (AMRs) have enhanced flexibility and productivity while also reducing tedious and repetitive tasks among employees. The AMRs allowed for improved coordination between sites and helped scale performance. AMRs also improve the working environment and ability to satisfy customers' needs with rapid digitalization (GEODIS, 2020). Automated solutions are becoming increasingly versatile and advantageous to promoting stable and efficient operations throughout supply chains. Given the characteristics of the knife manufacturing niche and the overarching power of the steel industry, automating downstream channels provides many operational advantages.

Recommendations

Process Activities (AI)

Below are the refined AI-focused process steps. This version works almost identically to the initial human-focused process. The only difference is that the manufacturing plant has added a plant supervisor. The plant supervisor oversees the entire manufacturing facility and ensures activities #1 through #6 go smoothly; however, they are not included in the utilization calculations.

1. **AI Loaders -** The loading machine on each truck replace the group of offloaders from this step in the human-oriented process. Now only one trucker is required for shipping activities.
2. **AI Pickers (reloaders)** – Five AI picker bots (1 per 2 lines) are responsible for reloading the molding machine and refilling the packaging station.
3. **Engineer**s – The engineers' job responsibilities stay the same.
4. **Assemblers** – There are ten AI assembling bots (one per line instead of two). Human errors associated with stenciling and adequately identifying defective knives from the molding and carving stages are mitigated.
5. **AI Picker (packer)** – Ten AI packers organize the direct assembly line's products by location. The robot can handle the more complex task of deciphering which finished products in the immediate line need to go in a particular shipping box. In the human-oriented process, each line had one resource responsible for packaging the finished products going to one location.
6. **AI Loaders** – Once packaging completes and the picker bot has placed all the shipping boxes at the load spot, onloading begins. The loaders in activity steps # 6 and #8 are the same resource.
7. **Truckers** – There are only five truckers because they are no longer needed for loading steps. They are only responsible for transporting the final products to the drop spot.
8. **AI Loaders** – Once the trucker arrives at the warehouse's drop spot, loaders begin offloading shipping boxes from trucks.
9. **AI Pickers (restocker)** – One AI picker robot at each location replaces the employees responsible for stocking and inventory management activities from the human-focused system.

Utilization Calculations (AI)

**Note – Please see the data analysis section for more details. Hourly activity time calculations can also be found in Appendix A.

Station	#	Activity	# Resources	Job Desc	
			1	**plant supervisor - oversee facilitiy ops (#'s 1-6)**	**1 per plant**
A	1	offloading	**5**	ai loaders - offload materials from tier 1 & 2 suppliers	1 per truck
	2	reloading	**5**	ai picker (reloader) - reload molding machines w/ resources	1 per 2 lines
B	3	molding	**2**	engineer - program/ service machines, oversee molding/ blade carving	2 per plant
	4	assembly	**10**	ai assemblers - stenciling (no quality check needed)	1 per line
	5	packing	**5**	ai picker (packer) - pack final products & place for onloading	1 per 2 lines
C	6	onloading	**5**	ai loaders - load final products at manufacturing plant	1 per truck
	7	trucking	**5**	trucker - route to retailer wait for loading phases to complete	1 per truck
	8	offloading		ai loaders - unload final products stores	1 per truck
D	9	restocking	**5**	ai picker (restocker) - unpacking, restocking shelves and reserves	1 per store
		total	**43**		

Utilization by Station

Station	# Resources	Activity Time (mins)									Workload	Capacity	Utilization
		1	2	3	4	5	6	7	8	9			
A	10	60	120								180	0.0556	50.00%
B	17			180	120	180					480	0.0354	78.43%
C	15						60	180	60		300	0.0500	55.56%
D	5									180	180	0.0278	100.00%
	47										**1140**	**0.0278**	
											19	**hrs**	

Data Analysis (AI)

The charts for the AI system follow the same structure as the human-focused charts. AI robots improve the efficiency of the supply chain and mitigate the underutilization of resources. They also reduce costs associated with employees and human error while handling more complex steps predictably. This AI-focused process requires a significantly lower number of individual resources to complete daily activities (43 compared to 127). This system also operates at a reduced total processing time (workload) as it completes two hours quicker, 19 hours compared to 22 hours in the human-focused process. This AI-focused system mitigates the overutilization of the trucking and loading steps (station C), which are now operating at almost a 50% reduced utilization rate. The AI implementation has also mitigated the underutilization of Stations A and B. In the human-focused system, these activities are severely over-resourced, prone to human error and even theft, as the knives are made of quality materials. Although the truckers' overutilization is mitigated, there is still a waiting period for truckers when cargo is either being

onloaded or offloaded. The bottleneck of this system is station D, as the manufacturing plant prioritizes manufacturing and distribution processes because they offer more scalable outcomes, because the wholesaler is unlikely to demand more knives on short notice.

Conclusions/ Suggestions

An AI-focused process offers increased scalability, efficiency, and accuracy throughout manufacturing and distribution activities. These include but are not limited to, reduced costs associated with wages, human error, quality assurance, theft, and unpredictability. Given the nature of the steel industry, its effect globally, and the current condition of the steel industry (and associated supply chains), hedging against increasing materials prices and global supply chain issues with stable, AI-focused operations will be advantageous in the long run.

The hypothetical AI-oriented process demonstrates more stable and efficient operations can offer more opportunities for scalable expansion. The higher profit margins allow for exploration and development into alternate downstream channels. This aspect is advantageous, specifically regarding the knife niche with its heightened popularity among online spaces as well as the increased adoption of business operations through digital or e-commerce platforms. These digital advancement opportunities can be catalyzed with fulfillment networks, like ShipBob or Shopify's Fulfilment Network (SFN), that automate distribution activities and streamline inventory management processes (ShipBob, 2022). For example, SFN promotes localization around target markets and allows merchants to customize delivery structures like whether products are to be shipped across the country, shipped locally, or even picked up locally (Shopify Help Center).

There are also investment opportunities with the ai oriented process. More stable and reduced operational costs make exploring the advantages of using innovative or sustainable materials more feasible. These can have higher initial costs for setting up the equipment or proper supply channels but can provide higher margins once the manufacturing process is in place and ready to be scaled. For example, moving from using plastic to a more eco-friendly or biodegradable material for manufacturing knife handles. There are also possible opportunities for utilizing 3-D printing materials, given the supply chain issues with steel and other commodity goods. Given the

global economic and steel industry projections for the next five years, investing in automation and improved operations will provide more flexibility to steel knife manufacturers and supply chains.

Appendix A

Activity Time Calculations (Human)

Human Focused					
Station	**#**	**Activity Step**	**# Resources**		**Time (hr)**
A	1	offloading	**20**	4 per truck	2
	2	reloading	**20**	2 per line	2
B	3	molding	**2**	2 per plant	3
	4	assembly	**20**	2 per line	4
	5	packing	**50**	5 per line (1 per loc)	1
C	6	onloading	**10**	2 per loc or truck	2
	7	trucking	**10**	2 per loc or truck	3
	8	offloading	**10**	2 per loc or truck	2
D	9	stocking	**25**	5 per store	3
		total	**167**		**22**

Activity Time Calculations (AI)

AI Focused					
Station	**#**	**Activity Step**	**# Resources**		**Time (hr)**
			1	**1 per plant**	
A	1	offloading	**5**	1 per truck	1
	2	reloading	**5**	1 per 2 lines	2
B	3	molding	**2**	2 per plant	3
	4	assembly	**10**	1 per line	2
	5	packing	**5**	1 per line	3
C	6	onloading	**5**	1 per truck	1
	7	trucking	**5**	1 per truck	3
	8	offloading	**5**	1 per truck	1
D	9	stocking	**5**	1 per store	3
		total	**48**		**19**

Human Vs. Robot Resource Chart (AI system)

resource	**activity #**	**count**	**funciton**
** ai **			
loader	1, 6, 8	10	on- & offload trucks
picker	2, 5, 9	15	organize, pack, stock
assembler	4	10	final toy assembly
	total	**35**	
** human **			
plant supervisor	n/a	1	oversee steps 1 - 6
engineers	3	2	unchanged
truckers	6, 7, 8	5	transport, waiting period
	total	**8**	

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