Università
Ca'Foscari
Venezia

Master of Science in

International Management

Final Thesis

Application of Artificial Intelligence in Traditional Supply Chain Management Decision-Making

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Academic Year

2019/2020

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Introduction

In the era of information technology and continuous innovations, the vulnerability of supply chain has increased dramatically due to greater fluctuation in demand uncertainty, supply risks, and competitive intensity among businesses, which often hinges the supply chain organization's ability to integrate and orchestrate the entire process from end-to-end. Since such ability has become the centre of many researchers and practitioners attention, supply chain management (SCM) is becoming more information intensive and focus has been not only directed to generation and collection of data, but also its usage in business decisions. Evidently, there are many pre-existing statistical methods that explored and adopted by industry professionals to leverage it to make better business decision. But with the new speed of innovations and agile industrial evolvements, the traditional way of processing information became nothing but bottleneck. Thereof, one of many new ways to help managers to perform better include artificial intelligence (AI) that has been existed for over decades but has not been fully utilized in some areas of supply chain.

In general, AI signifies an advanced computer-based technology that can mimic human behavioural patterns, create, and retain knowledge through its experience in problem-solving. Since AI has superior skills and ability to learn and comprehend new concepts, perform reasoning and draw conclusion, it has been successfully applied to computer gaming, semantic modelling, human performance modelling, robotics and machine learning, and data mining (Min, 2010). However, the potential application of AI has not been fully explored in the traditional management philosophy and practices in supply chain industry. As a result, it has sparked a motive for this thesis, to further explore how such system can be applied to comprehensive and complex, interrelated decision-making processes to solve joint problems in supply chain environment. And why it should be taken seriously in not only in a business environment, but also it extended network of supply and demand. With this goal in mind, the main objectives of this thesis progress around following:

- What are the existing literatures, assessments, and techniques in SCM decision practices?
- What are the existing applications of AI to SCM with the respect of practical implications?
- How development of systematic categorization of SCM decision periods can alter the application of AI?
- What are the sub-fields of AI that are most suitable for SCM applications and how can these characteristics help to improve the SCM efficiency and effectiveness?
- What are the future trends, outlooks for extensions of current AI and its related research and applications?

In the beginning, the thesis explores the decision-making processes to understand the very core of our research topic, how decision is formed, followed by its evolvement overtime in business environment. In relation to the research objectives, the paper the continues its course on exploring and explaining the characteristics of traditional SCM and its approaches that have been utilized for many years to support the changes in the industry. Based on its characteristics, the problems in SCM became broader and multifaceted. Therefore, Chapter 3 of this thesis is fully dedicated for studying issues in the industry in three different time horizons, short, medium to long terms. Meanwhile investigating variety of problems, the chapter also widely considers two important hypotheses, such as.

- Is modern concept of applying AI and Machine Learning in businesses are a fad?
- Is applying AI and ML tools and techniques will improve the quality of SC managerial decision making?

To approach these hypotheses, the chapter is organized in a way of raising relevant and challenging questions and openly discusses the elements. With the intriguing exploration, in Chapter 4, many risk mitigation strategies can be realized and presented, while comprehending flexible application of AI techniques across SC areas. For example, artificial neural network (ANN) in a complex demand and forecasting, machine learning (ML) models in the information processing, and robotics training, fuzzy logic in incessant bullwhip effect, and agent-based modelling in SC integration setting. Fundamentally, being aware of such factors can help the managers and business owners to adjust and redesign the SC end-to-end process, at the same time, it also displays how right network of systems can enhance the potentials of such algorithms.

Finally, in the next chapter, the paper introduces the big question of how AI is shaping the current and future of SCM, and what are the external factors need to be considered overall in the decision making, and concluded with remarkable notes.

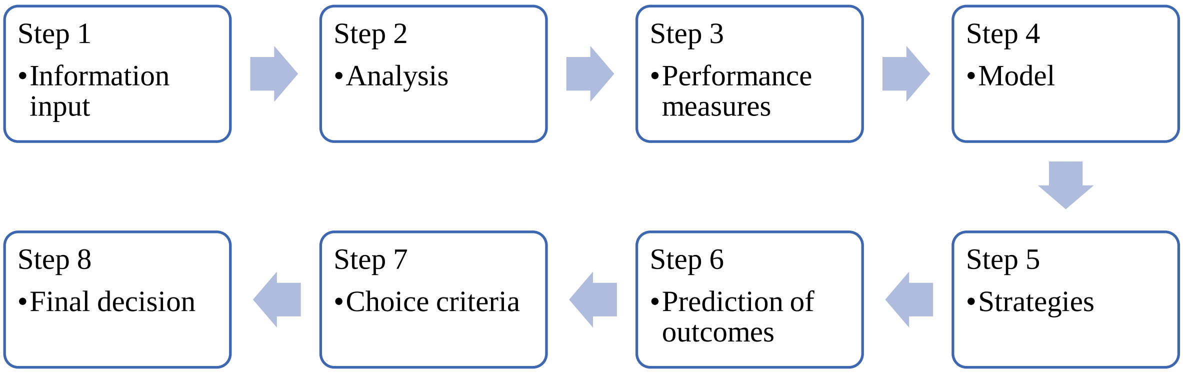
Chapter1. Decision Making

1.1 What is a Decision?

One can find many different definitions and discussions on decision tree, models, game theory and analysis, statistical modelling, and efficiency allocations under uncertainty, yet we know less about what a decision is itself. It is often associated with the outcomes and alternative courses of actions, thereof made me wonder, what makes this activity so special. While Fishburn (1964) provided us the definition of a decision in relation to its expected strategic value in each situation, Ofstad (1961) delivered more concise definition. According to his work, “perhaps the most common use of the term is this: to make a decision means to make a judgment regarding what one ought to do in a certain situation after having deliberated on some alternative courses of actions”. Essentially, it means that decision maker has series of alternatives that he/she can perform comparison between the alternatives and make evaluations of their outcomes. More importantly, a decision must have a followed action to justify its purpose, otherwise, it would have no meaning.

A decision, too, follow a subsequent number of steps, which is known as the decision process. This series of actions that generalizes what are the mental processes that human goes through before arrives at his/her conclusion.

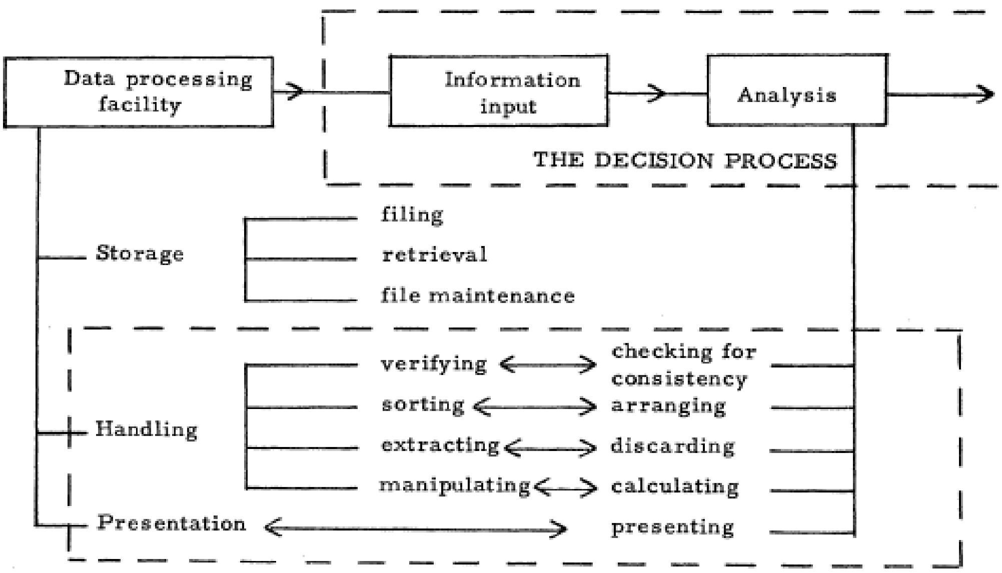
Figure1. Decision making process



Source: Eilon (1969)

Information is crucial for decision-making process, to analyse and define the performance measures. Data is being processed and analysed in a way that human can read and understand the meaning. If we examine, however, data or information alone, it may or may not make sense to understand fully. The activities involved in data processing consists of three major activities, namely (1) data storage, (2) data handling, (3) data presentation (Eilon, 1969). Eventually these three categories further divide into several different groups. For the simplicity, we will investigate traditional model, which was proposed by Eilon (1969). But keep in mind that modern data processing is more complex due to the intensity and availability of data.

Figure2. Data processing and analysis



Source: Eilon (1969)

Above Figure 2 depicts what does decision maker do when he or she engages in data processing and analytics. Before diving into checking for data consistency, which is thereabout same as verification function, decision-maker should ensure that data is available in his-her storage. In human terms, it is the brain activity of searching through his memory and experience. If the information required is unavailable, then he or she should collect related data from outside. Once the process of data collection and verification activities are complete, next is to sort and arrange the information, while discarding less relevant information for his or her analysis. After data extraction, then data calculation and manipulation activities can take place to trigger the model building part of the process. In a way, all these activities also can fall under the analysis function of decision-processing, therefore, it can overlap simultaneously.

Without these preliminary tasks, building model would be impossible. The main purpose of a model is to describe the behaviour of the system that the decision maker is trying to control, without no alternative courses of action to be considered. Prediction of outcomes is meaningless unless it corresponds to set of alternative strategies. And methods for choosing between them may well have to be delayed until the expected outcomes have listed. The final act is to specify the criterion of choice. One missing detail in the figure 1 is the feedback loop of arrows that interrelates the activities with each other and make the further decisions possibly better.

In reality, we do not follow every single step, sometimes we skip certain stages using heuristic reasonings, and other times the input or the need becomes irrelevant, therefore we cease the decision process. The key comment to be made here is distinction between rationality and irrationality of decision. Rationality depends on the endowed sensible and sane reasoning, with orientation of goals or meaning in present to achieve. Furthermore, according to Churchman, ethics and morality cannot be separated from the concept of rationality, since they are often embedded in the determination of goals, otherwise there is no way of telling what is absolutely right or wrong (Eilon, 1969). In other word, if the determined goal is evil, then decision would be considered as irrational. Though, rationality versus irrationality has more that we will discuss well along.

1.1.1 *Rationality VS Irrationality*

According to traditional assumption of classic economic theory, individuals who are behaving rational way, by default, would make rational decision. Though, taking example on two perfectly rational agents using perfect logic and starting with same information input, should theoretically, then, arrive at a same decision. However, it is not always the case in the real world. The assumption of classic economic theory ignores the fact that agents can have possible bias and being influenced by the externalities. Therefore, if he behaves irrationally, such as not abided by the selected criterion for alternative choices, due to his personal beliefs or bias towards other choices, then the preceding stages of decision process may be irrelevant and immaterial for the final resolution. Consequently, in this context, if the final resolution deviates from the expected value from following the decision process, then it should be considered as irrational. Conversely, this viewpoint can be presented from two different angles, from individual and organizational perspectives. If the decision-maker follows the process with the intention of satisfying the need and criteria of organization, then it becomes rational from the organizational point of view, though, he or she can profoundly disagree with the reference, thereof, from the individual stand point, it is irrational.

The economic theory constitutes an idea that a single economic human being behaves rationally on the basis of complete information. Thereof, to be fully rational, he or she must possess right amount of knowledge that can be justified and accepted as complete. In relation to Turpin and Marais (2004) discussion on classic rationality model, it is assumed that managers will have knowledge on all possible alternative, its possible consequences of implementation, well organized set of preferences, and computational ability to compare all consequences to determine the preferred mean of action. In other words, completeness of information lies in the criticality of information, with the degree to which data is correctly described, accounted, and objectified in the context, appropriate in the real-world settings. The completeness of information is often impossible without information validity and accuracy, which directly impacts on the correctness of decision. In the event of failure of obtain validity or accuracy of data, then the decision should be considered as irrational.

However, there are more distinctions to be made in the decision processes. Especially in terms of separating emotions and personal characteristics from the decision maker needs to be addressed under rationality framework. Since people are often attached to the status quo, it often involves changes in the prospects. If the decision-maker is responsible for the final choice, the function of final process will be defined by his/her own personality, beliefs, attitude, and value of judgment. Therefore, the decision process becomes a personalistic, otherwise in case of impersonalistic development, the decision becomes indifferent from all other individuals, who behaves rationally. Emotions, beliefs, and personal characters make our decisions unique from each other, but it also causes bias and limitations. When individual limits information processing short, sacrificing other alternatives by reaching what believed to be satisfactory resolution, rather than optimal decision, it is called as bounded rationality. While it is caused by the limited cognitive ability of individual, who believes that finding satisfactory solutions is optimal in the given situation or the timeframe, it is often hard to know what the best decision is. Furthermore, his or her resolution for given circumstance may well be different from that of others, with certain limitation, but at the end of process they may all still behave rationally by definition.

1.1.2 *Biases in Human Decision Making*

Bias in decision making, on the other hand, is different than the cognitive limitations. It is, too, formed by emotional attachments and beliefs, yet it distorts and disrupts the objective contemplation of an issue into the process and final outcome (Lumen, 2018). Humans are usually unaware of the biases that affect our judgment because we might commonly use them unconsciously. The most common type of cognitive biases is confirmation, anchoring, halo effect, and overconfidence.

- Confirmation bias occurs when decision-maker seeks out information that only confirm with his or her hypothesis, while ignoring evidence that disconfirm or differ the conclusions. This identified as a major weakness in decision making.
- Anchoring bias is when initial piece of information or experience impacts on subsequent decision, at the same time adjusting other information into anchored set of judgment. It is possible for us often being influenced by a comment of a colleague, friend, or family member that we recently overheard, or a headline of a newspaper read that day, unconsciously.
- Halo effect is similar to favouritism, where overall impression and its perception automatically influence the decision
- Status Quo effect is when people show a strong inclination to use alternatives that merely perpetuate current situation. Especially when people face choices, they often chose one that is closest to their current status, which is also known as playing safe.
- Overconfidence bias emerges when person overestimates the reliability of their judgments. This is also linked to the anchoring effect, where we rely on the initial information which leads to overconfidence.

As mentioned before emotions and beliefs are what makes decisions unique and personalistic. Although bias is still a part of personalistic resolution as per definition, it is a no longer the rational choice. The final discussion of differences between rationality and irrationality lies in the utility function of decision. When person acts to obtain the maximum utility by acting rationally, his or her choice may not bring absolute satisfaction to others. Which means in certain implications, rationality depends much on the context itself therefore it is a relative concept. Meaning one person's absolute solution may not serve same consensus to opinions of others. With that being said, utility of one individual may not be utility to others (Eilon, 1969). Utility of mass population may not serve best value at individual level as well. Therefore, rationality and irrationality may be very different for different individuals, even though they may have same or similar behavioural contacts to given issues.

1.1.3 Freedom of Choice

One of the most valuable attributes of being human is our freedom, an ability to choose from among several available alternatives in any circumstance. But under what circumstances, can we call it as freedom of choice? As Eilon (1969) noted in this research, that individual freedom exists when he or she performs personalistic control, where a decision maker is not affected by another person's needs, attitudes, behaviours, and beliefs. And freedom of choices is where individual has more than two or more choices available to him or her, without external influences to choose.

Having said that, when we consider freedom of choice, we tend to exclude the context, externalities, while concentrating solely on a personal implication. But what if we bring groups and organizations into the play, how does it change the nature of individual decision making? Undeniably, utility function of individual will be substituted by maximum utility of the group or organization. The goal set will be changed to common objectives that individual need. In that case, rationality of organization decision no longer be rational at personal level. Therefore, personalistic control is discarded and freedom of choice is no longer in present.

On the contrary, if a group or an organization is treated as one person, then all the factors in the decision-making process is relevant in all stages. However, the final decision-maker will become the manager who is in-charge of the group, unit, department, or the facility, which can be vulnerably influenced by all sourced of impact. Having examined various stages of the decision-making process, it might be a good idea that we return to the Figure 1 and question the method from the managerial point of view, where are the crucial points of the process exist in the organization? In which stage would the decision-maker be most vulnerable and affect the turn of events?

Traditionally, it thought to exist in the personalistic control, he or she already possesses. We have discussed how a data processing can take over the analysis part of the domain. However, in the modern case, both data processing and analysis parts are fully converged into computer-based systems, while other parts of the decision makings are encroached by power of artificial mechanisms, replacing need processes to rules. It simply follows input rules that are sufficiently detailed to cater for an ever-increasing number of contingencies to eliminate human effects. If that is the case, will the decision be still considered personalistic? When the control is completely gone, does that mean decision-maker is no longer a valid role in the process, and the decision becomes conformed and indifferent from one another? Before settling down on what may seem an obscure reality, we may need to examine the new decision models and their connectedness to modern environmental changes.

1.2 What is New Way of Thinking?

With the introduction of new digital technologies, human lives shifted significantly from one spectrum of primary reasoning and decision making to an unexperienced spectrum of secondary coordination of outcomes. The new generation of decision making is bounded to machines, replacing very human cognitive skills with short and fast cycle of complex computations, emphasizing heavily on efficiency. However, this overemphasis of efficiency is very risky in the eyes of subjective criteria. First and foremost, the ability of making sound decision has now become not only the selection of outcomes, but also to be able to deduct overwhelming amount of information, on top of what is already provided by the analytical tools. As we learnt, confirming one’s hypothesis is inadequate, thereof, we also should take account into examining disconfirming cases objectively.

In the past, managers and owners rely heavily on the experience and activities to arrive in decision, though, there were more development made over the years, shifting decision processes not only focusing on the activities that it involves, but also the decision-makers characteristics and other hybrid methods. With this, demonstrates the point that qualitative and quantitative models alone would not be sufficient enough in reality.

1.2.1 Decision Models

Various views and theories of decision-making can be found in literatures. The following model serves somewhat modern way of decision-making, based on the traits, rather than specific activities.

- Rational – this is the commonest of the type that emphasize on the logical and sequential listing of many potential options and evaluating them based on their pros and cons. It indicates the consideration of reasonable thinking of a choice maker to arrive the optimum selection. Since we emphasize on getting things right in our society, this trait has been studied and replicated a lot into individual models (Anon, 2019).
- Intuitive – unlike rational model, this type of decision making does not require absolute logic or reasoning, instead it is based solely on the choice maker’s feeling, senses, and intuition. As there are various types of people, intuitive decision making has many different modes, such as tarot card readings, coin tossing and many more.
- Combinations – in reality, many decision makers combine rationality and intuition to arrive the outcome. This usually happens when a person changes the parameters to produce more satisfactory result.
- Satisficing – instead of listing and evaluating the alternatives, this trait chooses the option that is good enough, ignoring other potential options. Similarly, this trait takes over the characteristics of bounded rationality, that mentioned earlier. Often there is a debate around the satisficing versus optimization, where it compares the nature of both elements. From the economic point of view, cost of searching information, risk, and timeliness, satisficing always makes sense because it costs less than finding optimal solution to a problem. Unless the decision-maker is only aiming to find the best solution at any cost (Anon, 2019).

- Decision Support Systems – involving computer applications, ranging from a simple spreadsheet to organize the information graphically to very complex programs such as AI, that can suggest alternative solutions, is the major evolution in decision modelling.
- Recognition primed decision making – according to Gary Klein, people make 90-95% of our decision in a pattern recognition. Ones the option is chosen, it is being streamlined mentally, and if the outcome seem not desirable, then another option is chosen and rehearsed again in the brain. Eventually more experienced we become, we recognize the pattern better and faster.

While incorporating these types of models into the businesses for better decision making, the information age brought another transformation into the table – vast amount of data. In the beginning, many believed that more disposal of data the better the decisions are. As a result, the sheer amount of data that managers have to deal with on a daily basis is utterly increasing, whilst dynamicity and agile business environment pushes them to work faster. However, many researches confirmed the opposite. The amount of information is not the key component for better decision; indeed, we only need to look at number of different tools and systems that are designed to support strategies while streamline the available processes (Pilipenko, 2018). Even though, above mentioned tools are technically different from one another, the core value revolve around the same objective of reorganizing critical data to help manager, executives, and business owners to analyse and make well informed decisions.

So how technology play a role in this process? It is believed and examined that AI and business intelligence (BI) are information storing, handling, and processing instruments that leverage various software powers to transform malfunctioning data into actionable information, in short amount of time. Its processing power was not only greatly appreciated by many businesses, its endless capabilities created a new generation of market game called information war. As a result of such game change, the traditional model of decision also evolved into more complex mapping, that may consist of more time-consuming aspects as such information transparency, democracy, sharing and governance, while overlapping most steps of decision process to one another.

1.2.2 Information Transparency

With increased information generation, its transparency becomes relevant issue in understanding to what extend people acknowledge the existence of such data to be accessible and valued. There is no common definition about information transparency, but in general consensus it means to have imperfect visibility and accessibility to timely and accurate information internally and externally. It requires fostering, producing, and maintaining distributed dialogues and communicate with those who are affected by, such as stakeholders (Wene and Espejo, 1999). The imperfection of information accessibility suggests certain limitation in the context, because in reality there is simply not enough time to engage in all available information, disregarding its relevancy. On the other hand, excessive secrecy of information can undermine the quality of public power and involvement in any process of information transformation.

In decision-making, transparency means to be able to know how, when, by whom the decision is made, and to hold the decision-maker accountable for. The economic outcomes of such exposure in the settings depend on both agents' (maker and receiver) rational beliefs, in such that by increasing information transparency mitigates the uncertainty about economic fundamentals. However, it also may increase the strategic uncertainty through precipitating multiple equilibria and less efficient group outcomes (Anctil *et al.*, 2004). Unfortunately, there is no right balance in transparency, though, there are variety of solution standards produced by international organizations. A few may have argued that the real problems related to information was born by unaccountability and governance issues at large, whilst transparency became a buzzword solution to it (Hale, 2008). However, without information disclosure and/or transparency, it often creates sense of disempowerment, mistrust, and frustration.

Transparency can be both viewed as a regulatory or voluntary requirement for organization, which by lawfully enforced or market commitment. In other words, it gets twinned with information protection, security, and obligatory openness. Even though it has been discussed largely from the organization point of view, little attention paid to its users' angle. So, what mechanisms should be promoted in order to allow and measure right amount of information transparency today? By doing so what are the promised benefits can we gain from it?

With such demand and aim of increasing the accountability, following structural mechanism is suggested.

- While transparency wheel is taken place, Bannister (2011, Hosseini *et al,* 2018) presented second model, known as transparency depth pyramid by dividing its requirements into three categories.
  - Data transparency – what information is needed and who are the stakeholders in the context.
  - Process transparency – how actions are performed in the context, examining processes, behaviours, and interactions. Belief is when deeper the transparency is, the more meaning the information becomes to the stakeholders.
  - Policy transparency – why action is performed in the context to understand the depth of intentions, policies and decision making. By disclosing why would help to improve the trust between information receivers and providers. At the same time, revealing the reasoning behind such decision can help the stakeholders to see its design benefits and flaws, so that outcomes can improve in the future.

However, in this systematic approach, we need to be careful with personal identity information, which is where transparency and privacy intersect with each other. To avoid such harm to both end of the system, privacy requirements need to be ensured as at early stages as possible with system analysis of disclosure of data and its management. In every single stage of transparency, we need to ask, how does this disclosure would help stakeholders in their decision making? What are other regulations to be taken into account as requirements? What privacy and security regulations should be applied and how to manage them?

The key benefits of doing so not just bring more monetary value to the organization, it will also promote good governance of exercising political and economic power among community, true participation of stakeholders, build capacity in policy formulation and implementation, balanced efficiency and effectiveness, and finally can become a weapon against corruption as a whole. It is also important to learn that even with recent boom of Big data science and management, above mentioned approach needs to be considered and practiced.

Then again, practicing and implementing transparency of information sounds reasonable and easy. Unfortunately, not everyone is ready or fully aware of information visibility, because disclosed information does not necessarily imply ethical consequences. Simple example is the upgrade of common operating systems like Windows, which often discloses information about the underlying computation of processes without any ethical consequences. Users may or may not read the agreement, thereof, the given consent upon approval, it discloses their personal usages to the provider. Even though the fundamental of agreement reached between two parties, receiver and provider, the disclosed information and its treatment may not qualify for ethical choice, thus, it is now fall considered property of providing entity. Inherently, information transparency is not an ethical principle per se, though seeing that it can be ethically neutral or exhaustive may impair the transparency (Turilli and Floridi, 2009). Therefore, it is challenging to achieve right amount of detailed information transparency while considering ethical principles and regulations to manage.

1.2.3 Information Democracy

Democracy is another intriguing, yet tough aspect when it comes to information. According to Jafarkarimi et al (2014), it is a form of governance, where everyone is equally and eligibly participating in the process of decision making and creation of protocols. On the other hand, based on Liautaud (Elliott, 2014), it is a combination of consistent information governance with decentralized access to data and decision making. Democracy often mistaken with transparency, though, the main focus lies on a principle of equality. Certainly, it also shares number of commonalities with traits of transparency. However, we will concentrate mainly on information related empowerment, its accessibility and causes of information gap in modern organization. We can all agree that information represents knowledge, and knowledge is the source of empowerment. If this source gets limited or unfairly biased, then it eventually creates information gap, frustration, inefficiencies, and even can cause moral-ethical issues at large.

In organization, the information democracy exists to promote the good of the firm. Users need have all the access to achieve the information and capabilities they require to do their jobs better, which then promotes common good (Dresner, 2012). Regrettably, not all firms have equal access to all information and capabilities. Sometimes, it is due to narrow understanding of the core philosophy of democracy, and other times it is due to resistance, power influence, and secrecy caused by fear. How can we have free and objective information when data is in the hands of entrepreneurs and factors associated directly or indirectly with various personal and political forces, you may ask.

First of all, the change should start from the traditional way of providing access to the information, a sort thinking that leads to one-size fits all exercise. Although, this practice allows data access uniformity and security, it is not enough to create enhanced performance. Instead, the access boundaries should be established by between users and the governing body to understand the extend which both parties could be satisfied with the control and availability.

Secondly, this is where information transparency comes to intersect with democracy, where information should be visible at all times under structured mechanism. Nonetheless, if transparency corresponds to accountability, then democracy shapes the responsibility of individuals and firms, in my opinion. Unfortunately, the view of democracy is often being examined from the political and governance standpoints, rather than pure information relations, which is why there is not many to no suggested system for democracies. Thus, to truly build and mandate information democracy among users and firms, we may need to try a trial and error approach to continue make, maintain, destroy and remake collectively.

1.2.4 Amount of Information (cost, availability, and interpretation)

A simple piece, yet most unanswered aspect of decision making is how much information is enough to produce optimal or nearly optimal decision. Based on the bounded rationality theory, as long as the cost of producing satisfactory decision is lower than cost of optimal decision, then therefore, the final resolution is rational and accepted. In other words, cost of searching satisfactory information is, in general, cheaper than finding high quality data. However, with the increase of technology, the generation of data amplified in multitude of speed, while its cost and availability of information at the same time enhanced.

According to Schleckser (2015), 75 percent of the available information is all we need to make decision. If the usage and availability is less than 75 percent, for instance 50 percent, it is decided that not enough to make sound decision. On the other hand, due to current agile competitive industrial environment, using 100 percent of information is too risky. Because first, it requires higher cost and takes longer time to arrive a final resolution. Allowing such may cost possible opportunities, whilst also information relevancy suffers from risk of expiration. So, the point of this is to balance the risk level and potential payoff between two extremes. However, balancing is not an easy act, specially when it comes to decision-making. In a lot situation, human beings use many cognitive abilities, unknowingly, combining it with its intuitions to judge, believe and gain confidence in its final outcomes. This confidence and abilities, as we mentioned before, comes from knowledge empowerment and experience. Though, it is not sufficient to justify the rightness and accuracy of information and reasoning behind this methodology.

Based on Gladwell (2012), revealed a great deal of details on decision makers and their qualities. Accordingly, talented people do not spend their time on neither the process nor the information itself, on the contrary, they devote most amount of time on perfecting the art of “thin-slicing” – a method of filtering to acquire right amount of evidence. In that sense, 75 percent of data may sound more acceptable. If we place the increase in volume of data to be least of our concerns, then methods of filtering become the right focus to produce comprehensive decisions.

Conversely, the qualitative information transferability still provokes debate among scientist and sociologist, where the reality of technology that is working on subjective information is yet lacking, what is quantified does not necessarily have an objective truth. As a result, it risks engraving legitimacy of social science and human inquiry against scientific quantitative methodologies (Ingrams, 2019, Boyd and Crawford, 2012). In addition to the phenomenal feature of big data, the scalability of large information and its search are vastly discussed among authors. Although, data can be structured and modified by the system, rising automation process of collecting and analysing data may not necessarily offer optimal solutions. Privacy and legislation issues are on the rise, in common with personalization and fragmentation in interpretation of information to selected people in general (Boyd and Crawford, 2012).

1.2.5 Specificities and Classifications in Analysis

While shifting our attention towards to automated analytical tools, our concerns continue with specification and classification of analysis that are being overlapped with information input, which is highly affected by the data transparency, democracy, governance, volume, and emotions. In general term, human perceives information even through their senses and categorizes them instantly and automatically in their brains, judging when and how to avoid risks, with limited probability in comparison to computer-based methods.

On the other end, machine based analytical tools are ensuring validity, accessibility, availability, and relevancy every point of data input and analysis stages, within given algorithms. But if following this enfolding, the ability of making sound decision has become a mere action of reduction of possible determined outcomes. According to Martin and Golsby-Smith’s survey in 2017, almost 81% of executive believed that data should be at the heart of all decision making, proclaiming that the phenomena of AI and Big data can eliminate intuition – gut feeling of decisions.

Nonetheless, human involvement still exists in almost every stage of data articulation process in any mechanism today, in order to answer more critical questions about the nature and meaning of data, its governance, delivery and final usages. The context of any given information is as important as its data provided. Taken out of the context, data loses its meaning and purposes. Historically, data are being created for the intention of developing stronger socio and heath science innovations. Eventually these data are now collected through variety of online tools and sources, creating mass articulated network for personal contacts, and behavioural network for examining communication patterns (Boyd and Crawford, 2012). These data are generic in terms of this classification, but not generic since all inquiry, context, and interpretations are unique.

In this case, the mere action of deduction is no longer a basic action, instead it becomes complex set of circumstances-driven solutions that are quite stagnant with his/her (decision-maker)’s ability and experience to specify the patterns externally and classify the potential actions that are suitable. The possible outcomes are, too, no longer considered generic, as an alternative, they become unique sets varied by the contexts.

1.2.6 Decision to Action

The result of every possible outcome is evaluated based not only on the merit, but also evolve on their ethicality. Many data collected publicly are not essentially proven to grant permission of manipulation. Not to mention, there are various other issues involved in the ethics of online data collection and analysis. Moving forward with decision to action, it is not guaranteed to be ethically correct if the decision is unethical.

Boyd and Crawford (2012) discussed the act of ethicality among researchers and suggested the importance of accountability in both field of study and subjects. Evidently, the broader concept of the accountability is privacy. When it comes to business accountability, it requires control, trust, and deep understanding and learning capabilities of big data and AI. Since data are created in highly complex context environment, ensuring the permission and safety necessitate multiple agents' responsible involvement outside of the algorithms.

1.2.7 Feedback

According to Shvetank, Andrew and Jaime (2012), quality of does not fully guarantee good decisions. This stage is the process of evaluating the outcomes and using it as a feedback to improve the mechanism further. The resolution needs to be assessed as per established criteria together with additional information about result quality back to the system in order to re-generate possible round of consequences. In this stage, all possible outcomes – confirming and non-confirming hypothesis should be produced with the intention of extending the system ability – a learning loop. Despite of significant investment in implementing, monitoring, and evaluating, this concept of feedback loop enables prompt fine-tuning of machines systematically. In comparison to human capacity to re-evaluate its outcome without biased judgment, the time and framework that AI and machine learning (ML) utilize far advanced speed and knowledge, which make them more attractive. However, the feedback information needs to be generated outside of the system, by humans. Meaning, this stage of involvement can become weak link (possible bottleneck) in the process by delivering weak or premature response back into the source. Such result-based approaches require mindset change, proper design evaluation training and unbiased timely processing of results. So, our question of whether decision-makers become obsolete in the first place, is unlikely even there are progressive technologies available on the market.

Emerging technologies have transformed the very nature of how decisions are formed. The traditional hindering approaches of people are no longer creating, collecting, and examining raw data hours and hours to confirm or disconfirm one's premise. Instead all the advanced machines with immense algorithmic capacity are performing these tasks in short time effectively and efficiently. Not only efficiency needs to be emphasized, the effectiveness of data discovery, selection, and analysis must involve highly governed and unbiased structure to eliminate our doubt in the stipulated potential outcomes.

In such that, these complex module generating mechanisms perform in no time with less error, also enabling us to depend on the technology further. Some researchers may argue that in the operations and support field of business, the machine learning and AI are replacing human critical thinking. But on the other hand, the system still requires logical understanding of given problems by human beings in order to solve root cause and other related matters in the future better through processing and feedback loops. In some cases, the judgment seems to be completed at face value of those possible actions. However, in the background of this key transformation of data commands varying degree of granularity, simultaneous processing of diverse information, redefining policies, and essentially a trust. The way we think in this information age is not just critically cogitate how to solve the problem, but also to comprehend on what ground the possible resolutions are being generated and compare them with other external information. In spite of everything, the AI and machine learning are not just panacea. They are the tools to aggregate overflowing information to the users, and their learning should be coupled with human insights in order to develop and finalize solutions. In the subsequent chapters, the report will explore how these mechanisms are being applied in the subfield of business – supply chain management, especially in the traditional management model of SCM, and how the operational practices are being evolved around the technology.

1.3 Understanding Natural and Artificial Decisions

Decades earlier, human beings did not possibly have abilities, time, and luxury to process all information in hand. Even though it was the case of our physical limitation that represented drawbacks, the decision process was fully under our control. Every human decision carried out with ethicality that produces alternatives of right and wrong choices. Excluding externality, the choice becomes much easier to compare with, based on the criteria of his or her free will or believes to bend. However, when it concerns external environment, the social norms and current situation have instant pressures that lead to either satisfaction or dissatisfaction. This process does not guarantee error free results. For centuries, human mind relied heavily on their previous experience and intuitions, which inflicts many cognitive biases and impaired judgments. It is because, we have developed simple heuristics of system for reasoning to cut short in order to arrive reasonable results under pressure of time and excessive information. The meaning of reasonable result does not define the optimal result, in fact, is it an almost unconscious decision, depending on the familiarity and gut feelings, cannot ensure decision validity and reliability.

On contrary, it is important to acknowledge that not all decisions are heuristic base. Human brain can function slower, conscious, effortful, explicit, and logical (Max and Don, 2009) when provided with sufficient time and commitment. While the heuristics often affected by emotions, logical thinking is being operated by the frontal cortex of the brain that controls and reduces hormonal activities of the hypothalamus gland. When our internal organic mechanisms confronting with various cell motions, there are also several peripheral factors to examine in order to fully understand the adversity of decision-making process.

However, with the information age, the processes have been evolved, shifting its partial activities to intelligent tools. This is when the artificial age of decision making has begun per se. We drew the line for insufficient information to define effective decision making. As a result, we reasonably believe that there are a number of criteria to quality for effectiveness, such as timescale of produced data, prioritization of information and its relevancy to the final decision. Though, with the opposite problem of having too much conflicting information, relevancy and right amount of data processing became a challenge. Furthermore, any decision by itself is meaningless, unless it followed by a concrete altering action to justify its purpose fully. Henceforth, the actions cannot be justified unless big data and AI technologies have built in mechanisms to confirm and disconfirm hypothesis it has initially given to solve. Although, there is still a doubt how much information is enough to constitute a good decision, it is certain that our dependency on artificial lives has grown immensely.

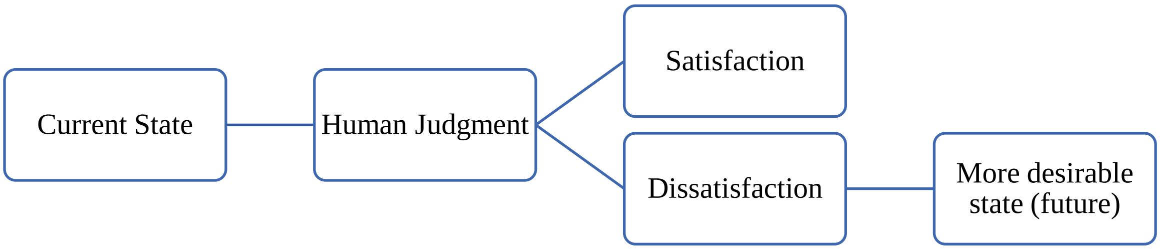
Especially the intuitive nature of human freewill often play an exquisite role in evaluating alternatives, to what extent it needs to be replicated to artificial technologies, are uncertain and presents ethical dilemmas. Building on the research, there are two different views about AI in recent time. In 1969, Simon Herbert wrote a book on 'science of artificial', which elaborates on artificial beings are designed to perform various human tasks, puts AI to be a relatively less innovative artefact. It cannot properly make decision because all set of information – inputs to outputs have been previously built in by the system developers. Consequently, the decision becomes conflict with the idea of a human configured programming. Therefore, if tasks are being performed accordingly, the decision is no longer consider exists, thus each situation have its own set of possible outcomes to be measured.

The second view of AI creates alternative discussion regarding cognitive approaches of the machine learning. Given that AI is regarded as a science of knowledge representation and reasoning (Newell and Simon, 1972), thinking of AI mimicking behavioural and rational approach is valid interconnection with decision making. Especially, all human beings have unique reasoning and experience, all decisions made by AI become very subjective. In other words, AI is not mimicking humankinds, but merely given the subjectivity of humanity. In economists' point of view, the rational decision makers consider two main characteristics – subjectivity and probabilities. Meaning, without the social interference component of intelligence, what AI encompasses is a large set of subjective raw data and strong processing capability through various conventional algorithms, makes it most efficient and effective computational and rational decision maker.

The debates around this genericity versus subjectivity has been discussed in many other journals regarding decision theory, some researchers may defend the idea of same rational decision of humanity, whilst others try to recognize the how different agents decide on same given problems. So, it is impossible to establish relationship between AI and decision-making, without first establishing the constraints – to what extent of subjectivism we concede AI to operate in our lives. Henceforth, the outcomes of decision are being evaluated based on the feelings and or goals, it is safe to group them into satisfactory and dissatisfactory criteria for further analysis.

The satisfaction results from when the outcome meets the original intention. On the other hand, the dissatisfaction arises from the difference between current state of affair conflicts with more desirable one, which is also known as a decision problem (Jean-Charles, 1996). Certainly, the personal dimension needs to be taken into consideration, because what is desirable for one person may not be attractive to another.

Figure3. Decision States



Source: Developed based on Jean-Charles (1996)

In this case, the final resolution is still under human control, therefore can be counted as natural phenomena. Note that the above scenario is only valid with certainty, whereas no longer true in case of uncertainty. The result is based on a criterion, not fully compatible, as opposed to having multi-criteria to analyse with. The recognition of a problem starts from the current state, where the decision will be defined by future outcomes, which is shaped by information of past and present that are drawn by the experience (Jean-Charles, 1996).

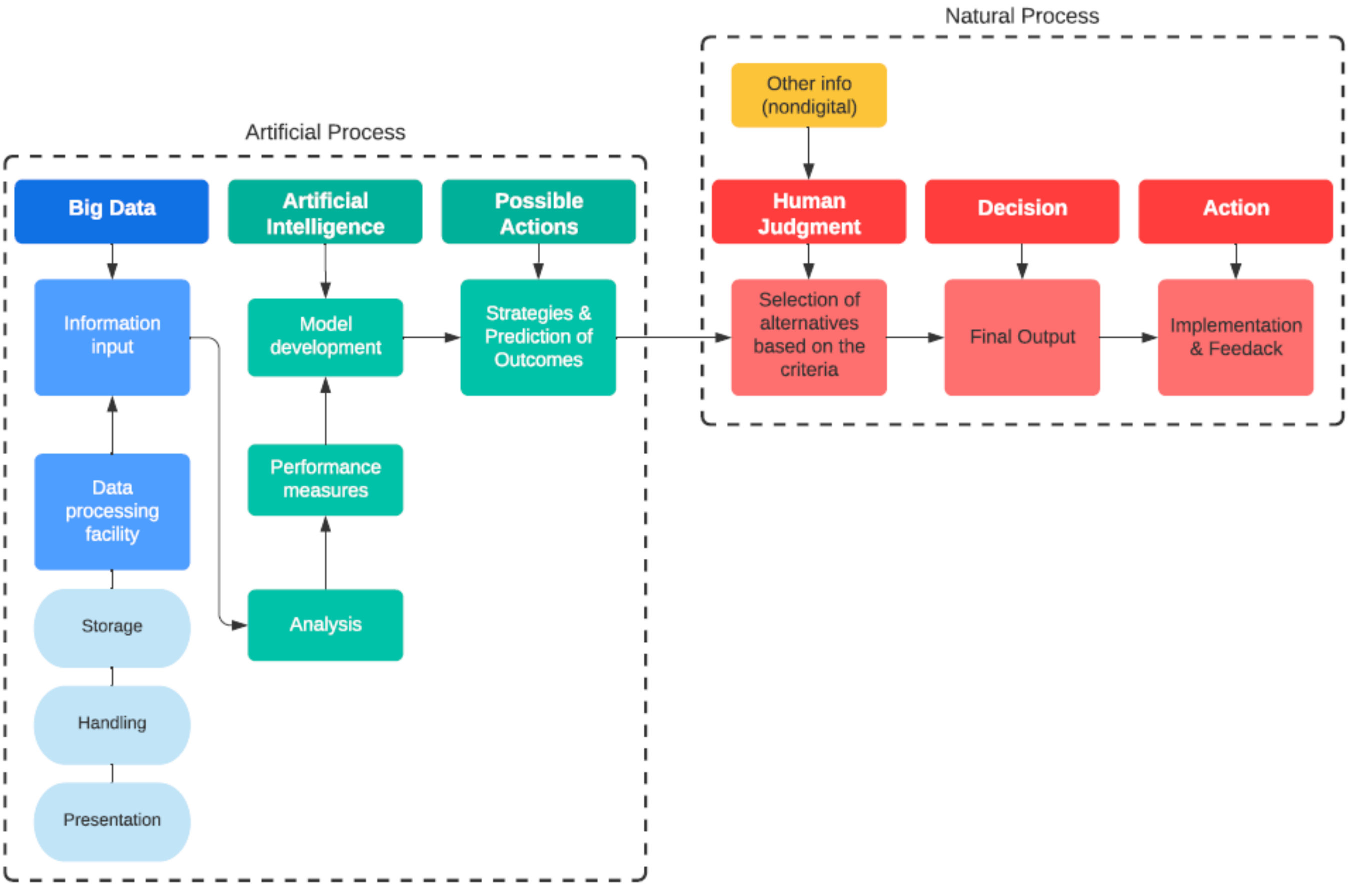
If the point of the judgment is natural, then why are we considering artificiality of decision? There are many other activities taken into account, such as collecting diverse information linked to the current state problem, assessing the relevance, developing alternatives and weighing them based on the criteria. Evidently, AI can perform all these tasks in a split second with higher accuracy, by definition process of generation a decision is artificial.

How can a machine guarantee success without understanding emotion and changes in the amount of fulfilment? How can the decision be optimal if the level of satisfaction often changes? And to what extent the human interaction should be allowed to make the decision ideal?

Proponents of AI claims to offer considerable promises and forms that it will deliver many values, such as aiding decision makers to select actions in real time during stressful processes and problems, reducing information overload whilst minimizing errors, enabling up to date information and providing dynamic response with intelligent agents. Moreover, it can provide communication support for collaborative decisions, deal with uncertainty through probabilistic analysis and customize knowledge exchange among the users. It is believed to be less affected by hostile environment and available 24/7. Despite of its benefits, the AI naturally harbours substantial uncertainty that presents threats. The first round of threat afflicts the organization that develop and deploy AI based artefacts and systems with imbedded bias. It can impact on many categories of stakeholders through rise in costs, unemployment, and depletion of certain human skills such as problem solving. The jolt of deploying AI is safety and security of information that relates to thrust issues. Data must be monitored and protected rightfully by the organization in order to ascertain the proper usage.

These views fixate on the central argument of this paper – what is the modern way of decision-making methodology? Some decision processes are practically continuous and involve strong problem solving, where the machine becomes more relevant. Unquestionably, life is not a program of linearity (Simon and Newell, 1970), therefore good practice will require human involvement in AI on each stage with evaluation loops, many different branches and reiteration. The perplexity of employing such program will also entail principle agents to be separated from the traditional decision-making instruments. Since connected devices can collect data in unthinkable volumes, every transaction, customer values, micro and macroeconomic indicators, the decision makers now can be informed better and faster, suggesting that bringing AI into the workflow as a primary processor for the internal data – routine decisions, and delegate qualitative adjustment to humans.

Figure4. Decision making model combined with AI and Human Judgment



Source: Developed based on Eilon (1969) and Colson (2019)

The importance of this model is that human beings are now no longer responsible for direct data administration, but rather reconcile processed data with rational subjective values, strategies, and cultures of the organization. The clear indications need to be drawn from machine driven analytics to human driven decision, which the evolution should take place within individual units of the organization. By now we understood that good decision making is no longer a step by step process, rather it is taking a few steps back to consider how actions might affect under the determined relevant paradigms to produce options, then taking a few steps forward to examine its impact on most vulnerable people to changes, and again step back to cut off those impacts, to finally arrive in better reasoned decisions, while minimizing the unintended consequences and regrets among natural and artificial mechanisms.

1.4 Decisions in Businesses

In the framework of business, types of decisions are arranged by hierarchy which aims goal orientation of the decision, its active period, and the nature of the business functions, such as operations, finance, R&D, customer services, quality and sales and marketing. More often, business processes entail a large number of decisions that affect business performance (Ghattas *et al.*, 2014). The criteria used for these decisions are not formally optimized, evidently, calculating traditional costs and benefits of decisions are no longer valid reason to pursue a common goal in the organization. Attempting to maintain and improve its performance, firms often employ various techniques and mechanism to guide decision making in business processes, such as processes, procedures, regulations, and systems.

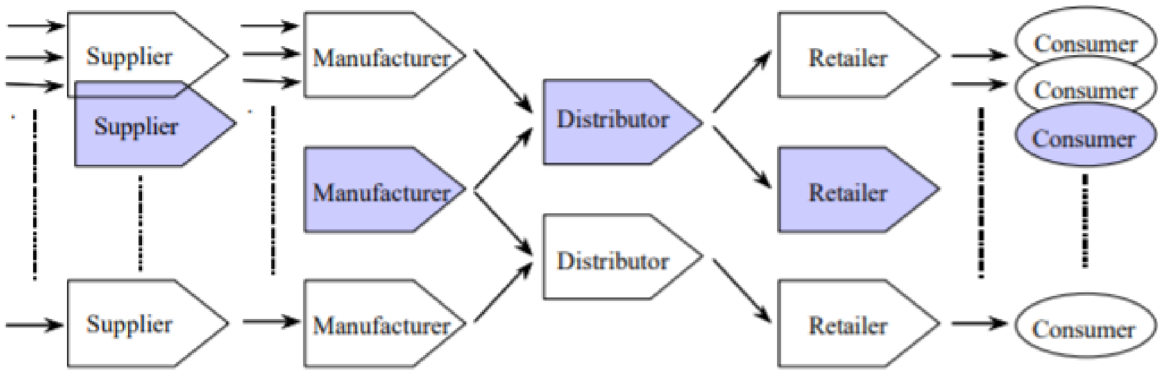
In line with our discussion of modern thinking and decision process, it would be great deal to further explore the relationship between business decision making and how systematic automations can help to improve functional/departmental/organizational performance. The result or outcome of a process that we are going to examine, moving forward, will be assessed in two main dimensions, (a) binary quantitative indication of the hard goal that business intends to achieve have been reached, and (b) qualitative measure that can indicate the extend which business objectives have been obtained. To have wider understanding of types of business decisions and its evolution, this thesis have chosen to concentrate on the supply chain-oriented businesses.

Chapter2. Supply Chain Management Models

2.1 Traditional Supply Chain Management

The simplest form of traditional supply chain management (SCM from hereon) involves transferring raw materials into physical products, then delivering to the final customers. In a broader scale, it includes designing of products, planning and implementation of strategies, procurement of materials, information flow, physical storage and distribution, and of course, monitoring and controlling of these activities with the purpose to create higher values at the lower costs in the competitive business environment. In this segment, the value refers to the amount that customers are willing to pay for products produced by the company. Earlier SCM activities were taken place within the regional boundaries, until a new innovation of ship vessels has led to cross borders with fuel engines and widened the trading borders. Since 1980s, the term of SCM has grown drastically among businesses, at the same time, the term has also substituted for logistics (Chiu, n.d). At this point, it is safe to say that each firm belongs to at least one supply chain – such as production, but most cases a firm has multiple suppliers and customers.

Figure5. Schematic diagram of a supply chain



Source: Van der Vorst (2004)

Even though Figure 5 depicts linear progression of activities, these movements are cyclical. Cyclical within the stages, as well as cyclical among the phases. In that, one process cycle will not hinder other processes within the SC network and adjust independently by the responsible agents. The clear example can be seen in the inventory function of the SC, after delivery of each products, the cycle replenishes the warehouse by producing new end-products.

Meanwhile of growing popularity of SCM, the traditional distribution channel existed until when the differentiation of products introduced to various markets through multinational companies (MNCs from hereafter). Nearly a century, manufacturer worked to produce and stock products, and deliver it to the customers with minimal diversification. Hence, this demand was based on a survival of a human, rather than a desire to acquire more. Consequently, controlling distribution channel was simpler and flatter with a few players. However, it caused greater inefficiency in the inventory management, due to a piling of stock at full warehouse capacity. During this period, inventory management presented the highest cost function in the organization, even today to some organization, it is still considered as the same.

Eventually along with the emergence of a new type of energy, the industrial revolution witnessed the rise of MCNs along with introduction of electronic goods and other differentiated products. The era started from the second half of 20th century and gave rise to the high-level automation technologies. Not only this period signifies major changes in the business environment, but also in the SC. The process of international and global agitation connected technologies and speed, as result, the new form of SCM emerged and put into practice.

In the new model, the enterprises have to consider a global market integration evolving production, purchasing, logistics and distribution, warehouse, support designs and activities, marketing, and global consumer response through diverse communication channels (Chiu, n.d). But the core focus of the organization stayed unchanged – better value at the lesser cost. Henceforth, the value does not signify the price of the product alone. The concept of value-added activity was introduced by Porter's value chain framework in 1985, characterizing the further relationship approaches among agents in SCM.

Table 1. Characteristics of SCM according to Cooper and Ellram (1993, Van der Vorst, 2004)

Element	**Traditional Management**	**Supply Chain Management**
Inventory management	Independent efforts	Joint reduction in channel inventories
Total cost approach	Minimise firm costs	Channel-wide cost efficiencies
Time horizon	Short term	Long term
Information sharing and monitoring	Limited to needs of current transactions	As required for planning and monitoring of processes
Coordination of multiple levels in the channel	Single contract for the transaction between channel pairs	Multiple contracts between levels in firms and levels of channel
Joint planning	Transaction based	On-going
Compatibility of corporate philosophies	Not relevant	Compatible at least for the key relationships
Breath of supplier base	Large to increase competition and spread risk	Small to increase coordination
Channel leadership	Not needed	Needed for coordination focus
Sharing of risks and rewards	Each on its own	Risks and rewards shared over the long term
Speed of operations, information, and inventory flow	Warehouse orientation. Interrupted by barriers to flows, localized to channel pairs	DC orientation (turnover speed), interconnected flows, JIT, Quick response across the channel

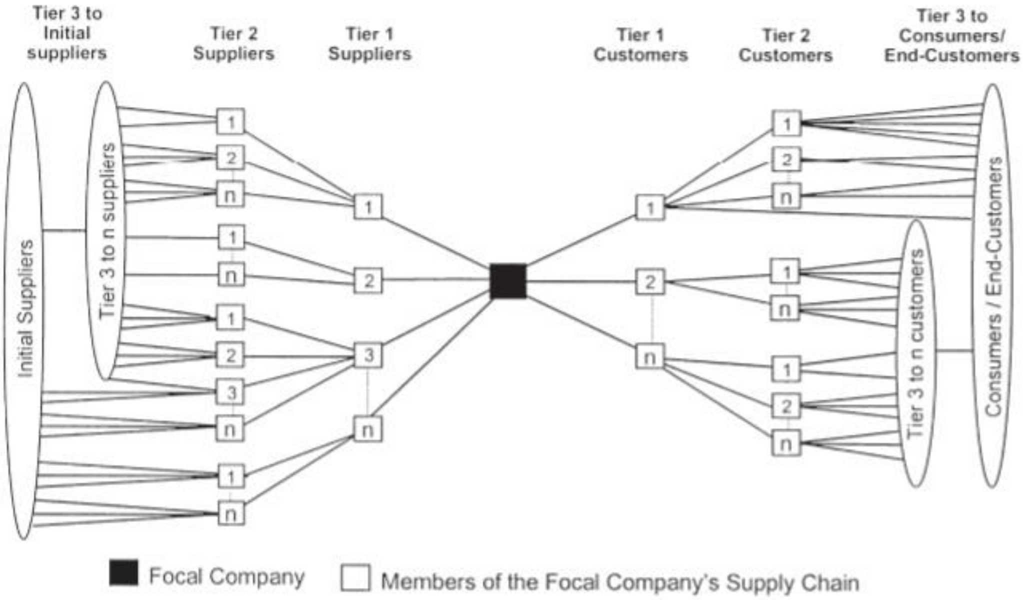
Even though tradition management approaches underline several independent approaches in this table, SCM stresses significant coordination through the activities. Which is why we can define SCM as an integrated planning, coordinating, and controlling instrument to deliver superior value to the customer at least cost as possible by satisfying all the requirements of engaged agents in the chain.

Worth noting along with growing number of complexity in the SCM, countless terms are being utilized and improvised by individuals and researchers over the decade, offering comprehensive and advanced views over the supply chain module, such as JIT, push pull, demand chain management, value chain management or value network, block chain network and more. Thus, this chapter is concentrating on root of all these sophisticated phenomena and fields, which is why supply chain will be further examined in the areas of key decisions, its agents, and practices together with modern approaches and obstacles.

2.2 Key Decisions in Supply Chain Management

The understanding of SCM has been reconstructed from assimilation of logistics across business to integration and management of key business activities. While the degree of complexity increases, managing connectivity of all consumption points has become crucial. As a result, the supply chain module shifted into network of connection, as shown below.

Figure6. Supply chain network structure

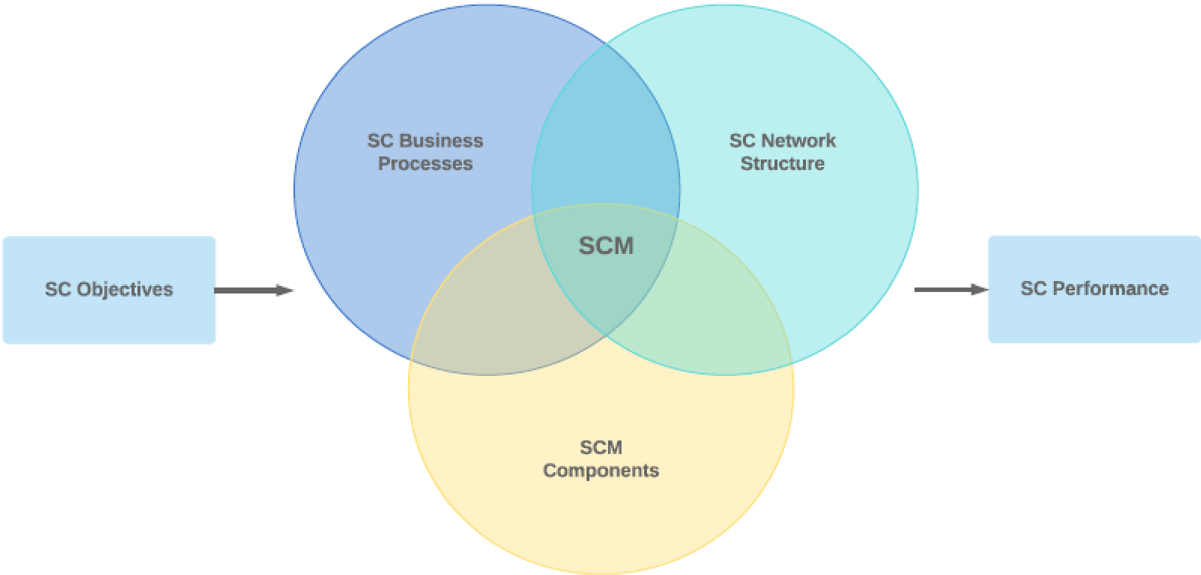


Source: Lambert & Cooper (2000)

End users at the both side of supply chain have the power as per the network, making the company as a middleman in the transaction. But not all suppliers are key in the network, therefore the linked relationship can be replaced overtime. Relatively, most customers are vital to any firms, and replacing one relationship to another take more time and effort, proving that the possess more power in this association. Power is represented in the horizontal dimension of the diagram – number of tiers, more distant it gets from the focal company, relationship become more fragile and replaceable. In the second dimension of vertical aspect portrays number of customers in each tier. Other words, distribution of power in each tier. Clearly, with increasing or decreasing the number of suppliers or customers will affect the structure of SC and relationship strategies within.

Managing this complex network of transaction is a very difficult and challenging task, which is why it is fundamental to link and differentiate the management framework by elements and key decisions. According to Lambert and Cooper (2000) indicated three distinct form of decision in the supply chain management. But to make the model complete, Van der Vorst (2004) suggested to include the external and internal supply chain objectives and performance which are measure by the degree of customers satisfaction and proportional contribution towards market success or failure. Frequently, performance is measure by internal key indicators (KPIs from hereon) to compare organizational efficiency and/or effectiveness of a structure with a set of norms and values (Van der Vorst, 2004).

Figure7. Key decisions in SCM



Source: Developed from Lambert and Cooper, (2000) & Van der Vorst, (2004)

Objectives – the formulation of business objectives, often require multi-party agreements by selecting numerous types of indicators, criteria, and norms to target attractive values for the organization. The values are set through the joint effort of every single participant, in other words, partner with the intention to totally measure and satisfy the supply chain, therefore improve the chain performance.

Performance – the main goal of identifying all chain process is the end result – performance output. By analysing predefined and integrated objectives and market requirements will be displayed in the incorporated KPI, which then justifies the very success or failure of each action.

SC Business Processes – the focal point of analysing and designing the supply chain is to define the key members of the processes and how to link them with one another. Some suppliers and customers can be more important than others. With each particular capability of a firm, main suppliers and customers need to be managed closely, while others require less monitoring. The chain is crucial for company's success which accommodates the supply chain objectives, thus, should be allocated managerial attention and resources effectively.

SCM Components – according to Lambert and Cooper (2000), they identified eight key supply chain processes that will help to integrate a business with its key members.

- Customer service relationship management
- Demand management
- Order fulfilment
- Manufacturing flow management
- Procurement
- Product development and commercialization
- Returns

Evidently, some SCM literatures suggest numerous strategies to improve efficiency and effectiveness of the business processes in the supply chain, which will be discussed later in this chapter.

SC Network Structure – In term of level of integration and management of such relationship, the network consists of two main elements: tangible – physical components and intangible – behavioural components (Lambert and Cooper, 2000). Hence, these two components are inseparable, and if physical components are changed, then the management components likewise may require re-adjustment. The physical and technical components consist of planning and control, organizational structure, product flow facility structure and communications and information flow. On the other hand, the managerial and behavioural side contains management methods, culture and attitude, risk and reward, and power and leadership structures. Since managerial and behavioural components are more complex and impose higher obstacles to SCM, it needs to be closely examined and encourage simultaneous organizational improvements.

2.3 Types of Process Links

Successful SCM integration requires a change from transforming and managing single function to interdependent management processes across supply chain. Traditionally, both down and upstream activities of SCM interacted distinctly, making whole function perform in silos. However, this is no longer the case when the organization wants to remain competitive and sustainable. Operating an integrated supply chain demands cross functional continuous flow of activities, information, and most importantly values. To effectively manage its physical product flow, as mentioned earlier, in many companies implement 8 key processes that are shown in Table 2.

Table 2. Business processes to integrate SC

Business Processes	**Description**
Customer service relationship management	Identifying service level agreement with key customers and provides information to the customers
Demand management	Balancing customer’s requirements with the firm’s supply capabilities
Order fulfilment	Integration of firm’s manufacturing, distribution, and transportation plans effectively
Manufacturing flow management	Pull the customer’s demands and push it through the end channel after production
Procurement	Developing strategic plans with key suppliers to support manufacturing process
Product development and commercialization	To reduce the time of new products to the market, customer’s must be cooperated into product development processes
Returns	Aligning processes to realize an efficient return or re-usable items

Source: Van der Vorst (2004), Lambert & Cooper (2000)

These processes became fundamental for many organizations, but not limited to 8, to developed effective supply chain. When the organizations expand internationally, there are more processes created and added. In this context, the idea of processes are guidelines, operating procedures that support a series of actions to be carried out within a team, unit, and business organization. As noted earlier, while creating and adding newly designed procedures for employees to follow, it is not necessary to link all together throughout the supply chain. Some links are more relatable and crucial than others, therefore it is inappropriate to integrate and manage them at same level of commitment. As a result, the allocation of scarce resources among different supply chain links becomes more challenging.

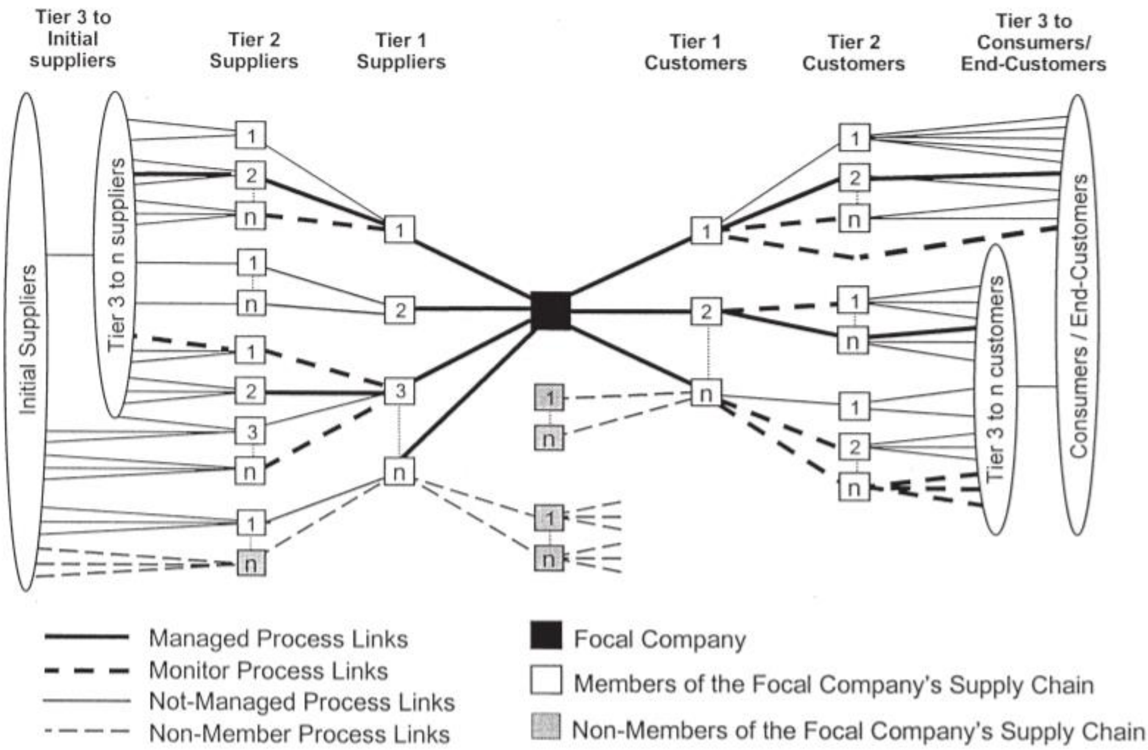
According to Lambert and Cooper (2000), there are four-fundamental links that can be identified between SC members. These are:

- *Managed Process Links* – links that are important to integrate and manage together. It has represented in thick solid lines in Figure 8 to show the significance of the relationship of focal company with its Tier 1 suppliers and customers. Not only in the Tier1, as represented in the graph, the company also can closely evolve Tier 2 and 3 suppliers and customers if they are identified as fundamental.

- *Monitor Process Links* – these links are not important to the company but required to be managed by other members of companies and simply monitored when necessary. This dash line therefore signifies this relationship.
- *Non-Managed Process Links* – links that are fully trusted and managed by other companies, meanwhile main organization is not critical or actively involved in its maintenance. It has been represented by thin solid lines in the graph. For instance, a company does not require to manage the raw materials availability for its suppliers. The producer wants certainty of its supply, but necessary to integrate and manage the link beyond its part suppliers.
- *Non-Member Process Links* – non-member links are often far from main organization's links and not being monitored by. However, it is important link due to its effect on the company.

Following Figure 8 depicts the interconnection of supply chain links in the company, where it has been represented in different link styles to provide further clarifications to those four-fundamental links. Especially, in the case of non-member process links, which has been presented in thin dashed lines, can convey the effect to the focal company. For instance, a supplier of the focal company can serve other companies outside. The management of supplier decides independently from the focal company, its own allocation of labour and material allocation. Therefore, their decision and performance allocation can affect the focal company or other related agencies that are linked.

Figure8. Intercompany Business Process Links



Source: Lambert and Cooper (2000)

On the contrary, the main question from above figure is that how firms control those key links? In brief, the focal company will integrate and manage the main links closely with their customers and suppliers. It actively gets involved in the management of supply and demand issues, while maintaining relatively well bargaining power against both parties on the network. Conventionally, the focal firm can impose higher bargaining power against its suppliers and force to become the only client in the business. However, in modern time, due to technological advancement and market openness, the management philosophy of such close relationship promotes strategic coordination and integration, to create competitive advantages. Therefore, to manage the managed process links above, the focal firm must create closely integrated supply chain, thus with customers, to involve, inform, and eventually generate better flow process for greater outcome.

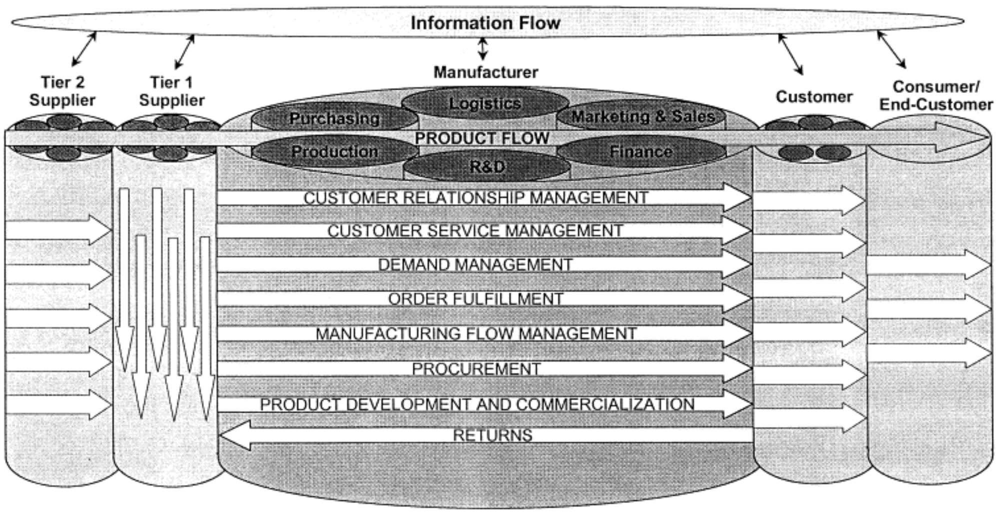
Based on these process links, it can illustrate the closeness of companies integrating and managing the links further away from its first tier of suppliers and customers. Most cases, when the link is critical to the company, it has been closely integrated, monitored and managed. Other cases, the company can work around the links by allowing its members to take in-charge in order to be flexible, independent and responsive without sacrificing the scarce resources.

Interestingly, as Cooper and Eilram (1993), they compared supply chain to a competition of relay teams, where the relationships are strongest among those who knows the positions and handoff the batons to directly. The entire team must be coordinating to win the race, and of course, there are major team members that connects the weak links of relationship.

Thousands of activities performed and integrated within and outside of the company, and by nature every company is involved in supply chain relationship with other companies. When, for instance, two companies create a relatioship, certain activites of their internal processes would be linked and managed between them. Since now both companies shared and linked some of the internal activities, these might considered as a supply chain network, according to Lambert and Cooper (2000). As a result, one organizational activity can affect the another. The result exhibited by Hakasson and Snehota (1995), that these links within and between companies has become critical cornerstone of creating superior supply chain performance. The integration also provides, in other words, increased profitability and competitive advantange, when it linked appropriately with its key drivers and members.

The key drivers in some companies can concentrate on its functions, while for other can drive from its strucutre or processes, or even combination of all three. Over the years, there are many new terms emerged for same or similar activities, steering confusion and repetition within. It is, then, believed that lack of inter-company consistency and conciseness would cause an inefficiency and signicant tension among users. At least with the development of functional silos, the departments became uniquely formed divisions that emerg with its own set of processes and activites. The additional observation has been provided by Lambert and Cooper (2000) on incorporation of internal and external supply chain relationship. Through their research, the number of evidence suggested that internal busienss processes can be extended to external suppliers and customers, which then may become the supply chain business processes, as illustrated in Figure 9.

Figure9. Supply Chain Management – the information disconnect



Source: Lambert and Cooper (2000)

The disconnects occurs vividly in this case, where the importance of integration and management of activities lie in the difference of values given to the functions of an organization. A critical process of one company is not necessary to be critcal to others. In each specific circumtance, the management needs to thouroughly examine, analyse and discuss its key porcesses with the users for better assimilation.

2.4 Components of Supply Chain Management

The level of integration and management relies on the number of functions, activities, and its links. Adding or subtracting more management components or increasing or decreasing the level of activities can change the level of integration and process links. In many literatures and cases on business process integration, reengineering and management components suggested several different modules. Valiris and Glykas (1999) suggested three classifications to business process reengineering methodologies, namely a. management accounting methodologies – focusing on redesigning the process and roles, b. information systems influenced methodologies – using modelling techniques through supporting processes and data, c. organizational theory based methodologies – with the aim to understand organizational environmental perspective. Even though there are many researchers assessed and suggested numerous forms of components, based on Lambert and Cooper (2000), we will concentrate on following nine aspects, under three classification methodologies as mentioned.

a. Management and Accounting

Planning and control – planning is a key to direct the supply chain to desirable outcome, meanwhile control enables to measure performance based on predeveloped metrics.

Work structure – it investigates how firms performs its tasks in each individual division. By understanding it work structure allows to draw organizational structure and its flows in general.

Organizational structure – it can be referred to as a boundaries and linkages of a firms and its supply chain, as well as its integration among one another.

b. Information Systems Design

Product flow structure – it is designed to express the network of structure ranging from sourcing, manufacturing, distributing to its customers. Rationalizing this design affects all member within the organization. Therefore, the network structure should involve various members in order to develop crisp and comprehensive scheme.

Information flow structure – for many authors and researchers, this Is the key aspect of successful SCM. The kind of information passed along the chain of links and frequency of transfer influence the overall efficiency of supply chain. This may be the first and foremost component that should be part of integration and management planning. The speed and frequency of information define the speed of operations through cycle times, delivery period, reduced order period and so on. Traditional system might have characterized by the warehouse orientation – having larger safety stock to be prepared for demand fluctuation (Cooper and Eilram, 1993). However, the flow of goods is interrupted by the lack of structural development and exchange of information, which thereof, necessitates interconnected information flow system.

c. Organizational Theory and Culture

Management methods – the corporate philosophy and the techniques are very difficult to design and integrate. Depending on the complete and inclusive structure of business – top down or bottom up approaches are being implemented. The difficulty arises from the new forms of management methods, such as network and matrix relations.

Leadership structure – the strongest leaders motivate and direct the entire supply chain into its right path, while followers require complete, transparent and accurate information in timely manner within the supply chain. Incomplete and lack of power and leadership, thereof, can cause the commitment issues to other channel members. Henceforward, attitude of wrong reinforcement can lead to exit behaviour in majority of cases.

Risk and reward structure – this structure mainly concentrate on the commitment of members in the chain. Balancing risk and reward entail long term obligation of management to its member with the intention of creating highly involved workforce.

Culture and attitude – they are very important, yet most studied organizational study. Compatibility of corporate culture across its channel members cannot be ignored or underestimated. Engagement of culture and employees are time consuming means; however, the result is a promising success. Culture and attitude involve values, norms, and belief that incorporate employees into the management of the firm.

Even though, nine components with three different classification have been mentioned in this session, there are various number of components and combination being formed by firms. The physical and technical components are being incorporated with the supply chain network under the umbrella of department activities. As depicted in Figure 6, many of these structure and philosophy can be assimilated with one or more processes. For instance, demand planning process in sales and marketing department can apply components like planning and controlling, workflow and activity structure, product, and information flow, while maintaining risk and reward structure within the organization.

In recent years, the managerial and behavioural aspect in SCM are being observed and expanded its course to many different levels of integrated studies. Henceforth, this aspect of the study will be discussed in the next session - approaches and practices of SCM.

2.5 Supply Chain Management Approaches and Practices

Unfortunately, there is no concrete list of approaches that has been developed over the years. Organizations are continuously seeking to improve their sustainability of supply chain by adopting different types of management approaches in relation to their strategic objectives such as transaction cost approach, channel coordination also known as integrated approach, complex network approach, risk management and or theory of constraints, total quality management (TQM), business process reengineering, supply chain roadmap and many more.

2.5.1 Transaction Cost

Initially transaction cost theory applied to economic agent – basic unit analysis to validate the unit price is well established. Costs fall into three main categories, search and information, bargaining and policing and enforcement costs. Over the years, the complexity of transaction cost has grown to include R&D costs and other administrative activities, making cost of product rise. With the increase of production costs per unit, the businesses started looking for cost lowering alternative, such as outsourcing of secondary activities to third party producers. By moving its secondary activities outside of the company changed the supply chain network, eventually transaction cost approach took part in the management decision making module.

Economist Ronald Coase and Oliver Williamson are credited for introduction and spreading the concept of Transaction Cost Economy (TCE), which explains the fundamental need for companies in the market. Theoretical reasoning of TCE emphasis on the efficiency and effectiveness on the hierarchical distribution of resources and authority, more than market due to the imperfect information – uncertainty and bounded rationality. In SCM, however, transaction cost theory provides alternative decisions between make or buy – focusing on production and procurement functions. The main difference between TCE and SCM is that TCE examines single transactions, while SCM introduces broader spectrum of activities related to transactions, group and manage them consecutively.

Under this approach, this thesis will serve background works of TCE, followed by its operations focusing on alignment of transaction to three different modes of governance – market, hybrid, and hierarchy, continue discussing the cross over between TCE and SCM, and conclude with the extension of the theory. The most important content in the exchanging of goods is a human factor, who has a cognition and self-interest. Human actors are rational only limited to the capacity of his/her reasonings, thereof, all complex contracts are incomplete – having gaps, errors, omissions, and others (Williamson, 2008). To avoid imposed self-interest and lack of cognition, thereby to force recognition of terms and credible interims contracting mechanisms are suggested.

Operationalization of TCE depends on key attributes both transactions and governance structures (Williamson, 2008). The dimensions of the structure call for attention to specificity of assets, uncertainty, and frequency. The specificity of assets refers to interparty relationship of a transaction – the investment supporting a specific value of transaction to increase its original cost with the purpose of redeployment. Uncertainty in this context serves a meaning of disturbance to the required adaptation. Lastly, the frequency signifies the net effect of repetition and setup costs, which will vary with the situation. The governance structure of TCE consists of three parts. Markets and hierarchical are the polar modes, while hybrid contains mix of these two structures that exist in the middle.

- *Market structure* – high powered incentives with little control and legal rules in contractual relationship
- *Hierarchy structure* – on contrary, it has low powered incentives, high autonomous control
- *Hybrid structure* – it compromises both autonomous and coordinated adaptation

With the challenges of how the business transactions needs to be structured between two parties will depend on the complexity, uncertainty of the subject, recurrence, and familiarity of parties, and involved commitments, without difficulty of reversal or significant economic losses. Especially dealing with multiple parties in the supply chain network, TCE is definitely a rising topic of every managers who require to align firm's interest with scale and scope of each party. TCE is not only concerns about the transaction and its governance in general, but it also considers firm's organization. In various context of governance, application of TCE can be seen in the Table 3.

Table 3. Application of TCE in Various Governance Context

Governance Context	Key Focus	Contracting Parties
Vertical Integration	Outsourcing and inhouse manufacturing	Buyer and supplier
Multidivisional firm	Allocation of resource in the external capital market	External financial firms and business owners
Franchising	Expansion to global market, resource allocation and partnership development	Franchisor and franchisee
Corporate Diversification	Multiproduct firms	Horizontal equivalent firms or activities
Foreign Direct Investment	Foreign market entry through financial investment	Firms and foreign subsidiary
Joint Venturing	Alliance of firms to enter into a new market	Firms alliances and subsidiaries
Supply Contracts	Buyer-supplier contract	Buyer and supplier
Corporate Finance	Financial assets, debts and equity	Firm, debtors, and equity providers

Source: Ketokivi and Mahoney (2017)

Elaboration on Table 3 has indicated several different types of government context. However, it is also noteworthy that the categories of these context are not limited to as mentioned above.

Some may argue that the TCE theory is disjunct from SCM theories. However, while cross-referencing several researches, such as Ketokivi and Mahoney (2017) and Williamson (2008), it is unjust to separate supply chain from cost of economy. It may be also because that encompasses of SCM literatures and researches are mainly developed on the nature of management philosophies – planning, controlling, structuring and their relations, and less emphasis on financial perspective, while TCE purely focuses on sunk and opportunity costs associated with uncertainty, asset specificity and frequency of transaction among parties. Henceforth, in accordance with Mentzer *et al* (2001), the object of SCM is to integrate and manage the flow of sourcing, control of materials from an integrative management perspective, TCE also could be examined in relation to the contractual development and relations among multiple agents in the supply chain network together with costs coupled in each department ranging from raw materials, components, buffer inventories to logistics distribution and human resources. Lastly, in the network of relations, one of the management decisions concentrate on make or buy as to efficiently allocate its resources, where the initial characters of TCE can better serve.

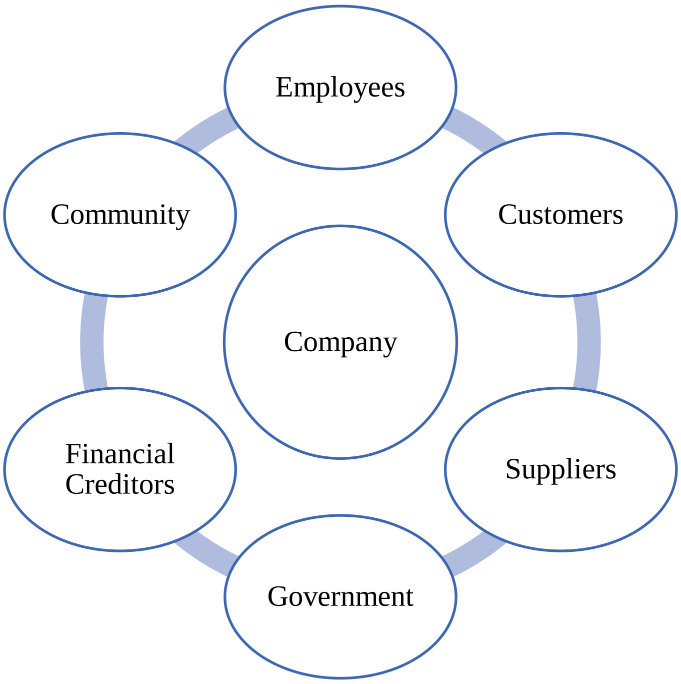
2.5.2 Channel Integration

As continuation of integrating and managing the supply chain, the channel integration emphasis on internal adoption processes moving outward gradually. The very first step of this approach begins with finding the bottleneck within. An analysis of bottleneck helps to improve on cost reductions and resources allocations, and reveals further opportunities for innovative savings, which leads to reduction in transaction cost as well. Meanwhile integrated supply chain can grant efficient suppliers' relations by reducing redundancy, increase the accuracy of delegating responsibilities to entities closer to the key actions. Other promising benefits of this approach are, reduced barriers by rearranging procedures, increased synergy, faster response, lower cost of manufacturing, better capital investment, shorter cycles and increased competitiveness, and productivity. However, it needs to be carried out with proper planning and control of management, full dedication of involved parties. Otherwise, due to the project size, continuous implementation, its costs and time, the worst-case scenario, the firm can shut down the operation for certain period or even to close it.

The integration process can be carried out in two ways: functional integration and process integration. Many companies approach integration on a function-by-function basis, focusing first on highest returning function, such as inventories, procurement, inbound logistics, manufacturing, distribution and services (Anon, 2000). By concentrating on the functions, firms can utilize either all-inclusive approaches incorporating all functions ranging from raw materials to delivery to its customers, and/or implement a closed loop approach including assets divestment, reworks and even customer returns. Despite of embracing integrated functions throughout the supply chain, the network also should be open to function shiftability – capability of being flexible and adaptive, ensuring responsible members of SCM can perform these functions at the lowest overall costs and/or at shortest cycle time (Anon, 2000).

The complexity of identifying and interlinking functions within the supply chain caused many issues over the years. As a result, companies started experimenting and applying the approaches of integrating by processes. Since the business processes are fundamental backbones of the network, analysing and assimilating them provides successful level of details. Through obtaining critical insights, these complex activities can be coordinated and managed effectively between key functions and supporting or non-value-adding activities. Whilst emphasizing on significant effects of SCM integration, it is important to have performance enhancing tools and customized processes, for instance, information technology, channel delivery requirement and platforms, clear marketing segmentation and financial support systems. Not only physical and processes-oriented supports are key to success of integrated SCM. According to Agility Reports (1997), it also includes the stakeholders of the companies as shown below.

Figure10. Stakeholders of Supply Chain Management



Source: Developed based on Agile Report (2017)

Following critical success factors may provide useful understandings, but not limited to;

- Organizational buy in – including employees and management to be fully committed to the factors of integration. Some managers or employees can present attitude of protecting their turf and sabotage the change. To minimize such risk, all communication and decision making should, at least, involve employees and their concerns toward the change.
- Management should communicate clearly on risks and benefits organization-wide. System of reward must be congruent with the proposed changes and consistent throughout the network.
- Network design needs to be adaptive and open to changes. Many cases it is suggested to perform in small cross functional groups with process champions, allowing cooperation and dismantling pre-existing silos.
- Exchange of information among stakeholders need to be encouraged and handled with appropriate technologies. Customers and suppliers in the case, are the foremost agents to be informed. It can be helpful to provide them with sufficient information and updates until the project completion. Standards provided by government agents and involved parties provide great view of how to measure and implement the process integration approaches.
- Strategic commitment must be compatible with the changes that are being carried out. The key aspect of such compatibility is not to misplace the core value of the organization.

Even though, there are only two different types of integration approaches mentioned in this session of the report, there are more innovative methods and systems developed in recent years. The crucial part of such phenomena still falls in examining either organizational functions or its processes in order to understand and apply. Evidently, with the careful and thorough analysis, each participant should develop internal case studies within the supply chain, conform against its external relations, standards and needs, and then simulate the project by applying different techniques that are suitable for ones need.

2.5.3 *Complex Network Approach*

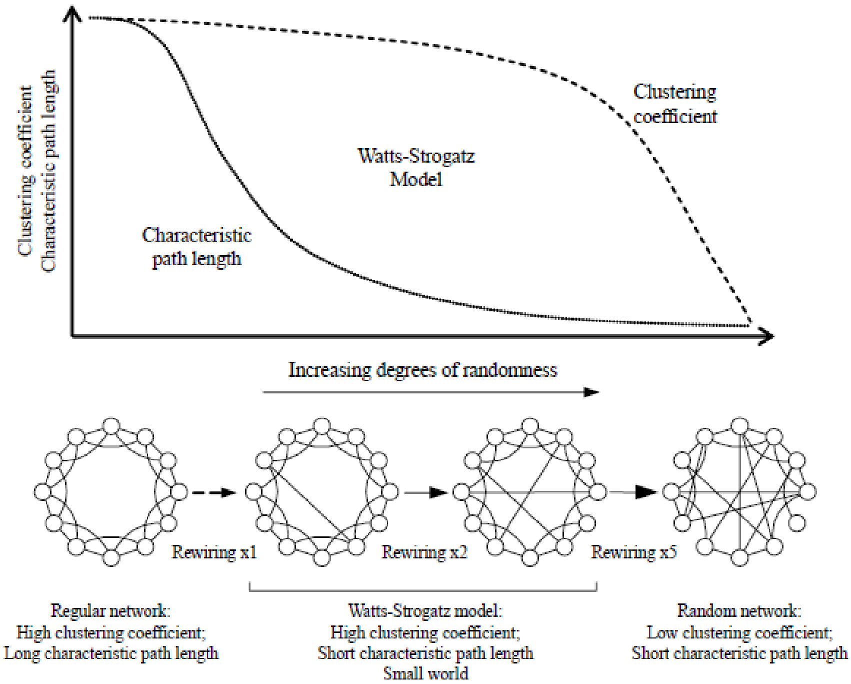
This method approaches the supply chain network as a complex adaptive system instead of traditional view of a linear system interacting through dyadic relationship (Hearnshaw and Wilson, 2013). The linear view of dyadic relations fails to adapt to the heterogeneity of the international business aspect, while it oversimplified the density of such network. The complex network approach, on the other hand, neither oversimplify nor filled with exhaustively details. This method, indeed, was developed through mirroring properties of network model with real world supply chain agents. It is defined as a systematic approach determining the best location and optimal size of facilities in the supply chain and confirms the optimal flow of goods by employing mathematical modelling. Compared to previous model of integrated approach, this method concentrates on creating sophisticated and efficient relational model by fixating on topologies between regular and random network sets.

Traditionally, the network model has been applying either a regular network model or a random network model due to their mathematical capabilities and traceability. In the case of regular model, it has a regular topology defined by a lattice structure and an ordered set of connections between nodes. On the other hand, the random model, which has a random topology determined by a random set of network connection between nods. The topology indicated the ways of indicating how constituted parts are interrelated and/or arranged on the network. While defining the two end spectrums, there are many other complex network models with topologies exist in between the regular and the random modelling.

The most common and well-known models are the Watts-Strongatz (WS from hereon) model and the Barabàsi-Albert (BA from hereafter) model. Of the two, WS model was the first one that mathematically characterized by transforming regular network through random connections. The model contains many local connections similar to regular model, but also has the least amount of random connection that allows long distance transmission across a network (Hearnshaw and Wilson, 2013). The long-distance connection in the WS model shorten its characteristic path length, while demonstrating the presence of small world property. As a result of its limited number of connections have been wired randomly, this model preserves the property of a high clustering coefficient found in the regular model, but not random network, as illustrated in Figure 11. These characteristics place the method closer to the boundary of regular modelling. In fact, the WS model allow the efficiency transfer of flows through the entire system, even though, supply chain managers may only know their immediate tier of firms. That is to say that WS model effectively optimizes two conflicting supply chain objectives, which are high transaction costs of maintaining long distance connections and need of transferring flows of efficiency throughout the system (Mitchel, 2009). Moreover, it allows improved decentralization of network chain by focusing on emergent synchronization of process nodes.

Despite of its advantages, the WS model also presents various types of problems when analysing the types of connection in the supply chain. For instance, the random reconnection does not define the various exchange relationship between nodes sufficiently. Furthermore, this mechanism is not suitable for dynamic supply chain that often changes its member agents and their relationship. Instead, it suggests that the SC is historical and non-growing fixed system.

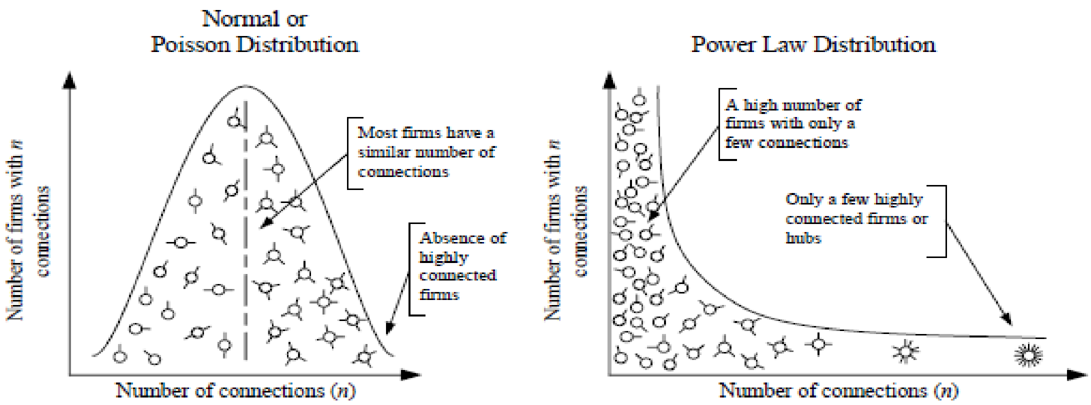
Figure11. Watts-Strogats Model



Source: Hearnshaw & Wilson (2013)

After WS model emerged, Barabàsi and Albert introduced an alternative network model known as a scale-free network (Hearnshaw and Wilson, 2013). Similar to WS model, BA model has small-world property, yet it achieves short characteristics path length with an average connectivity that is relatively lower than any other network models. Due to the lower average number of connectivity and shorter path length, BA model provides higher efficiency and lower cost performance, which is highly economic than WS model. Additionally, this model demonstrates a power law connectivity distribution (Figure 12). Thus, the model is able to elaborate on hub-network firms within the supply chain. However, the drawback of such model, in comparison to WS model is reduced synchronizability due to short path length and presence of hub nodes (Hearnshaw and Wilson 2013). This shows that a power law connectivity distribution reduces synchronizability, while in turn, the hub structured firms can inhibit system-wide coordination.

Figure12. Barabàsi and Albert model



Source: Hearnshaw & Wilson (2013)

However, there are also opposing findings that hub nodes, indeed, can synchronize faster than peripheral nodes with fewer connections, without limited the overflow of information throughout the network. Even though many mechanisms can lead organization to obtain scale-free network by self-organizing processes, BA proposed in their analysis – growth by preferential attachment methodology. Unlike WS model, the growth parameter is being recognized and dynamically adapts into open system nodes, which can enter and exit overtime (Hearnshaw and Wilson, 2013). Furthermore, when new nodes enter into the network, it does not just randomly connect to other nodes. Instead it accommodates the rationality of economic benefits and motives of each firms and connects with them in different ways.

A natural form of this type of presence is a rich-gets-richer, were specific behaviour applies to cases where firms will enter and develop their supply chain network to create competitive or to obtain first mover advantages. However, it is a false assumption that all firms are homogeneous in nature with little or no differentiation. Even though, based on the information, the BA model presents higher efficiency in the supply chain, there are several opposing arguments that can show that this mechanism is still incomplete. Based on the studies, the first objection comes from the growth speed in the supply chain network. Concerning mainly of the mature supply chain network, it will likely to have fixed number players in the network. Secondly, argument concerns about new firms' dominance regardless of mature industry players, such as Google. And finally, a decaying clustering coefficiency overtime, which may not be sufficient when presenting supply cain networks.

To understand the suitability of such SC model, it is important to examine it in relation to adaptive phenomena. According to Hearnshaw and Wilson (2013), observed and highlighted various strategies, while considering the relationship between the network structure and its resilience, cascading failures, and adaptability.

- *Resilience* – system's strength and ability to carry out its functions despite of external disruptions or damages. Although, scale-free network shows resilience against random disturbance events, it is also vulnerable to collapse when faces removal of a hub node (Albert *et al*, 2000). As a result, it is safe to posit that the firmness of channel leader defines the resilience of supply chain system for all connection type against random disturbance events (Hearnshaw and Wilson, 2013).
- *Cascading failures* – this can occur when the supply chain capacity cannot accommodate incoming demand from the market. Not only unavailability issue, the major implication applied to SC bull-whip effect, in relation to materials order size, unavailability of materials or resource and others. Given the various impacts, the most effective and obvious implication can be SC managers to adapt or develop managerial strategies to increase resilience. For instance: timely information sharing to increase agility of SC and preserving redundancies across function –
- *Adaptability* – evidently, this phenomenon signifies the capacity to adapt to dynamic and unexpected changes in external environment. While maintaining connectivity through resilience, adaptability requires reconfiguration of connectivity to fit into a new demand. Research on adaptability shows that smaller networks are model adaptable and persist over time when nodes are fairly stable and fixed in the network.

As mentioned previously, a key advantage of the complex network approach is to analyse multiple units at the same time. By theorizing and accumulating on the key properties allowed complex network model to be more applicable to real world supply chain practices and network structures. We reviewed two common concepts of network structure and evidently both promise fairly attractive advantages to the firms. WS is more suitable for fixed number network nodes with less adaptability, meanwhile BA is more appropriate for those SC that has complex environment and require to be more agile. The dyadic relationship in this case, is not forgotten, instead it has become a complementary approach to supply chain network theory.

Although, the real-life full application of WS and BA model in modern supply network is relatively limited, the recent research found that an example of air cargo transport system, comprising passengers' airlines, and full cargo airline, which has certain complex network properties. The model application is also examined in global trade of metals to study complex trade activities and various economic actors. Some researchers may argue that the scale-free network appears to present efficient and resilient supply chain systems, its properties application have not been studied and tested fully on each individual types of supply chain connections. Therefore, continue testing and discovering these two models in heterogenous firms may help managers to understand the interactions and complexity in various types supply chain networks.

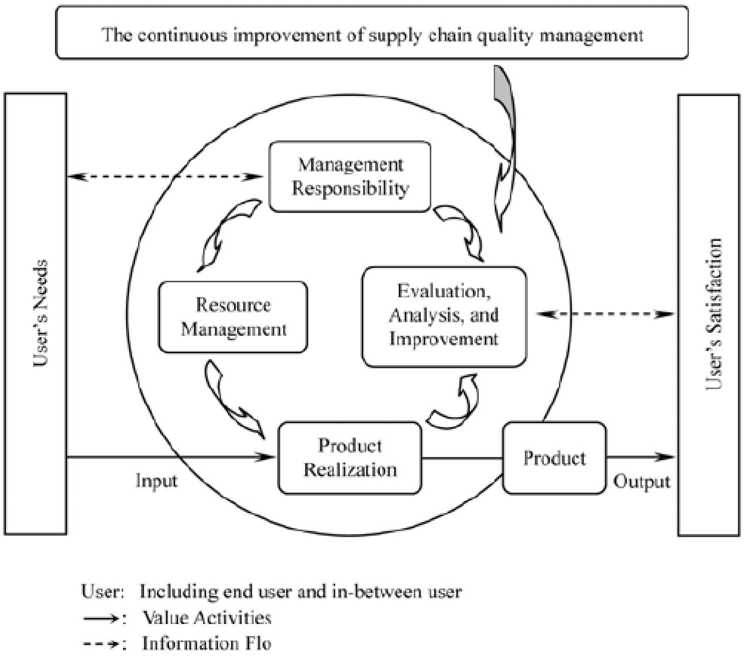
2.5.4 Total Quality Management (TQM)

The phenomenon developed around after World War 1, with effort to increase the quality of mass-produced products nationwide. The philosophy has evolved from quality assurance, eventually merged with a sophisticated statistical sampling model. The model gained more popularity during post WW2 when Japanese manufacturing started investing in quality management processes. The definition of TQM, therefore, driven from quality management procedures, ensuring the continual practices of detecting and reducing or eliminating errors in manufacturing, while streamlining SCM, improving customers experience, and acknowledging the need for employees training for assurance.

Unlike previous models, the TQM starts from the management initiatives and procedures, aimed to achieve the delivery of quality products and services for better returned values. As a result, there are 8 core modern TQM principles that promotes the improvement of operations efficiency and providing competitive advantages throughout the SC network.

- *Customer focus* – the core principle of TQM started from customers' satisfaction and their focus. Hence, the quality is identified through customers' needs and it is also accepted by the end users. The end users often include not only single consumers, but also suppliers, manufacturers and whole sellers. Since the SC network creates complex communication channels for its users, the key problem arises from understanding the needs of the customers and communicate with them clearly.
- *Leadership* – two management leadership has been examined and highlighted in the TQM module. In one end, the internal flow of working process and success factor will depend on the manager's recognition and support of employee's achievements. While other leadership can be noted in the SC network, which requires core enterprise must act as a leader to consider adequate needs and expectation of other members to strive for better target (Chang, 2009).
- *Involvement of stakeholders* – the exertion of enthusiasm and creativity of all the employees is the prerequisite of the actual outcomes of quality management. Therefore, in the supply chain, work atmosphere and ethics must be established to inspire the creative involvement of the people. Rules and responsibilities should be clearly identified, and all must include forward problem solving – independent decision making under the guidelines. Furthermore, it is also suggested that the SC 5s – seiri, seiton, seiso, seiketsu, and shitshke, in other words, self-learning, self-motion, and self-knowledge principles to be adapted by the organization (Chang, 2009).
- *Process Management* – while ensure product quality, the process management also needs to be reviewed. Following figure shows the SC quality management based on the principles of process management.

Figure13. Process management



Source: Chang (2009)

The processes have its own independent objective that mutually will serve the end result of the company. If they are not properly in line with the target, the conflict arises in the supply chain, disintegrating the network of communication among members.

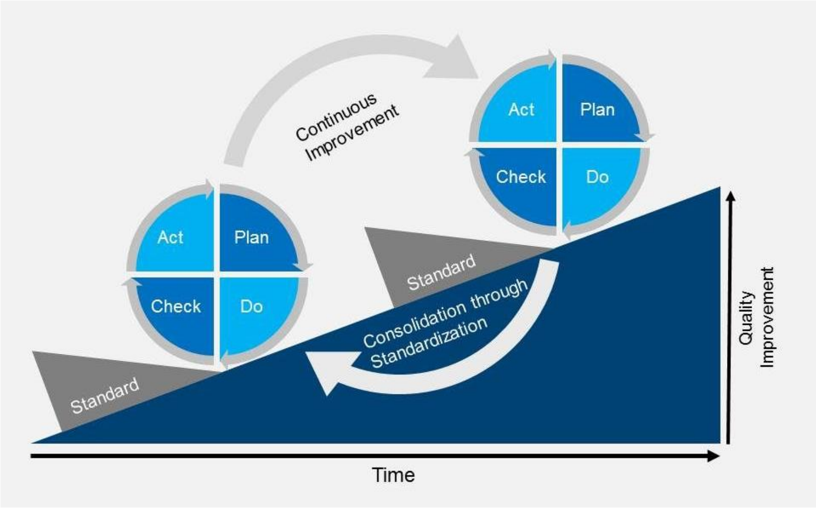
- *System management* – the approach of system management treats supply chain as a holistic system and believes that coordinating and promoting subsystem management will make system greater than the sum of the improvement of each subsystem and improve validity and efficiency of the final target (Chang, 2009). Therefore, in SC network it should identify and confirm the dependent relationship among the processes, break boundaries for those members, and integrate the processes.
- *Continuous improvement* – The core philosophy of TQM is its continuity. Enterprise must improve quality of products, services, and processes continually to reduce costs throughout the chain while satisfy its customers. While internally assuring the permanency, the external members of supply chain also to be involved in the process to eliminate hidden cost in the network.
- *Decision making quality* – the foundation of making right and effective decisions depend on the sufficient quality of data and its handling. In supply chain, there are many modern technologies built as support system such as EDI, ERP, MRP2, POS etc. Even though the effectiveness of such decision is significantly subjective, the general idea surrounds the timeliness and correctness of the final decision to rectify or avoid the problem (Chang, 2009). All in all, decision should be made based on the prior measurement.
- *Mutual beneficial suppliers' relationship* – Organization and its supplier are closely dependent. Working closely with trusted suppliers allow organization to control and monitor the direct material quality, which is the main factor that determining the product quality. To support and collaborate with suppliers on the quality management approach, managers can establish product inspection system and comprehensive evaluation model together with its suppliers.

There are many proponents in TQM where concepts and ideas were developed by notable individuals, such as Deming, Juran, Crosby, Feigenbaum, Taguchi and Ishikawa (Waller, 2002). Each concept and theories represent different types of approaches to obtain better quality management in the SC.

- *Deming's Wheel of Quality*

Deming's idea of quality improvement is a cyclical and continuous process that is presented in Figure 14. There are 4 parts in the wheel – plan, do, check and act. Once organization achieves better standards, it will then continue perform the cyclical process to ensure retaining the higher quality in time. Like general TQM approach, Deming strongly believed in top management contribution and commitment towards the continuity while encouraging teamwork

Figure14. Wheel of quality



Source: Waller (2002)

- *Cost of quality and non-quality*

Another noteworthy approach is costs of quality and total quality costs, which was introduced by Crosby and Feigenbaum. In their model, the total cost of quality contains external, internal, evaluation and prevention costs. External costs relate to non-conforming goods have left the factory, time processing and dealing with the problem. Internal cost, on the other hand, mainly concentrates on defective products found at the factory, time of repairing, cost of replacement, and emotional cost to employees. Cost of preventive actions are those steps taken to minimize the problems by achieving standards – through training, development of systems, analysis, and investments. Finally, the cost of evaluation includes verification of quality standard, production testing, and marketing to the final customers. Considering these 4 elements, the cost of quality and its mathematical relationship is shown below (Waller, 2002),

$$Cost = \frac{Ce + Ci + Cd + Cp}{Cb + Ce + Ci + Cd + Cp} * 100$$

Ce – the external cost

Ci – the internal cost

Cd – cost of detection (evaluation)

Cp – cost of prevention

Cb – the base production cost

Evidently, in practice, it is difficult to separate the costs, thereof, the calculation can be estimated to give sense to manufacturers. Inspection and quality control module often require tools and techniques to support. Depending on the location of the manufacturers, the tools and techniques can diverse. Most often used methods are, ABC analysis, brainstorming, Hoshin, Ishikawa diagram, JIT, Kaizen, or continuous improvement, pareto analysis, pipeline map, poka yoke, scatter diagram, spider web, Taguchi and many more. Following is the summary table for all mentioned models.

Table 4. Summary of TQM tools and techniques

Tools	Content
ABC Analysis	Special form of Pareto or frequency model, used to determine the financial value of stocks relative to the quantity, or number of suppliers relative to the value of purchase (Waller, 2002). It is useful tool for management to improve resource allocation, which directly links to quality of operation.
Brainstorming	This concept is often performed by cross-functional team in the organization to put forward ideas related to the issues. It is particularly useful tool for discussion quality-related issues.
Hoshin	The term Hoshin is the short form of Hoshin Kanri, translation of directing management control and focus to a right way. It relies on a system of forms and rules. One of the main concepts of Hoshin is to thrive minimizing non-value-added activities.
Ishikawa Diagram	It is also known as fishbone diagram or cause and effect diagram, because of its shape and use. It is useful analytical tool for quality inquiries and can be adapted after brainstorming to see clearly of contingencies.
Just-In-Time (JIT)	This management practice is about production of exact amount of goods and delivery of it when needed. By utilizing the tool, delivery time and inventory level are kept on an absolute minimum.
Kaizen	Thriving for continuous improvement is to endlessly try to establish higher level of quality operation. The ultimate goal of the technique is zero defect.
Pareto Analysis	It is a graphical representation of frequency in a cause of problem. The principle of the analysis is to solve the most critical problem, which has most frequency, before devoting resources to the less frequent area of activities.
Pipeline map	The map is used to understand the activities in for physical supply chain, broken down into length and volume to show leanness and flexibility of the system.
Poke Yoke	It is a false safe approach with the goal of increasing the reliability and the quality of product, process and service, through integrating system false-safe devices.
Scatter diagram	The diagram depicts a presentation of the dependent variable with an independent variable. It is purpose to show the correlation between two entities, and if so, the measures can be taken to rectify the problem.
Spider web	It is a pareto type analysis where the information is presented in a graph similar to spider web. The criteria need to be determined by the entity together with range of scores.
Taguchi	They are based on building robust designs by creating tolerance for unavoidable manufacturing variables. According to Taguchi's philosophy, overlooking quality target is better than hitting it a few times.

Source: Developed based on Waller (2002)

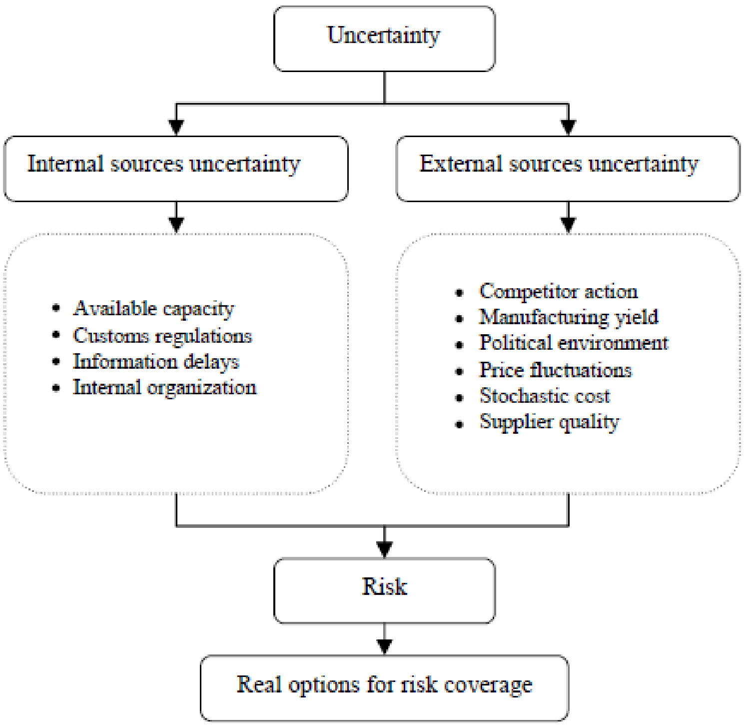
2.5.5 Risk Management

In recent years, many organizations observed both external and internal risks arising from its entire supply chain, including management. The main complexity is driven by dynamicity and ever-changing global market, followed by intense competitions. The right management tools and techniques of SCM is connected to the possibility of obtaining a greater competitive advantage to the firms on the market. The complexity of such market is propelled by uncertainty in the network, for instance, uncertainty of product and services demand and complexity, outsourcing or inhouse production development, technological development and adaptation and many more, which is including subsystems of SC network (Cucchiella and Gastaldi, 2006). In this context, we can propose that complexity of market is equal to its uncertainty. Since the sources of complexity and uncertainty inside in a single network are numerous and multifaceted, it is correct to undertake that current SC businesses are vulnerable yet possess increased exposure to market risks.

The element of risk is defined as the extent of loss – element of loss, importance – significance of loss, and probability of emergence – uncertainty of loss, according to Yates and Stone. Following this definition, we can identify the supply chain risk as resulting: the probability of an issues and failures associated with inbound supplies to outbound products and services to the market which can cause inability to meet customer demand and expectation, in severe cases, it can cause vital health and safety hazards to consumers (Lavastre *et al.*, 2012).

Several researchers studied and identified numerous different types of risks related to SCM. According to Van der Vorst *et al.* (1998), it is possible to group the sources of uncertainty inside the supply chain network into 3 categories: forecast horizon, input data and decision processes (Cucchiella and Gastaldi, 2006). These categories of uncertainties can be subdivided emphasizing more on specific problems, though it may mislay other ambiguities coming from external part of supply chain network. The most common and general utilization of categories are developed based on the environmental characteristics, such as internal and external aspects of the SCM, that is shown in the Figure 15. The graphical representation briefly lists the components of each types of uncertainties in the SC networks and moved down to risks associated with those uncertainties. However, in this case, risk is generalized and illustrated together with options to mitigate those risks.

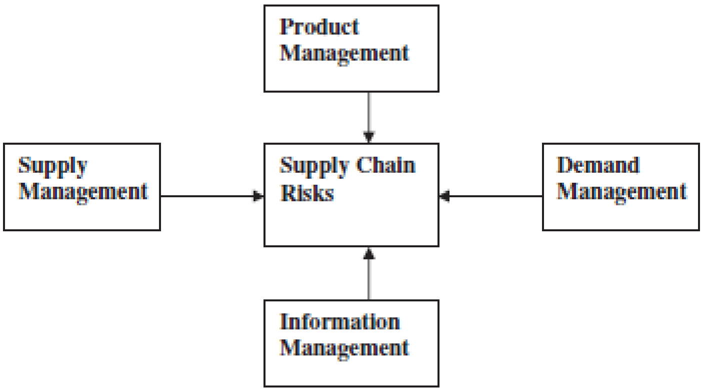
Figure15. General categories of uncertainty



Source: Cucchiella and Gastaldi (2006)

In relation to the literature of Tang (2006), the supply chain risk is described as operational risk or distributional risk that are inherent from uncertainties such as customer demand, supply, cost, ecological and economical. To mitigate these risks, there are four main approaches proposed, as it is expressed in Figure 16. Depending on the natural characteristics, we can also define the risks as known and unknown.

Figure16. Four main approaches for SC risk management

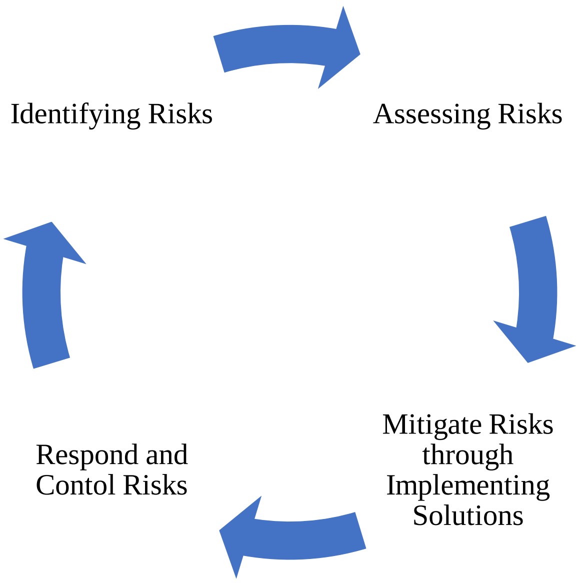


Source: Tang (2006)

- *Product Management* – focuses not only on the products and services, but also way of producing the produce – either make to order to make to stock, capacity of production, process sequencing and employees related management methods.
- *Demand Management* – the module of demand management largely concentrates on economical modes of shifting demand across time, market, products, while also examining product substitutions and bundling.
- *Information Management* – the core function of information management serves as to create interconnected transparent and traceable supply chain network via information sharing, vendor managed inventory and collaborate forecasting approaches, but not limited to these.
- *Supply Management* – this is the biggest and most important part of the risk management in supply chain network that includes network design, suppliers' relationship, its selection and order allocation processes, and contractual terms. In numerous analysis of supply management, majority focuses on multiplicity of two suppliers with deterministic lead times, due to its complexity of discrete time model. Most of analyses, then, consider the two supply modes: regular and emergency. Regular serves constantly to the firm with regular lead time, while emergency supplier is available instantaneously. In this two suppliers' system analysis, the optimal ordering policy is defined in the form of inventory beginning of the period versus the demand of the same period. If the inventory beginning of the period is z, which is lower than x, then the order is (x - z) units by using emergency mode and order (y - x) units by employing regular mode. If $x < z < y$, then only order (y - z) units according to regular processes or other nothing (Tang, 2006). However, owing to complex analysis of the optimal ordering policies, most cases are restricted to the certain classes of ordering sequences and/or policies. It does not consider the external factors such as supplier's material availability and delivery issues.

Meanwhile understanding and mitigating risk through objective tools, such as adapting above mentioned management approaches, many other researchers have attempted to find risk management strategies, which resulted in following areas, identifying risks, assess risks, implement solutions and control risks. As a result, the definition of risk management has broadened as the process of taking strategic steps to identity, assess, mitigate risks in the end-to-end supply chain. The key significant of this approach of mitigating risk is simpler than categorizing every single problem in the organization and finding a solution.

Figure17. Approaches to Supply Chain Risk



Source: Lavaste et al. (2012)

All in all, by integrating risk management techniques into management model of SC will help the organization to be better prepared for uncertainty, even if it is unforeseeable and unavoidable. Meaning the organization needs to be proactive, aware of the risk through constant communications and effective structural designs and allocate resources professionally to mitigate any risks. It is a long-term strategic tool to demonstrate the willingness and collaboration between partners and organization and manage different SC at the same time.

2.5.6 Theory of Constraints (TOC)

Anything that limits the operation or a system from its maximum performance is considered as a constraint. It can be both physical and non-physical ranging from raw materials and capitals to poorly motivated employees and absenteeism. It is evident, according to Noreen *et al.* (1995), the core idea of TOC is that every system has at least one bottleneck or limit which bounds the system from getting more out of its operation. As a result of its weakest link, the SC network can fail to perform effectively and efficiently, for example, part production can slow down due to delays in the delivery of materials from suppliers, which then cause the shortage in the distribution to the retailers. According to Min (2015), the supplier's production capacity is regarded as a "drum" that sets a beat throughout the supply chain. It is also known as a bottleneck that sets the rhythm in the factory system. Size of the inventory held at the firms is considered as a "buffer", and "rope" signifies the link between the upstream and downstream supply chain. This logic of "drum-buffer-rope" of TOC methodology would protect organization from any constraint and allow continuous flow of improvement in the processes (Min, 2015). In comparison to takt time, which is external constrains, Waller (2002) identified drum as internal constrains that can be administered by good management functions.

There are five steps for managing system constrains:

- *Identify the constrains (weakest link) in the system*
- *Exploit methods to overcome the problem without committing to potentially large expense*
- *Subordinate all other decision to step 2, meaning non-bottleneck resources should be allocated for supporting operating capacity at the maximum effectiveness*
- *Elevate the bottleneck through adding more labour, or invest in new equipment, for example*

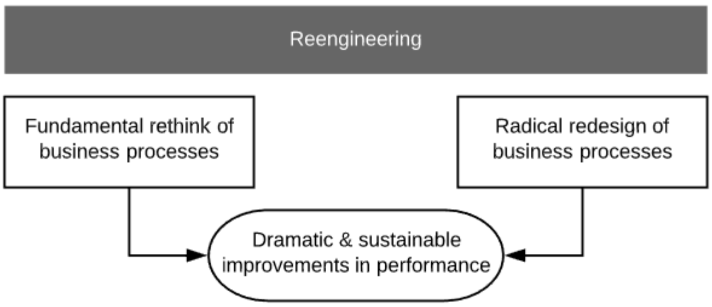
- *Do not let the inertia to settle in, keep on looking for other constrains to continuously improve the SC.*

Many organizations utilize bottleneck philosophy to analyse and improve their performance. The successful implementation of TOC is not only in its simplicity to implement, but also provides improved capacity and product diversity, increased profit, while obtaining reduced lead-time, and effective dynamic process flow within the system. Notwithstanding, the drawbacks of TOC are including difficulty in ongoing maintenance, concentration on single constrain which becomes limit to the other functions, time consuming to determine the constrains, short term effectiveness that becomes long term struggle and sometimes an issue can be outside of organizational control.

2.5.7 Business Process Reengineering (BPR)

BPR is the advancement of management knowledge to enhance the organizational performance by emphasizing on the radical change or designing of strategies, processes, guidelines and structure. Earlier the paper referenced its three methodologies suggested by Valiris and Glykas (1999), since the concept application varies business to business. In some way, BPR is a classificatory extension of SCM components. Researchers like Hammer and Champy (1993, Seeley, 2003, Eftekhari and Akhavan, 2013), believed using clean slate approach – a collection of activities that takes more than one kind of input to produce output that generates value to the customers, which can be seen in Figure 18.

Figure18. Business process engineering model



Source: Hammer and Champy (1993, Budiono and Loice, 2012)

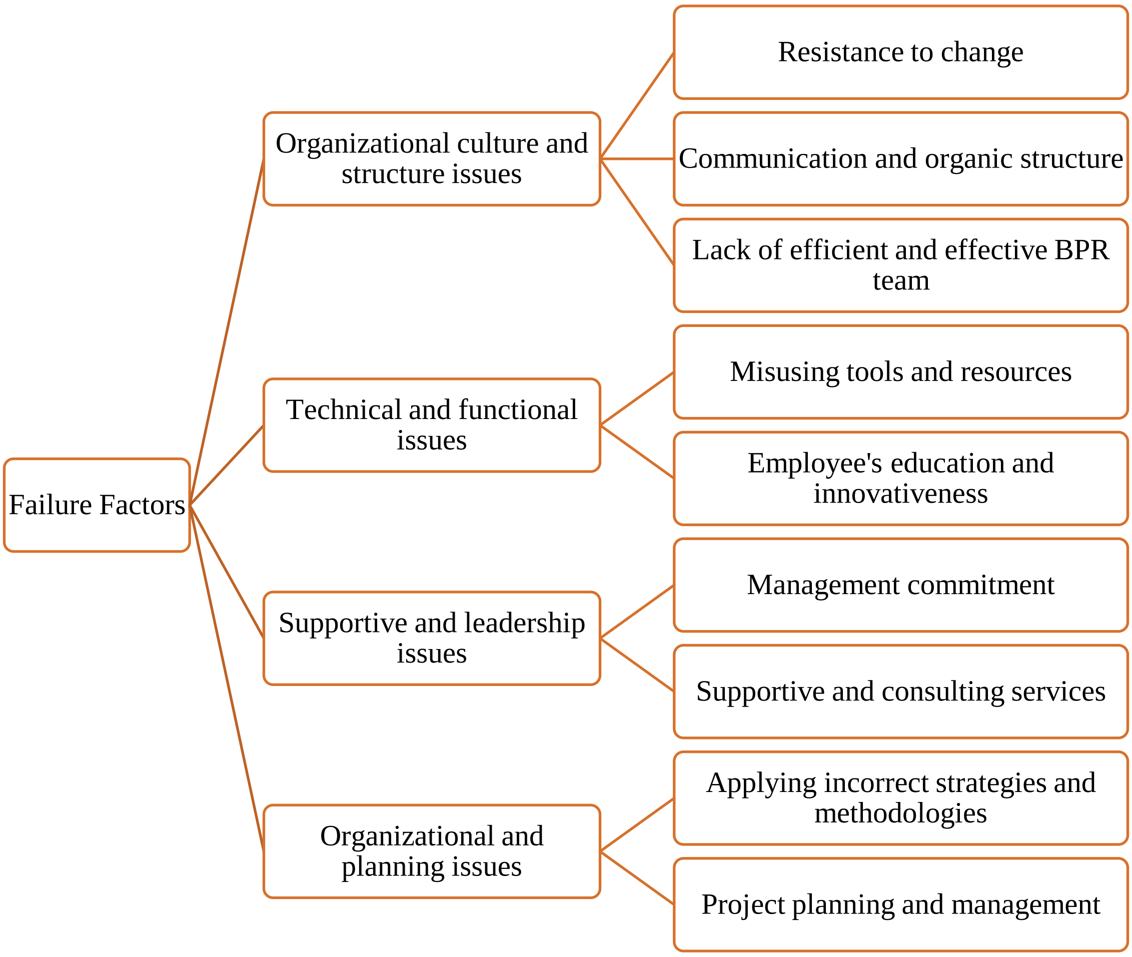
In BPR, the process starts from the outcome, not from the tasks itself. Designing and engineering of processes will organize the business around the final value to the customers by identifying key member that are directly involved in the production of values, information that are necessary for production as well as after production, dispersion and centralization of resources, linking of activities, centralizing decisions, and creating information sources around the key work stations. While evaluating its value creation, process owners are also required to generate cycle process of continuous improvement. As for some researchers, they have approached existing processes, simulation, and best practices, instead of input, such as Hesson and Al-Ameed (2007, Eftekhari and Akhavan, 2013), by decomposing sub-phases of existing processes. The important synchronization of BRP later proposed by other researchers such as Cheng et.al (2012) suggesting knowledge management in combination of BPR, best yet by Eftekhari and Akhanan (2013), employing IT tools to construct and examine the BPR. Adoption of IT tools brings us, then to the modern approaches and development of new SCM terms and modules.

IT tools are used to overcome the barriers of communication among diverse functions, creating more flexible, team oriented, coordinative, and empowered culture to fuel the process of reengineering (Eftekhari and Akhanan, 2013). With these means, we can safely define IT tool role as an enabler in the project of BPR to provide superior link in the integration. It also serves the purpose of a supporter to facilitate the implementation of BRP across organization. As well as it is a facilitator and catalyst in the organization's change process through modern developments.

However, with the constant reminder to obtain a competitive and sustainable organization demands organizations not only look at the advantages of an approach, but also study its side effects. Despite of achieving improved performance, the failure rate associated with BPR is incredibly high. Usually the failures are caused by the resistance to change in organizational members or recognition and redesigning of processes and its continuous implementation. When the project is as big as reorganization the entire corporation, the pitfall of implementation can occur even in the smallest stage. In the research study of Eftekhari and Akhanan (2013), the key failure factors of BPR have been identified together with suggested methodologies to lower the associated risks, illustrated in Figure 19.

Having these critical failure factors will allow the firms to understand the initial risks associated with this BPR approach and eventually reduce the probability of failure factors through innovative solutions. Each implementation stages can also be categorized into stages of – before, during and after phases to understand the obligation and organize the resources better throughout the system of IT.

Figure19. Identification of BPR failure factors



Source: Eftekhari and Akhanan (2013)

In general, BPR is a controversial method for organizational deigns and reengineering. It is recorded as high risk at the same time, high return approach. However, BPR is designed to serve organization wide change and improvement. Therefore, it is not served as a solution of departmental issues in SCM. The lower risk factor lies when organization embraces IT tools and software and validate it in relation to the initial goal of the project of implementing BPR. Clearly, each individual real business case will serve better understanding and recognition of success and failure of this approach.

2.6 Modern Supply Chain Channel

The traditional SCM is rich in well-known and innovative approaches to facilitate managers, who are coping with uncertainty and complexity in ever-growing business network. Some practises such as TQM and TOC are adapted by many organizations across the globe and proven to be successful by large companies. While other tools and techniques are still being maintained among diverse selection of companies, but not fully exploited by their management. Even through researchers and practitioners have proved the importance of these theories and its promised outcomes by working on real world examples over time. However, today we are facing numerous types of additional models in relation to upcoming fascinating technological developments, such as supply chain mapping, blockchain, industry 4.0, AI and machine learning, python modelling and many more. These tools require to provide effort not only on to be sustainable, at the same time need to incorporate modern business environment and characteristics as well. The globe is linked with interconnected trade networks, cross-lined freight routes, global commerce, and outsourced manufacturing. The simplicity of local suppliers has been replaced by global agents, who can provide similar goods at lower costs in compatible lead time. As a result of increased complications and nature of modernity may factor into the limitedness of research that can support and/or prove that these methods could be sustainable.

This is maybe due to the fact that there are still so many companies are using outdated software or accounting methods in their supply chain network, receiving outdated information or utilizing paper documents flow and people-based approaches in production and transportation. Furthermore, changes are often hard, especially when it comes to an unknown technology and/or practice. In the modern SCM, the traditional characteristics that we have discussed earlier have been replaced with three main elements – technology, continuous improvement, and resilience.

2.6.1 Continuous Improvement

The culture of continuous improvement is embedded in the core function of the SCM to be able to sustain and differentiate itself from competitors. The organization can build strong team of motivated professionals that often questions the current status quo to make it better. With the emergence of sophisticated technologies, more and more tools are being innovated and adopted by different companies. A firm can decide whether to practice Six Sigma as their quality and continuous improvement methods, or other tools such as Agile SCM, Toyota Production System, Baldrige Criteria and so on (Elliott, 2015). Since production side is being taken care by advanced technology, the continuous improvement tools can be applied to help eliminating non value-added activities within the SC network. To become lean and flexible supply chain organization, the amount of investment and time needs to be carefully examined. The commitment from the management must be apparent and continuous in relation to employees training and recognition to keep them motivated. Many global organizations like P&G, Coca Cola, and Nestlé require employees who has high degree of commitment, creativity and motivated, in order to support their current pace of changes within and among.

2.6.2 Resilience

One of the most challenging part of building a resilient SC is developing effective communication network and collaboration among network members. The more disconnected the structure of SC are, harder to create short procurement cycle, better quality, attractive and appropriate cost, and ultimately it will impact drastically to the end users. In accordance with Elliott (2015), who restated Accenture survey, that collaborating with suppliers increase the result of fast procurement function up to 50%, with potential savings of 30% of more. Henceforth, by creating strategic suppliers' relationship, the organization can gain advantage of monitoring the processes of their suppliers and influence their quality to become better. Many organizations organize supplier evaluation or auditing process once a year to make sure they follow and enforce the standard, such as IKEA who often keen to develop strong relationship with suppliers by imposing a high threshold of standards to comply with. If the supplier is behind the quality regime within its facility, then they help them to achieve the operational improvements through training programs. This type of suppliers' relationship programs or approaches are key to building a resilience SC network. Both inside and outside of the organization members need to collaborate with the intention of maximizing the value created and captured by all parties through effective and efficient communication network.

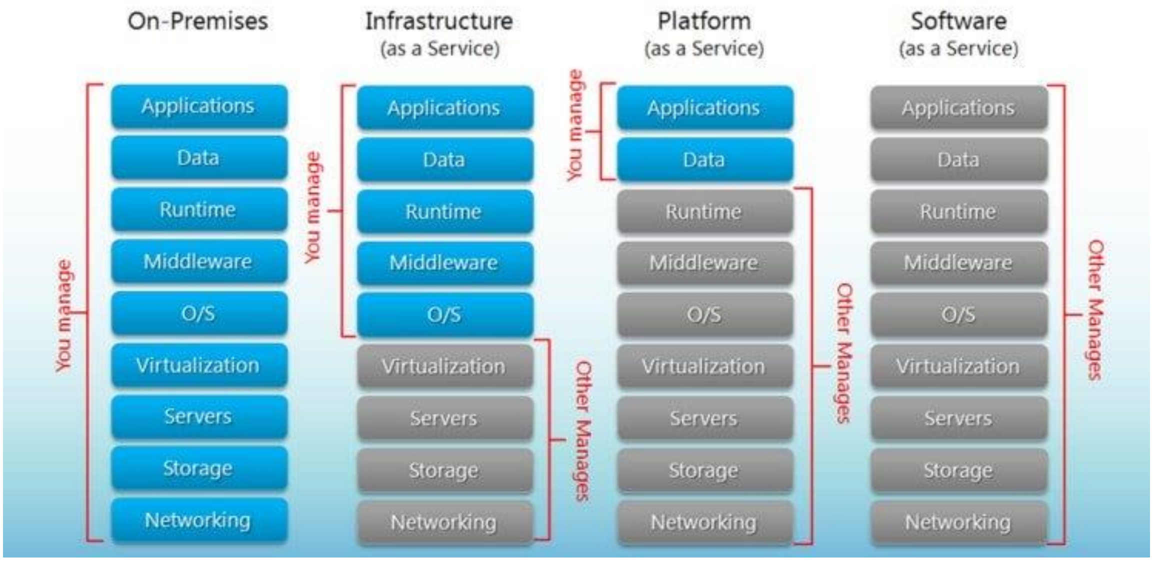
2.6.3 Technology

Innovation is a key to any business developments and supply chain management for centuries. To meet customers' demands and sustain in the market competition, leveraging modern technologies to simplify processes, reduce costs, improve customer satisfaction, provide better control to the system members and overall improve organizational continuality and optimization is apparent and justifiable (Elliott, 2015). Since introduction of MRP 2 and ERP, the system has been developed further into an integrated SCM tool. Other than ERP software, the internet of things (IoT) technologies present very promising opportunities that will help all members in the SC to track products with increased visibility and reduce the impact on disruption of natural disaster or material shortages. For instance, Coca Cola recently reinvented the vending machine that not only offer variety of original products, but also present fountain of sodas that can disperse up to 126 different flavours. Combination with radio frequency identification (RFID) technology, the freestyle soda vending machine can track and monitor the material flow, while feeding the back office with data analysis of most popular flavour among its customers. When the inventory in the vending machine is low, it automatically sends signal back to the company for refilling without external involvement. The data collected and sent by the vending machines is further analysed and used by market department to understand its consumer behaviours, propose strategies to improve sales, which ultimately increases the revenue of the organization (Elliott, 2015).

Another phenomenon emerged over the years into SC is Industry 4.0, the trend towards automation and data exchange of machineries in manufacturing environment which includes cyber-physical systems (CPS), IoT, industrial IoT, cloud computing, cognitive computing, and AI. By installing such omnipresent use of sensors, the expansion of wireless network of communication and network technologies, it believed to reduce the human errors, lower the costs, increase the manufacturing flexibility, achieve mass customization, increase speed, and improved productivity, while offering better quality to the customers. Meanwhile the tangible and intangible benefits have been realized by many researchers and practitioners, this communication of technologies also generates massive amount of information data, which can be both helpful and harmful to the organization. Since mentioning the side-effect of this outstanding term, it does require years and years of investment financially and physically. Furthermore, it is not only about the transformation of the whole sphere of industrial production through merging technologies, it also includes the transformation of network designs and human capital into whole new dimensions. Industry 4.0 is also expected to have a major implication on global economies through efficient manufacturing, fast flow of goods and services, especially investment pouring into the specific industrial developments. The uncertainty of this philosophy is related mainly to the labour market. Many discussions on Industry 4.0 by professionals does not include the its effect on labour market – either it will decrease or increase the job availabilities in certain sectors. Since this term consist of large amount of sophisticated systems and technologies, it should not be ignored to highlight the AI, cloud, and cognitive computing.

Cloud computing and AI are effortlessly reshaping the business, guiding decisions on major industries from agriculture – crop harvest to banking and finance. Even the technologies that enable AI and its development platform are rapidly advancing and becoming affordable. Surprising enough that for small and medium size business owners are being pushed to create e-commerce platform on cloud to be present and connect with its customers. As a result of this market demand, the surge in popularity for SaaS, PaaS, and IaaS, while with the update rates, cloud computing becoming the norm among businesses and customers. More and more users expect such service to be bundled together with any software, otherwise to be offered as an additional service product at certain costs. The difference between above mentioned services are shown in Figure 20.

Figure20. Breakdown of cloud computing services



Source: Bernheim (2017)

However, despite of the promises, many organizations who employed such technology is falling short, in terms of organization wide usage. Based on the recent data, shows only 8% of firms engage in core practices that support extensive adoption of AI, and others utilize it on ad-hoc basis (Fountaine *et al.*, 2019). Not with standing, some industries are lacking behind due to the semi-integrated AI processes. For a long time, AI software tools and its expertise hid in the information technologies division of the organization and did not have the managing power or the sources to incorporate. This case, especially, can be observed in the supply chain side of the businesses, where it is common to find companies with multiple software platforms to support single department performance, such as operations. Traditionally, supply chain is described as an integrative business philosophy to manage multitude of distributional flow channel from inputs to outputs to final customers (Cooper and Ellram, 1993). This means the SCM shifts the unit of analysis from a production unit to a single or multiple warehouse, inventory management, quality management, purchasing and financial, marketing and sales, which span over various division in a company. The managerial tasks become more intricate as a result of automation in production, not only managing physical inventory, now they also required to monitor the intangible data through cutting-edge information systems.

On the contrary, how certain are we in terms of effective adaptation of given technologies and how effectively did the management models catch up with these advancements? Conventionally, each unit of SC within a vertically organized entity, performed independently from each other, creating information variance that caused performance dispersions. Furthermore, much of the knowledge in SCM resides in its constituent parts, such as purchasing, logistics, information technology, quality, and marketing. Over time, these specific knowledge base and independent agents created functional silos that made successful implementation of SCM a complex and extensive challenge to managers. So, finally, the question is can implementation of AI solve these pre-existing problems and continue supporting management with superior analysis? What are the other concerns in regards of applying AI in the management? Moving further along this paper, the framework explores and tries to answer this question by examining various types of SC operations and management issues, protocols, cases, and continue discusses, proposes, and recreates forthcoming dialogues.

Chapter3. Supply Chain Management Problem Scope

3.1 Discussion and Hypotheses

In this session, suitability of AI/ML in SCM network and decision processes has been discussed, beginning with exploring two hypothesis with the intention of understanding current hype among businesses and the scope of problems in term of its decision horizons: (1) long-term strategic decisions, mostly executive level concerns, deal with strategic alliances, expansion, human resources, products development and investments, (2) mid-term tactical decisions, mid-management level issues that contend with joint demand planning, customers' relations and fulfilment, suppliers selection, inventory planning (Min, 2010), and (3) short-term operations decision making that copes with everyday problems, such as shortages, machinery maintenance, orders routing, picking, cycle counting, and delivery receipts. Indeed, in this session we will try to further explore current applications of AI/ML through real business cases in relation to the decision time horizons.

Hypothesis1: Modern concepts of applying Artificial Intelligence (AI) and Machine Learning (ML) are not just a fad, instead it has a promising future.

AI and ML are not just recent phenomenon. There is no doubt that data driven technologies have become the most powerful and eye-catching technological force in the past decade. Thanks for symbolic data collection tools and necessity of innovations, the phenomena of utilizing advanced computer science has come to reality with mind boggling abilities in everything from vision, audio and language processing to complex signals and data manipulations.

While the researchers and computer scientists predicted the models of AI and ML back in 19', the limitation of data did not allow them to successfully test, prove, and implement the technology. This led to exponential expansion over the years when data science and cloud storage introduced and became a necessity for every business. With the endless flow of real data, the capabilities of these mathematical methods have been brought to challenge and allowed AI/ML to progress in both linear and nonlinear forms of data (Rowan, 2020). But having these enormous amount of data does not ensure the quality of progress made in technological field. As a result, the concept of applying AI in business environment seems like craze to many. To support AI technology, the users should have proper set of information architecture to feed its purposes. Without it, the sophisticated AI/ML are nothing but an expensive investment to companies. Although, this advancement is receiving a lot of attention nowadays, users need to understand all the steps required to implement it successfully, not only information architecture, but also ranging from knowledge engineering and high-quality data sources, which are hard to find. In many circumstances, most applications require a significant amount of time, hard work and preparations on the part of human, before starting their own magic.

Evidently, the reality of things may differ from our expectation. Like Roy Amara (Davenport, 2018) once mentioned that "we tend to overestimate the effect of technology in the short run, while underestimate the effects in the long run". The fallacy of AI in modern time is where everyone expects to have fast and easy solutions without any technical issues. Therefore, some may argue that the true AI does not yet exist. And yes, number of companies tend to overuse the terminology of AI solutions and offer expensive services, meanwhile the system is no longer competitive or partially invalid in comparison to the expected results, that can sadden, worst, can haze the reality of our slow development in the nature of AI/ML. The expectation formed by customers are mainly affected and formed by media sources and/or craved marketing and sales. To avoid such high expectation and followed by big disappointment, first companies should focus on the concept of "under promise and over deliver". At the same time, educating customers via companies' network channels and partners are key to desired satisfaction. The customers research on the products and services are an external force that is uncontrollable, while educating them will reduce this risk eventually. This discussion can be further extended to the information clarity and delivery strategies. The information clarity includes well-constructed data in regards of company's products and services, transparency, and security.

Even though many organizations receive and collect thousands and thousands of data information every single second, the usage of this data is still under study. Data gathering and transformation are being questioned by the quality of the algorithms, the next issues, such as transparency and security impose more doubt in the development of AI in businesses. The meaning of transparency in this context, is an explainability of how the decision is being formed. In technologies like AI and deep learning, it is impossible to know exact variables and models being used to result at an outcome (Davenport, 2018). Because there are millions of variables in a single model, which have no inherent meaning to the human observers. Therefore, understanding and explaining how algorithm decides the matter is still underdeveloped, in this case, unexplainable. One of the typical cases that has been documented in regards of AI's usage and bias is definite during hiring processes. Not only small companies, but also big organizations with AI expertise experience such problems, and one of them is Amazon.com Inc. In recent case, the technological specialists of Amazon.com Inc. discovered that their new recruiting engine has biased judgment against women candidates (Dastin, 2018). Even though the automation is the key success of the business, the expert system has been ranging and scoring candidates based on the selection criteria and training data of resumes submitted to the company over 10 years of period. Evidently, the reflection of the male dominance across the tech industry over past 10 years was not sufficient enough for the system to learn. As a result, it taught itself to prefer male candidates over females, and downgrade those resumes. Since the problem has been published, the company disbanded the entire project after losing hope for new edition of the program and shifted towards recommendations generated by the tool and traditional methods of hiring (Dastin, 2018).

However, blaming solely on the underdeveloped technology would be unfair. The technology requires unbiased training modules to generate concrete and accurate decision. In this case, from the ML and AI point of view, the past 10 years of data and hiring decision of human resources are more biased than technology. With the current laws and jurisdiction, better data management and manipulation, and better pipeline methods, the AI still can eliminate unconscious human bias through better sorting, selection and recommendation (Polli, 2019). Since the ML and AI technologies serve higher capacity than humans, in terms of handling large quantity of incoming and outcoming information, additional evaluation assessments, and internal auditing functions can be reduced or even eliminated the risk of such bias. If internal audit is impossible, organizations such as PWC, Deloitte and other external audit firms, can evaluate these systems periodically. It is, therefore, to state that AI/ML are no longer a fad but brings out tradition hidden issues in industries and raises awareness among its users.

The next debate of fallacy comes from the basic definition of AI. Many of us, today, imagine AI as a robotic technology, which function without human interruption and tries to conquer the world, just like in the movies. However, the structure of AI is actually wider than what we expect. It has various applications and algorithmic roots that have been named slightly differently than being just called as Artificial Intelligence (AI). Commonly people use AI, ML, Big data and analytics, or even deep learning simultaneously. But according to Davenport (2018), below table illustrates the description and types of technology that has been known under the umbrella of AI.

Table 5. Deeper descriptions and applications of AI technology

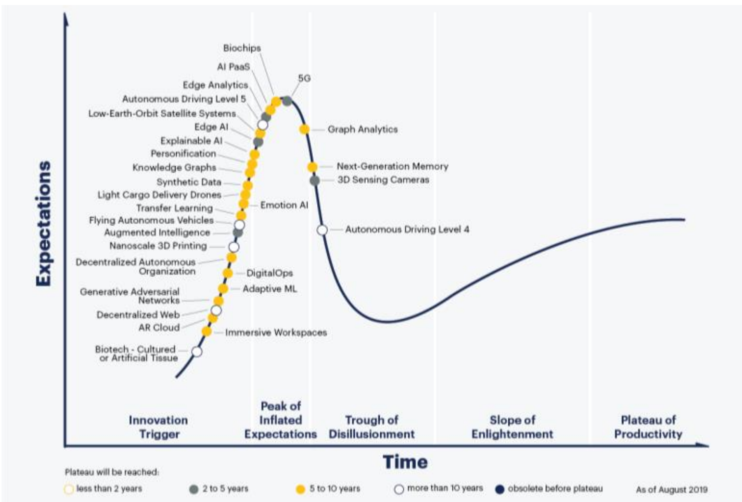
Technology	Description	Applications
Statistical ML	Automates process and fitting models to data	Big data marketing analysis
Neural networks	Artificial neurons to weight input and related it to its output	Credit card fraud in banking services and weather prediction
Deep learning	Neural networks with many variables and layers or features	Image, voice and text extraction – Google
Natural language processing	Analyse and understand human speech and texts	Chatbots and intelligent agents – customer services
Rule-based expert systems	A set of logic rules defined by the experts	Insurance underwriting, credit approval in financial services
Physical robots	Automation of physical activities	Factory and warehouse tasks – Supply chain
Robotic process automation	Automation of structural digital tasks and interfaces with systems	Credit card replacement, validation, and online credentials

Source: Davenport (2018)

For technical users, these definition serves the purpose to select the genre to begin with and deepen their research, while for nontechnical consumers, front end user friendliness and its capacity to perform their current tasks efficiently, such as more sophisticated query and reporting tools, customized dashboards, and interface etc. And for companies, who are finally proposing these solutions, the more they get to know about their users, the more the recommendation can be tailored or even developed. Therefore, it is suggested to learn the users beforehand creating multiple platforms that can confuse your customers.

Even these matters are taken into consideration, there are more important and complicated issues to deal with in the world of AI, relating to its costs and complex integrations with current systems. In relation to product life cycle curve, once most products get adopted by the majority of users, the cost or the price of the products get reduced or generalized to the market. However, AI is not fully developed and yet adopted by many. According to Panetta (2019), there are increasing number of new technologies in emerging AI field, expanding the hype among customers, which is shown in Figure 21. Though, many cool machine-learning innovations are illustrated on the chart, from the return on investment point (ROI), it is still far away to be acknowledged. Thereof, only big companies and technological start-ups are the early adopters of these technologies, and mainstream companies still falling behind.

Figure21. Gartner Hype Cycle for Emerging Technologies 2019



Source: Panetta (2019)

Without a doubt, there are also previously introduced innovations that are available to the users at reasonable to cheaper price. However, the labour market does not have enough knowledge and force to support the expansion of it. The positions for data scientists, analysts and developers are fairly recent and appeared after its technological materialization.

Due to insufficient knowledgeable and unexperienced workforce, implementation of such technology is also challenging for many businesses. According to Polachoswska (2019), the biggest challenge that organization face when adopting AI is its integration with company's culture and existing systems. Integration process is not just a plug-in and go. The process needs to have a project champion, pre-set of data infrastructure, storage, labelling, feeding, modelling, testing, and training. The AI/ML also should have feedback loop to continuously improve the model-based outcomes. However certain data are heavily dependent on employees, their technical expertise which are non-existed and stored systematically. Furthermore, allowing AI to enter the workforce may create mistrust and anxiety among employees, whose fear is losing their jobs to machines. As such fear continuous to grow, people may hide information and misfeed the system. On top of that, for the system to be fully and accurately function, continuous data feedback is the baseline requirement, where many businesses do not have the capability to do so. The main resolution beforehand implementing such sophisticated systems, the management should acknowledge the importance of AI in the workforce and create trusting environment for employees, let them to understand that ML is there to assist not to steal their jobs. Trainers, in this case, are scarce, in fact, the managers and the implementers need to be the one to ensure the quality of training. Moreover, data modelling and its strategies need to be laid out properly in relation to the implementation. Finally, no implementation is complete without any customization, therefore anyone who is looking into upgrading the system into sophisticated AI and ML, need to be prepared for lengthy and expensive process in the near future.

Technical infrastructural challenges aside, the main reason for AI being seen as a fad is due to the lack of understanding of such technology among non-technical users. This presents biggest challenge, yet the cost and success of ML in the workforce. Surprisingly, over the decade, the appetite for adopting ML and deep learning technologies worldwide has increased across industries ranging from simple shops to banking, customers services, manufacturing, and fashion. Consequently, 64% of employees are feeling safer to trust robot assistance than their managers (Oracle, 2019). This survey was conducted across 10 countries, including over 8000 employees, managers, and HR leaders, and revealed the new reality of things in modern time. Not only trusting robots and intelligent assistance, 65% of workers are optimistic and excited about having relationship with AI at work. The survey results by Oracle (2019) continues to reveal more shocking outcomes, that can alter our final thoughts on fad or fact of AI. Since it is evident that the AI/ML is no longer a fad based on all the reasons mentioned earlier, it is may be our time to rethink about the reality of human interactions and relationship at work and how it is being affected by AI, instead.

***Hypothesis2: Applying AI and ML tools and techniques will improve the quality of SC managerial decision making*.**

- *First and foremost, the question should address why Supply Chain Management (SCM) is suitable for AI?*

As discussion earlier chapter, SCM consists of all activities surrounding input to output to the final customers. With the increased demand and promptness require all parties involved in SC to process external and internal information quicker to make decisions. However, human capabilities are limited in terms of increasing incoming data, and processing, in given time. The ongoing challenges of attracting and retaining right talents and customers, while staying competitive in the market pressure companies to converge into new advanced technologies and practices to embrace all possible opportunities on hand. Especially in SCM, excluding external information, managing internal data from operations, for instance, needs plenty of attention, time, and skills, which many professionals may not possess. To combine these characteristics in SCM, it is the right time to embrace AI and ML powered lean and agile SCM. Otherwise, late adopters are no longer able to enjoy the competitive advantages that such technologies offer.

One of the convincing debates of adopting AI into SCM is knowledge transfer and retention, processes integration, and augmentation from Generation Z to New Digital Natives. Henceforth, transferring intangible knowledge from older workforce to newer generation through not only on job training, but also through advanced technologies should be a priority. To continue progressively with knowledge input and create effective communication channel between human and machines affirm the compatibility of AL/ML and modern SCM. Furthermore, it can also help the industry to prepare right expertise and professionals in the long run.

Starting from the enterprise resource planning tool (ERP) until today, there are many ML induced predictor tools have been introduced and advanced with this industry. The shop floor (production floor) are getting filled with robotic technologies, feeding the system with real time information, on top of that reducing human errors, increasing production speed, efficiency, and efficacy. Workers are forced to shift towards monitoring and advisory jobs rather than traditional tasks. Moreover, forecasting of products are gaining more accuracy via real time consumer feedbacks and market demand, while cross referencing the relative resources available in the facility from raw materials to final products. Customer services are no longer bothered by repeated questions, instead they are handling more complex requests while conversational AI robots are taking in change of simple calls professionally. More captivating changes are also happening in warehouse distribution and logistics area, where certain robots are handling heavy products lifting in the warehouse, monitoring inventory rigorously and efficiently, such as Amazon Inc. Not only inhouse inventories are able to be monitored, but also physical movement of the goods in trucks and other means of transports are being observed in actual time and allowing more transparency in the SCM.

According to Capgemini survey, about 83% of executives believe that the lack of end-to-end visibility is the barriers to organizational growth (Squintani, 2019). Departmentally these processes can be somehow managed or dealt with, however, integrating as a whole organization is devastating processes that no one can handle under time pressure. Remarkably, AI/ML can process unlimited number of data in short period, in a given algorithms and arguments, and can inform and advise the decision maker better, while enhancing the visibility across SC. After all, SC is already starting to be equipped with more robotic and ML dependent technologies, it would be wasteful not to embrace these changes in the near future.

Since the adoption of ERP, this system allowed functional upgrades in a given circumstances and readiness of the organizations across the world. Not only that, this tool enabled single, partial, or full integration and implementation via its diverse modules, allowing more flexibility and customization among its users. Unlike financial services and consulting businesses, SC industry can adapt and integrate considerable number of different platforms into one, as long as it ensures smooth operations with greater returns. Many would agree that working on various different platforms may cause increased human errors, therefore allowing AI/ML to automate and guide principal users in SC may attract and strengthen the process ties. Henceforth, data production, transformation and transfer in this industry outperform any other single businesses. Therefore, another key reasons for pursuing AI/ML adoption in SC is due to its rapid generation of tireless amount of internal and external information coming from all the related agents in the value chain. As noted by Min (2010), the one area of AI's potential application that is not have been fully explored is AI in SC management philosophy, which requires comprehensive, complex and interrelated alternative decision choices that it could suffice. This is very crucial not only for the system, but also for the experts in the industry. With these thoughts in mind, integrating and experimenting the recent improvements in the artificial neural network of machines and variety of subfields in AI, the SCM traditional methods and practices would benefit greatly in the future.

- *What are the main goals and advantages of adopting such an advanced technology?*

Successful SCM requires many decisions relating to the flow of information, products, and financial capabilities. The decisions, we can categorize into three different phases, depending on the impacts. Primary choice regarding location, capacity, technology of the plants and warehouses are generally considered strategic preferences, which has a planning period of several years – also known as long-term planning horizon. Second phase comes from choice of suppliers, product ranges, distribution channel and transportation mode selection, which belong to tactical level and can be revised yearly, quarterly or month – known as mid-term. Finally, raw materials, semi-finished goods and finished product flows in the value chain network are operational decisions that need to be carried out continuously and being modified instantly on the daily basis – which is called as short-term horizons. Putting together types of decision horizons with SC branch of activities, these may look as shown below:

Table 6. SC branch activities by planning horizon

Time Horizon	Related activities
Long term	- Financial resources planning - Strategic planning - Brand management and R&D (product development) - Sales management - Human resources planning - Information technology
Mid term	- Demand forecasting - Financial budgeting - Scheduling and production planning - Quality assurance and control - Inventory and warehouse management - Procurement and sourcing - Customers and supplier relationship management
Short term	- Production and shop floor management - Technical maintenance scheduling - Distribution and transportation planning

Source: Min (2010)

The main goal and advantages of adopting AI/ML in SCM varies depending on the application of each activities. For instance, according to Timme and Williams Timme (Min, 2008), the annual cost of a single unit inventory might range from 15% to 35% of its product value. Thus, the firm's success is dependent on its product competitiveness and availability on the market, often times companies hold adequate amount of physical goods. Applying AI/ML can enhance these constant requirements and market movements by producing and providing real time, up-to-date information, which is often difficult to estimate and predict, or even obtain by decision makers. Considering Allen 1986 (Min, 2010) studies on how inventory management assistant system (IMA) improved the effectiveness of inventory management by 8-18% of cost reduction, the expert systems like AI can offer promising new approaches to solve planning problems.

Apart from inventory, AI techniques are also being applied to SC transportation and network designs to provide optimal combination of solutions for routing, scheduling, consolidation, intermodal connection and many more. The problem application expanded also to external sourcing and network designs, such as road network connectivity, parking space utilization, freeway ramp metering and other various transportation network designs. The statistical result of how it has been improved in this case is still unknown. However, the techniques or heuristics that AI/ML offer is more flexible and capable than the traditional methods to accommodate various structural problems. There are other types of AI/ML application in SC are visible, for instance, purchasing, demand planning and forecasting, order-picking, and placing, customers relationship, and e-businesses. In the following session, the report will address several real-life cases of AI/ML application in specific industries, arranged by its time horizons.

Several researchers have reviewed the challenges in alignment and integration of multiple stages in supply chain with AI/ML, while recognizing the need for strategic and operational coordination of SCM challenges. Even though increasing number of journals emphasized on the design and analysis of SC as a whole, the need for individuality imposes critical concerns among managers. As a result, ERP systems were then introduced to overcome these integration problems and assist management. But it focuses on general processes and do not have amplification towards better decision making. On the other hand, the discussion and evidence suggest that AI/ML can improve the singular department activities better than traditional tools. Because, it has equipped with substantial amount algorithms, capacity to recognize patterns in the information, and potential eligibility to learn from its actions. Not with standing, the AI/ML has also proven to decrease functional errors and increase accuracy of information, which leads to better educated decision making. Obviously, the subjectivity of success or failure of final decision depends on human expertise and knowledge. At the end of the day, the main consideration of devoting some of the repetitive tactical duties and tasks to such machine assisted systems will allow employees, managers and executives to dedicate more time to complex, and master well informed, and strategic decision making.

- *What are the risk factors considered in broad SCM environment?*

It is not easy to replace old technologies and focusing on full extension of AI/ML driven SC. The whole process of acquiring and implementing demands time, investment and expert knowledge, which companies are not necessary to have. Not many businesses can afford such incredible system and train their employees continuously. Of course, in comparison to 10 or 20 years ago, there are many single modules that can tailored to the business needs. But it takes also considerable amount of time to be customized, implemented, and rolled out successfully. This process alone creates and brings out many underlying issues within the company, therefore, some executives and owners tend to avoid such changes.

Secondly, AI/ML for most companies, with 78% of organization implementing it to enhance its operational efficiency and efficacy by more than 10%, according to Squintani (2019). However, in different level of organizations across the world experience same problem in the company: scepticism. Surprisingly, based on the Accenture's survey among 1770 managers in 14 different countries revealed that more people in higher level trust AI than first line managers. In relation to the survey, there are still many managers and line supervisors fear of losing their jobs to intelligent machines, where it is being viewed as a harbinger of doom (Kolbjornsrud *et al.*, 2017).

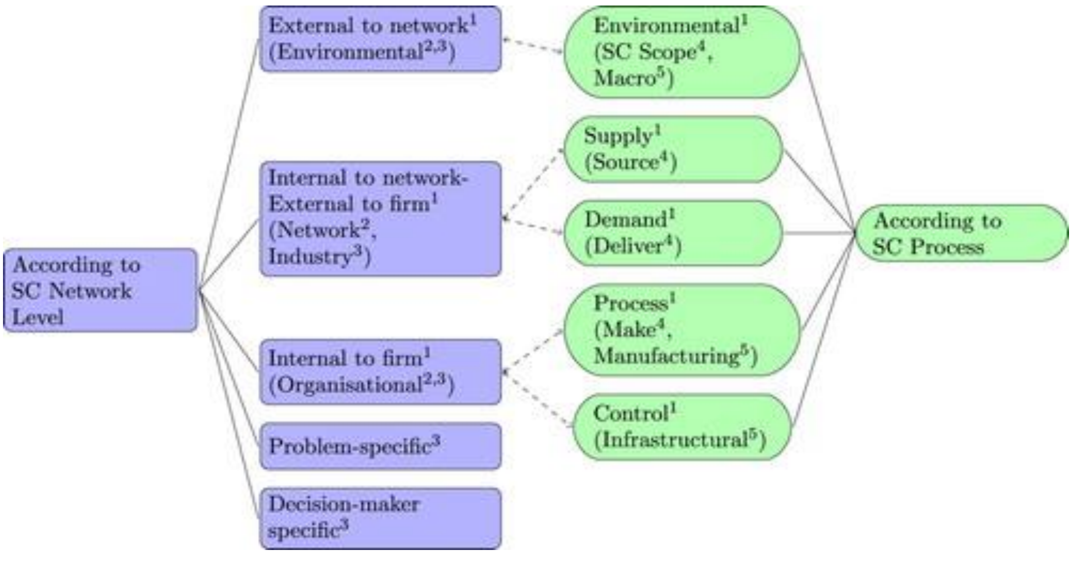
In this case, executives no longer can assume that mid or lower level managers and employees will share appreciation towards AI/ML. More so, replacing certain tasks will bring more hesitation and negative circulation among employees. This underlying issue or simply a concern may trouble the overall emergence and adoption of such systems. Given the fact that national and cultural differences, full adoption of AI/ML seem impossible. However, before adoption, it is recommended to tailoring adaption in the organization, which is why SCM is most suitable to begin with. Furthermore, AI needs control and it is not self-sufficient system from the start. As a result of its initial demand for expert knowledge, it creates skill gap among employees and the system. Evidently, to close this barrier, the company requires to hire or outsource trained professionals. Needless to say, it represents another significant amount of time and financial resources from businesses.

Lastly, the security and transparency of information are still under discussion of many researchers. AI/ML related technologies are not only used for information processing, but also learn to perform better. This complex monitoring and processing system become intelligent overnight, which is exactly why it is often difficult to notice or identity mistakes and errors. Moreover, as discussed in the previous chapter, this system carries confidential information about businesses. Thus, it requires high powered quality network security mechanism, that can jeopardize SC performance if any accident occurs (Robinson, 2018).

- *How can AI and ML can strategically be applied to SCM to mitigate risks and uncertainties?*

The definition and discussion of risk have been subjective or objective across industries and its management. Especially in many different SC literature, it has been classified various ways depending on the scope and goals of the researchers. According to Baryannis *et al.* (2018), the two most common SC risks classifications are shown below,

Figure22. Common SC risks classifications



Source: Baryannis *et al*. (2018)

As illustrated on the Figure 22, the left side categorizes the risks according to its level within the SC network and how they affect or sourced from. It is then subcategorized into three level, which are recognized as external to the network – environmental risks, internal network but external to the focal firm – industrial network risks, and finally fully internal risks – organizational. There are also 2 alternative components introduced into the graph, characterising individual decision makers and problem specific decision. Hence, there are many imposed risks to SCM, why should we bring more uncertainties of utilising AI/ML into the processes?

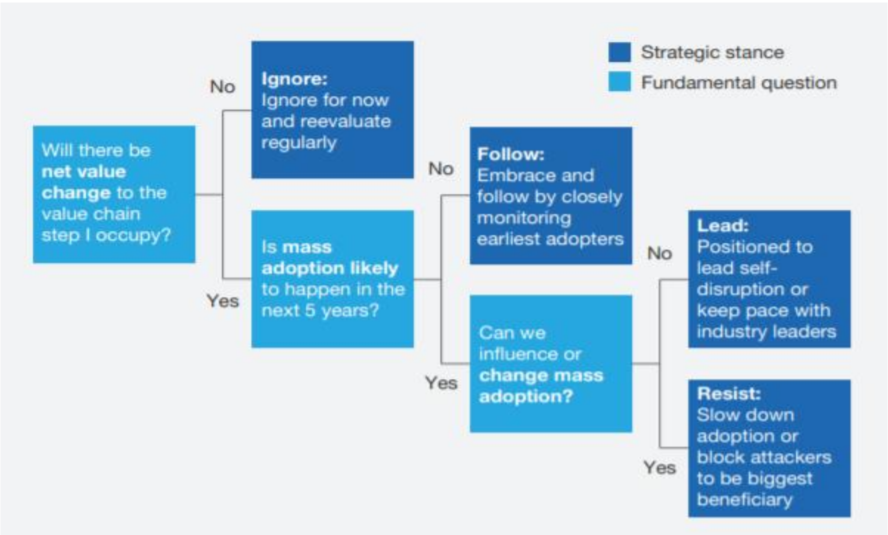
One of the key reasons of applying AI/ML into SC risk management philosophy is to reduce the curse of too much information for managers. Especially with its high capability of assessing, examining, integrating, and informing users on all internal, external, and sub-internal events and uncertainties, it could reduce the information processing time, efforts, and errors. However, most common mistake that many companies do is not allocating sufficient time and research to understand and examine the importance of constructing strategies including AI/ML technologies. Instead, they take ad hoc approaches that might not up to scale, cannot be proven out new or upgrading technologies, and eventually fail to build systematic capabilities internally (Baan *et al.*, 2017).

While hype surrounding AI/ML and related technologies, many companies remain unsure what to do with the technology and how long does it take to fully absorb within the company. Based on the McKinsey survey conducted among CEO and C-level executives in one of the leading industries expert country of China, shows the reality of strategic priority and understanding. The result indicates that 43% of top managers and executives do not think that AI/ML as a strategic priority, meanwhile 43% think it is one of the elements, and only remaining 11% surely considers it as top priority (Baan *et al.*, 2017). In relation to many expert journals that discuss the barriers of executing AI in the business is the lack of expertise and talents in the area. Even though it is the reality, the such case can be mitigated through business leaders' determination and informed selection of the technology, in my opinion.

The steps of any strategic implementation include following activities;

- Determination of potential application, advantages, and fit of the technology in line with the nature of business
- Testing scenarios of AI generated industry disruption and benchmark key arguments
- Define strategic stance together with selecting underlying AI/ML initiatives in each single activity
- Selection of strategic partners, consulting companies based on the criteria
- Implementation and integration processes of AI/ML into current business while examining how external environment could evolve
- When making AI/ML transformation happen, executive also should determine exist strategy of mitigating risks
- The feedback scheme also needs to be laid out clearly and communicated among employees for future prehension

Figure23. Strategic Stance on AI



Source: Baan *et al.* (2017)

While preparing for internal implication, the practitioners and researchers' value considerable external effects on SCM. Traditionally, industries dealt with predictable or unforeseen future events by long term fixed contracts with its suppliers and customers to ensure the continuity of the business. The interest for investigating and mitigating risks of natural and economic disasters has been increased over the decades and pressured every management to be proactive than reactive in order to have sustainable profitability. Especially in the case of following practices led the SCM to be more vulnerable to adverse events, such as;

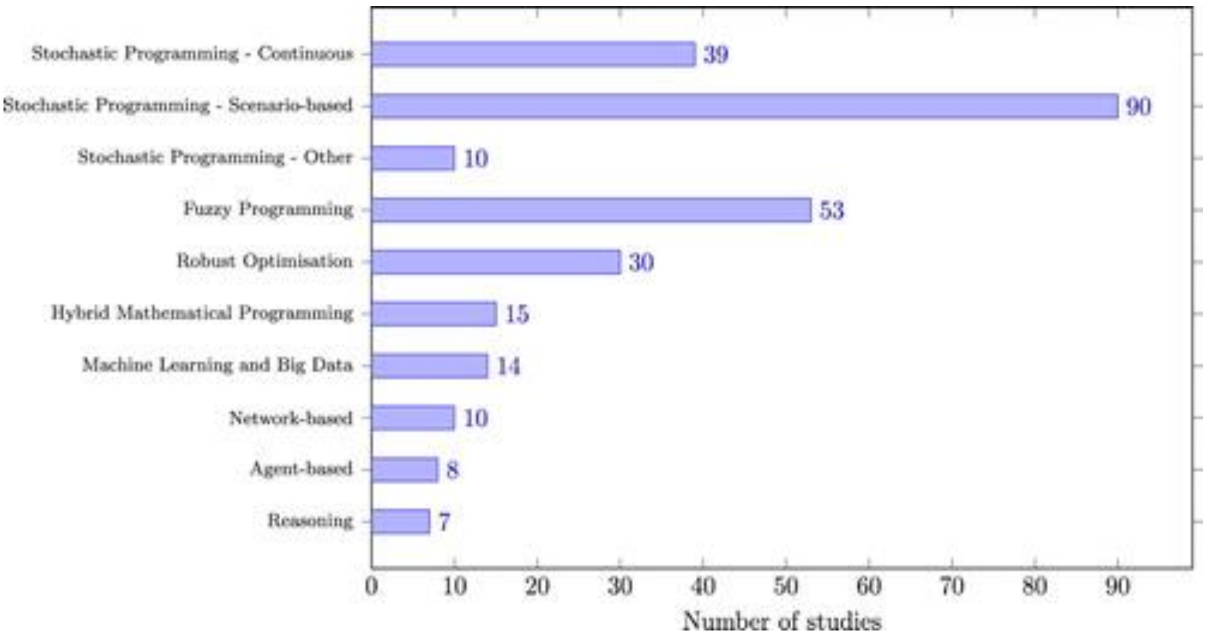
- Adoption of lean management and JIT philosophy in the production and logistics to have increased efficiency
- Increased horizontally integrated SC network enhanced the complexity and expose to more risks out of managers control
- Global crisis, such as natural disaster in Thailand floods, pandemics like SARS and Covid-19, and economic instability and recession attracted more attention and slow movement in investments

In terms of risk mitigation strategic application, SC managers can follow either a reactive or a proactive approach: the former is applied after the risk occurrence, while the latter allows to identify the risk factors before it occurs (Baryannis *et al.*, 2018). So, the relation between internal implication of AI/ML and external risk mitigation factors may rely on how to apply these technologies to further strengthen the explored uncertainties. Methodologies and techniques that fall under the umbrella of AI are various. According to Baryannis *et al* (2018), it has been categorized into five broad categories:

- Techniques that rely on the mathematical optimization
- Network based approaches to explore possible problem states and transitions among them
- Adoption of Agent-based modelling and multi-agent system interactions
- Automated reasoning based on the existing human knowledge inputs
- ML and big data analytical techniques

Based on the risk mitigation approaches adopted by SCM with the support of AI/ML techniques are shown below.

Figure24. Distribution of adopted approached in SC risk management



Source: Baryannis *et al.* (2018)

The comparative graph suggests that 50% of reviewed studies are based on the use of stochastic programming to handle uncertainties. Other mathematical modelling techniques including robust optimization and fuzzy logics are measured at 11% and 19% respectively (Baryannis et al., 2018). A few other studies indicated hybrid application combining various different mathematic programming approaches and solutions proposed by AI based technologies. These includes, Petri-Nets and Bayesian network, multi-agent systems, automated reasoning and ML and big data analytics. However, the studies are still limited to the real-life practices and outcomes. While most of the reviewed reports are focused on the designing and evaluating a mathematical modelling, which takes a number of risks into account, the focus is less on the applicability of the models in the real practice. In accordance with examined data, only 39% of managers believe that some approaches have provided insights to assist decision making, while only 8% of the approaches and models are being materialized such as ML and big data, agent-based system and reasoning (Baryannis et al., 2018).

As a result of imbalanced decision making and unawareness of such application, AI/ML is not widely used in the managing risks and uncertainty. To improve the quality of decision making and awareness among its users, it is believed that developing and including proposed AI/ML techniques into the strategic applications in all areas of SCM. Therefore, the further sub-section and following Chapter 4 of this report is dedicated to exploring the industrial practices and application analytics in detail.

3.2 Decision Making Time Horizons: Case Analysis

3.2.1 Long Term Strategic Application of AI/ML in SCM

First and foremost, the most vulnerability of SCM comes from macroeconomic factors. While board of directors and investors are pushing firms to develop a defensive position, it simultaneously requires firms to be more innovative and performance oriented to enable the fast-growth and competitiveness, where the balance is difficult to be achieved or maintained. Such as Brexit, trade war between United States and China, pandemics like Covid-19, financial recession in USA will impact directly on global supply chain throughout 2019 and 2020 (Chainalytics, 2019). Thus, it is hard for many producers to avoid macroeconomic health and the resulting impacts on respective field of SC. Various development projects – disruptive product innovation, processes, and systems, evidently require long term commitments from investors and host country's economy. In addition to internal stakeholders' interests in mind, often so, leaders become victims of array of speculative news concerning the impact on material shortages, currency rate spikes, and transportation hold ups. Whilst cost efficiency has been looked closely, changes in macro environment can cause increased utilization on financial needs of the companies. The long-term commitment of SCM comes from effective financial resources allocations, human resources planning, innovation management, sales and market that leads to brand image management, and other activities highly related to strategic existence of the company. These activities are mainly performed as a high level of executive management decision making processes. Once the strategic applicability confirmed by the executive, they are being communicated throughout the company, and comes down as a departmental goals and performance. AI/ML, especially, Big data management is currently one of the most popular topics among business and application has been explored, but not yet have been applied by majority. In relation to survey result indicated on MHI Industry Report, which involved 1001 industry professionals in SCM, only 13% replied that they are somewhat using AI. 28% of respondents found to be relying on predictive analytics, which is a part of AI/ML techniques (Leonard, 2020).

One of the key reasons of lower application rate of AI techniques and tools might depend on the its systematic execution is still reliant on human intervention. In relation to Kakatkar, Bilgram, and Fuller (2019), noted that AI may not be ready to completely take over highly creative tasks within the innovation process, but it shows promising results to support innovation managers. However, there are many real business cases available supporting the potential values and current usages of AI in innovation projects. Starting from Google home and Apply Alexa, they are AI driven technology that has been used a newborn technology, at the same time, functions as data collecting bots to the company. Using AI at the front end with the users allowed company to enhance the features of the current products, while also experimenting data driven AI technology to support its innovation – ranging from simple yet most performing functions like Google analytics, translation, and knowledge gap to transcending technologies like Google glass, self-driving cars and many others.

Another case can be seen in the personal care products that are developed in Germany. In the pursuit of a new blockbuster products, one of the German manufacturers commissioned a cross-functional team to conduct an in-depth analysis of online users-generated content in consumer needs. The key focus of the development was to find and investigate key problem areas in body care segment and construct a new product. Traditionally going through a large amount consumer related content information would require days and days' worth of manual effort of leading innovation managers. In this case, the cross-functional team then consisted of innovation manager, data analysts and AI professionals. The first thing the team utilized was to AI to investigate and reduce the analysis burden from the team, while improving the quality of insights. The team received about 1.75 million response online feedback, which presented first challenge of sorting the relative response of title with consumer needs. Such binary classification required subset of the post needs to be labelled correctly in order to allow supervised algorithm to classify the responses. As a result of the sorting and manual subset of responses, the team ended up with 5000 posts, which then continued qualitatively coded, and finally an automated procedure of encoding raw text data to unique numerical vector had begun to fed the AI algorithms(Goldberg, 2006, Kakatkar, Bilgram, and Fuller 2019). In other words, the algorithm was based on the neural network modelling for natural language processing, which is a part of main AI techniques – strength of decomposing large amount of consumer text data into several simpler tasks.

The value after processing captured by AI in many different ways to support the team's effective decision makings. First and foremost, the algorithm managed to identify needs related responses with 75% accuracy (Kakatkar, Bilgram, and Fuller 2019). Secondly, the techniques that AI utilized to simplify the data readiness and classification, and significantly reduced the time and efforts of the team, in general. However, it is proven that AI is still far away from replacing the traditional role and supervision of innovation teams and management. Instead it has been redefined the role of analytical and decision-making processes. Furthermore, by allocating certain tasks to supervisor AI, practitioners can concentrate on orchestrating and improving the quality of work, conducting qualitative analytics of internal and external potential problem areas, and promote collaboration among employees. The finding of the result, in this case was more qualitative measure that actual output after the AI application. However, it is reported that the manufacturer continues using the technology together with the cross functional teams to enrich better understanding and performance overall. Other areas of in innovation department, such as target market analysis, trend analysis, foreign direct investment analysis, other than products' feedback from consumer also can be performed by AI with the integration of digital presence.

Another important area of SCM that started utilizing is human resource managers (HRM), who have begun incorporating specialized data analytics tool into their decision-making processes. Promoting, collecting, and screening potential candidate is one of the major time-consuming tasks for HR employees. At least, posting, promoting, and collecting major number application are being done by public software platforms like Linkedin. Further the extension of such software, also can sort the applications through analysing patterns, prediction likeable hired, and present the final numbers of application to the companies. And it would cost significantly less than manual processing manpower and shifting higher yielding in terms of interviewing appropriate candidates (Hamilton and Sodeman, 2019). However, the application of big data or AI should not be limited to screening appropriate candidates. Since it promises wide range of benefits, HR should direct these AI techniques and big data tools to capture strategic linkage between human capital and profitability, enhancing departmental functionality of skills training and knowledge development, and finally discovering steps to contribute to the competitive advantage of the overall SCM. Companies like Amazon.com strategically place big data analytics in the front end to objectively evaluate candidate through functional and analytical test. They also encourage the candidate to respond to voice generated questions and record their answer via their website. This is one of the competitive advantages of the company, showing their foremost technological advancement to the public. Of course, remaining screening and decision criteria remain confidential, by utilizing such platform help the company to reduce the processing time and gain more efficiency in their HR department. Unfortunately, in most SC related industries, HR is relatively less supported by their top management. These functions are traditionally thought to be soft skill oriented subjective, yet easy. Thus, the complexity is rising together with increase in cost and turnover rates. Additionally, HR departments often justify their own relegation by overfocusing on the transaction rather than strategic concerns. Which means, managers tend to focus more on the short supply and administrative costs of new employees than retaining manpower and knowledge transfers.

According to Hamilton and Sodeman (2019), the primary concept of utilizing big data in HR function is the concept of ML – where software takes a segment of data set and continuously processes until it learns the correlation between variables through pattern recognition and other developed algorithms, and completes the tasks by determining the association and predictions for the given problems. The result can be shown in a graphical dashboard and other types of visualization to make it easier for the users to process. However, the model is still not fully functionable without errors. There are two main problems discovered by researchers in the past, identified as chronic problems with ML accuracy – overfitting and algorithmic bias. Overfitting problem happens when the machine detects patterns that do not have content validity, especially in a large data set, the irrelevant correlation can and will occur statistically. On the other hand, algorithmic bias happens when training data is poorly designed and verified. In both cases, the problems are driven by previous data set and human errors. One of the cases that researchers from Northeaster University, University of California, and Upturn – a public interest group, have proven is Facebook's tailored advertising. The company's algorithm, apparently, delivered housing and employment ads stereotypically based on the gender and race of the users (Schulte, 2019). Evidently, since then more development has occurred in the big data and HR system application areas. Today, many large companies like Target, Hilton. Cisco, FedEx, PepsiCo, and others use predictive hiring tools to reduce time and costs and believed to increase the quality and tenure of new hires. But which point the algorithm is being utilized during the hiring processes of these companies are unknown. Some may be used as advertising to the target group, such as Facebook ads, in other cases, it may have been used during screen and scanning of candidates' information. More data sources and real time applications are available for HR to receive internal and external applications, the system should be trained fairly and correctly to overcome the strong algorithmic bias. This allows decision-makers a great chance of obtaining better insights, vision, and allow opportunity to further discover underlying patterns and problems, and proactively respond to them as much as possible.

Although most processes are automated or involve less human contribution in the SCM operation, retaining and/or acquiring right talent with technical and analytical skills are critical and invest-worthy. It is also important to remember the differences among individual members in the SC; therefore AI/ML alone is still not sufficient enough and it is far from replacing traditional jobs like HRM. While internet and big data changed whole dynamic of workplace and employment structure, not only providing job opportunities with decent pay is considered fit for the society. Companies need to juggle with flexible work hours, benefits, trainings, and other socio-economic engagement with its all aspects of activities, which is why HRM should devote more time in the strategic position and processes than limited its time with hiring and selection processes. With the support of AI/ML technologies, the effectiveness and efficiency of HR capital can be improved dramatically in SCM.

3.2.2 Mid Term Tactical Decisions of SCM

The discussion further continues its course in the suppliers' selection and relationship process in SCM. The process by which firms identify, evaluate and contract with suppliers is subjective in terms of the decision-making methodologies and successful deployment. Typical phases of selection process require enormous time and consideration from soliciting to validation of inter-related information and resources, at the risk of tremendous financial resources of the firm. Furthermore, the problems become diverse when nature of production changes from make-to-stock to make-to-order (also known as Just-In-Time). However, not every company apply proper multi-criteria approaches to arrive in final solution to select a supplier, who are in-line with the needs and goals of the organization. More often than ever, the management short cut the process by favouring one supplier than others and sabotaging the financial and operational outcomes. In many cases aim of supplier selection is focused on short to mid-term partnerships among suppliers than focusing on creating competitive advantage through developing strong strategic partnerships (Aksoy, Sucky and Ozturk, 2014). As a result, it is evident that managers need a sustainable supplier evaluation process that considers appropriate multi-criteria analysis, to reduce time pressure, lack of expertise and avoid ethical dilemmas.

The aim of examining the supplier selection process is that it has direct impact on the competitive advantage of the manufacturers through three primary processes; (a) supporting and improving business processes across the SC, (b) next generational model that can handle complex multi-enterprise processes, and (c) expedite the rapid product cycles and new product introductions. Having integrated supplier network allows the manufacturers to provide competitive pricing, high quality products and services to their final customers according to the demand effective. So how does AI/ML techniques and tools can help manufacturers in this challenging process improvements?

There are little to no attention given to the concrete decisions and appropriateness of selection of suppliers in SCM. Especially in the case of multiple sourcing, with multiple criteria and capacity constraints of various suppliers are discussed less in the literature. Not to mention, even though are the only limited numbers of mathematical programming available for such analysis, priorities of decisions are given to a net price of the raw materials, purchasing costs in addition to the transportation, and reordering and storage availability, and lead time. To reduce the decision-making time, the most managers use scoring techniques, which are available and simple to use. However, would their judgment justify the end result of insignificant improvement in their supplier's performance and relationship?

The comprehensive review of Ghodsypour and O'Brien (2001, Choy *et al.,* 2002) have addressed several mathematical techniques in relation to problems in supplier's selection, such as linear programming, mixed integer programming, goal programming, and non-linear programming. Whilst exploring these approaches, the researcher developed decision support system, which used integrated analytical hierarchy process (AHP) with mixed integer programming and considered various aspects such as suppliers' capacity and buyers' limitation of budget issues together with quality, delivery and other common problems of SC. The intention of utilizing DSS is to help managers to consider both qualitative and quantitative factors of selecting suppliers and make their purchase decisions. Later the researcher developed the non-linear programming models to solve multiple sourcing problem, which takes into account the total cost of logistics, ordering costs, together with limitations of capacity and budgets. However, DSS mainly concentrates on the internal information input, and disregard the externality of the environment, such as raw materials shortages on the market, natural disasters, and economic turmoil. Thus, integrating AI/ML techniques with DSS might help to solve this problem.

One of the major developments made during 20th century was flexible and interactive DSS to aid optimal selection of partners for businesses by Gupta and Nagi (1995). This DSS takes formally combined concrete data as well as user's fuzzy qualitative information to provide near optimal selection of suppliers. The approach starts with construction of an AHP comparison matrix with default pairwise evaluation of attributes using fuzzy input functions, while users provide the priorities, which makes up the Fuzzy-AHP synthesized model analysis (Choy *et al.,* 2002). Other researchers such as Herrmann and Minis (1996, Choy *et al.,* 2002) also described variant approaches that evaluates the prospective suppliers from the early stage of product life cycle. The method evaluated the proposed design with respective partners and provided recommendation to the product development team, based on their given prioritized factors – such as fast and inexpensive production – agile suppliers. The approach was applied by flat mechanical part producers. The main strength of the variant was integrating issues related to product modelling, automated generation of group technology codes, concise and detailed product descriptions and process plans of similar products. The result was shown compatible in the flat mechanical parts, but still required additional research for non-flat and non-mechanical products, overall.

Another application of AI/ML technique – case-based reasoning (CBR) approach is a subset of knowledge-based system, which is different from rule-based system. This approach is capable of explaining the activities in the context of the case, unlike rule-based system. In contrast with traditional AI approaches that generally rely on the knowledge of a problem domain and tend to solve the problem based on the first principle, CBR is a ML technique that solves new problems by utilizing specific knowledge in the past and basic encoded competencies (Choy *et al.,* 2002). In other words, CBR is an incremental learning model since it has new retaining experience each time it solves a problem – system that is capable of learning by itself. There are several physical applications of CBR can be seen from different kinds of industries. The most common is the constructions and building industry, where the system is used to identify possible causes of defects with potential solutions, while rule-based systems are being utilized in medical care to diagnose the bacterial infections. Besides of these applications, the growing implementation of CBR can be seen in SC-CRM. The CBR system in CRM model is also known as support management automated reasoning technology (SMART) system, that is integrated with existing call-routing and logging system to gather information. As a result, the company could collect customers information and related problems, concisely summarize, and feed into the system, and eventually perform case searches against the previous files in order to show optimal suggestion to the current customers issues. By using this system in the customer help desk, company can keep their customers loyalty and brand image intact. It is evident that CBR tools are useful in searching the knowledge-based information, comparing various different data to inform the file users. Therefore, it can be seen as valuable techniques to be considered using even in supplier selection process in relation to ANN to validate the search result in SCM (Choy *el al.,* 2003). Even though, there are not many evidence supporting such application, relative modification can help supplement conventional measures, which are mainly dependent on the purchasing and procurement managers.

Another sophisticated example of advanced technologies applied in actual case is farming operations. The agriculture industry entails complex decision-making problems and characterized by multi-layered uncertainties and alternative courses of actions. Especially in modern time, where sustainable farming aspect is on the horizon, crop farmers required to considered variety of enabling technologies to optimize the plant. The Precision Agriculture (PA) integrates and relies on the IT equipment, services and most importantly software to electronically monitor soil and crop conditions and target the treatment with high level of details (Choy *el al.,* 2003). The rapid development of wireless sensor network with effective design and low cost which integrated with internet of things (IoT) empowered as a feasible tool for automating and support decision making in the farming.

The reasons for utilising such technology in the traditional agriculture industry is obviously due to reduced crop production over the last decade, in relation to increased environmental concerns, food productions and prices to the final customers. Furthermore, automated soil testing and analysis will help to reduce the inaccuracies of lab tested results, that caused by human errors (Vincent *et al.,* 2019). The IT equipment – such as sensors play significant role in the collecting information about various real factors that affect agriculture development, for example. The key factors influencing crop yields are according to Vincent *et al*, (2019), climate conditions, soil productivity, groundwater characteristics and its availability. However, in the extension of such research, Aubert, Schroeder, and Grimaudo (2012) also took account into individual characteristics and social influences. After the extensive data collection, the next stage is the analyse the information. In most common cases, neural network-based models are widely used to improve the efficiency of the model. The classification problems are being handled by a decision tree, support vector machines and such, that can be easily simplified, while complex multi-class classifications are handled by the neural network algorithms. When the measures are evaluated and reflected by the constructed models, the parameters are presented to the farmers as choices. Both researches, PA technology, which was done in support of Canadian farming industry, and AI based agriculture, where it is being examined and integrated multiple sources of current GPS, multi-layer perceptron on land, showed significant amount of improved performance. For instance, the AI based models in sustainable agriculture by Vincent *et al*¸ (2019), performed better in the accuracy and found improvement in other performance measures. The model also provides a reliable decision on the suitability level of the land in different categories, helping farmers to assess their land appropriately. On the other hand, PA technology and model application showed higher acceptance and adoption from the farmers, due to its ease of use, vendors support, precise and usefulness of information provided, with compatibility of existing technology. The extent of IoT use with AI in agriculture is not limited to above mentioned functions, it also includes image-based insight generation, disease detections in plants, analysis on readiness of the crop, field management and resources optimizations. However, there are still a lot of more data to be required to feed and train the system for better precision. The future of farming industry is largely reliant on the adopting cognitive technological solutions, continued research, and support from the government for its sustainability and robustness.

The application of AI/ML tools and techniques in SCM mid-term decision making can also be seen in logistics and distribution planning, forecasting and demand planning, inventory, and warehouse planning functions. The main advantages of utilizing AI/ML can generally be recognized as enhanced, precise performance to achieve long-term goals of the organization. However, the future implication of these advanced methods is to make it easier and sustainable for the users for integrating, substituting, and supporting other industrial activities at large.

3.2.3 Short Term Operational Analysis Involving AI/ML Techniques

One of the most prevailing usage of data analysis and big data is during emergency SCM, in conjunction with social media tools. Based on Kim *et al.* (2018) analysis of how big data or data collection from Facebook and Twitter can characterise the emergent social networking. They illustrated the importance of strategic implication of monitoring heterogeneous online network during disaster response (Yong *et al,* 2019). The operational point of view, such situation persuade management to make instant decision with the result of saving millions of lives.

AI in medical field is not so recent phenomenon. Its applications and disruptive innovations are proven to provides efficient analysis, medical records, and fast consistent results. Especially in different fields of medical industry, AI/ML is being applied differently.

- Medicine – AI provides advanced diagnosis, treatment personalization and drug developments with accurate undertake on time processing. Particularly in vaccine development, where the pandemic such as SARS-CoV 2 hits the global population, the role of AI has increased. According to Grossman (2020) revealed, COVID-19 presents a potentially problematic challenge even for AI, since there is no sufficient data on similar DNA structure. For the time being, AI is functioning to speed up the COVID-19 diagnostics by reducing the time for CT scan under 5 minutes. Due to highly infectious disease like SARS and COVID-19, the application of AI techniques has been hiked, even though the challenge still lies with sufficiency of information. Moderna Therapeutics also uses AI to accelerate the learning cycle drastically, to provide better insights and production of data, were otherwise inaccessible and unachievable (Grossman, 2020). So far, the company has produced potential vaccination, even though the methods remained secret. Thus, the vaccine is ready for trial on humans, with the further detection and observations on the patients.
- Surgery – Doctors and surgeons are effectively integrating AI with surgery by capturing data of all phases. The main role of AI technology and techniques during surgery generates an evidence-based clinical decision to improve patient care and workflow of the surgeons (Haleem *et al.,* 2019). Another potential application of AI during surgery is the surgical adjuncts or robots. While adjuncts – microscopes and image guidance service medical and physical advantage to the surgeons, permitting quicker and accurate procedures with fewer errors, surgical robots perform a range of soft and rigid tissue procedures quickly and safely without human surgeons.
- Cardiology – AI is also used in cardiology to reduce the risk of sudden cardiac arrest among patients. The purpose of utilizing AI in such intriguing part of medicine is to provide better care to the patients at large. The concepts and techniques of AI has been used over two decades in cardiology. While broad form of this technology is providing improved decision-making among practitioners through evidence-based diagnostics, narrow form of AI is performing specific tasks, such as implantable devices with sensors with remote monitoring via sophisticated algorithms for patients require cardioverter defibrillator – patients with possible sudden cardiac death (Itchhaporia, 2018).
- Hospital administration – not with to mention, another wide application of AI is in hospital administration, where it improved and synchronized various factors and data in contrast to the

improved medical records, automation of customers, and patients' data storage, information collections and results (Haleem *et al.*, 2019). On a day to day basis, the system accurately predicts the cause of disease of a person and provides possible treatment solutions to the team. Overall, it also contributes to increased efficiency of doctors and staff workflow and control.

In the above-mentioned subfields of medical industry, we only mentioned the general term of advanced technology – AI. The following table will provide different types of AI techniques in the medical fields.

Figure25. Types of AI techniques in medical field

S. no	Technologies	Description
1	Machine learning (ML)	• Machine learning systems are programs which are self-improving and learning with no experience or being trained over some time • They can evaluate the medical results automatically and present them with a probabilistic degree of accuracy • ML algorithms can make decisions with the following algorithms and methods such as supervised learning, unsupervised learning, semisupervised learning and reinforced learning • In the medical field, this technology is used to identify the probability of disease • ML is helpful to save the record of the patient for better treatment
2	Artificial neural network (ANN)	• Artificial neural network works and is inspired by the neural structure of the human brain, working on the concept of backpropagation and layers (input layers, hidden layer, output layers) • ANN functions similar to neurons as each neuron is connected similarly to each ANN neuron has weight and are connected • Through the training of ANN with large sets of data, the best weight equivalent to bond strength in human brain neurons makes sure that the best path is procured through ANN • Helpful in forecasting the incidence of disease and in decision-making
3	Natural language processing (NLP)	• NLP refers to the speech recognition and evaluation of languages with different techniques • There are many independent NLP algorithms such as parsing, POS, tagging using Hidden Markov model (HMM) • In the medical field, this technology is useful for clinical decision trials and supports and analyses the unstructured dataf • It is also used for automated coding and maintains clinical documentation of the patient
4	Support vector machine (SVM)	• A support vector machine determines the class groups of data for the given input data • It solves the problem of data classification in the primary basis • They are used in e-mail spam filters when an SVM classifier is trained; it can be used to see new and unseen data points for future correlations • Used for collection and processing of medical data • Appropriately manage patient and are helpful in making an evidence-based decision
5	Heuristics analysis (HA)	• This technique uses a trial and error method for detection and discovery to solve a problem • The basic algorithm on which heuristic analysis works is by using such a practical solution which may not yield the optimal goal but works sufficiently to fulfil that goal • Heuristic analysis is best to approach for patient safety and efficiently identify different problems

Source: Haleem *et al,* (2019)

AI uses complex algorithms dedicated for the analysis of complex and substantial medical data, that directly affects the patients' well-being. Not only towards to the patients, the AI/ML techniques provide support to medical education, training, research, and development. It also being utilized in the finance and innovation management – such as drugs and vaccine development, which helped to reduce and time and cost of daily operations, made it leaner and agile.

As such, it is evident that AI is highly recommended and widely applied in complex medical industry successfully, and it is proven that it has potential to support even the traditional management philosophy of SCM, ranging from production issues, machinery maintenance, and scheduling related errors, inventory problems and distribution setbacks. These activities often require immediate decisions and followed by actions of the employees to promptly react and solve the incoming issues. In this matter, AI/ML algorithms alone cannot satisfy the physical need of manufacturing. Instead, it needs to have collaborative and advanced digital technologies in the front end of the production lines. Under the umbrella of Industry 4.0 and blockchain – which promotes application of robotic technologies, the phenomena of Smart manufacturing emerged. Smart manufacturing is a broad characterization of utilizing computer integrated lean and agile manufacturing that encourages high flexibility, rapid adaptability via collaboration of superior trained employees and digital technologies (Waycott, 2016).

In the case of one of most well-known and premium clothing brands – The Ralph Lauren Corporation (RLC), the company is working with IoT digital technology to achieve more authentic and transparent SC. The IoT platform provides unique digital identity for its five categories of products: apparel, footwear and accessories, home, fragrances, and hospitality. Since the company has complex SC of hundreds of trusted manufacturing partners, the purpose behind implementing IoT in their network is to track each produced item to support brand integrity, operational efficiency, and consumer engagement (World Economic Forum, 2019). At its core, the mass scale digitization produces Active Digital Identity (ADI) in the cloud to manage data throughout its SC while a uniquely assigned label and QR code links item with ADI in cloud. Correspondingly, the consumers also have ability to authenticate the products they purchase through the digital platform, providing assurance and clarity, thus this protect brand integrity and connectivity. The information is also collected from consumer end in regards of RLC products and recommendations. This data and product life cycle ensure the brand productivity and high performance today.

While AI helps the management and supervisors to make instant decisions based on the given decision support and data, blockchain or IoT digital technologies improves physical traceability, transparency of operations, and of course, data collection at the production level. Furthermore, these advanced techs promote sustainable SCM, where possible materials can be examined and reused throughout the process. For example, Apple Corp demonstrated that the most of their aluminium parts recovered from iPhones can be part of the 100% recycled aluminium enclosure of a MacBook Air (World Economic Forum, 2019). To do so, the company must have trusted partners who are willing to supply quality parts that will benefit both parties, whilst engaging considerable amount of data and practicing strong SC transparency to ensure the life-cycle of semi-finished products. Hence the company is already the leading manufacturer of advanced technology and innovation, the application of AI/ML based control and monitoring techniques are immense and upward. The Apple Zero Waste Program was started from 2015 and in 2018, the effort of the company showed significant result. Their SC for final assembly of all facilities for iPhone, iPad, Mac, Apple Watch, Air Pods, and Home Pods are all certified by UL Zero Waste, where Apple suppliers can re-use the parts of these items.

The last example of real time application of AI/ML techniques and tools inside the SCM short-term function is regarding predictive maintenance planning. The facility management (FM) of SC is considered reaction function rather the proactive decision. As a result, it is often failed to preclude from the potential issues, especially in production equipment and machineries. According to Cheng *et al.* (2020) the annual cost of many SC FM is accounted for more than 65%, which mainly includes property, land, and assets of the business. To reduce this inefficiency, researchers proposed many different modules, and one of them is Building Information Modelling (BIM) and IoT. There are also computerized maintenance management systems (CMMS) and computerized aided facility systems (CAFM) that focus on capturing invaluable information (Cheng *et al.*, 2020), majority of SC professionals still use traditional spreadsheet to communicate, track, and transfer FM information, resulting delayed response, inefficient operational management, and inconsistent data maintenance at the same time. On the other hand, proposed BIM module will serve to facilitate the maintenance activities and its planning, data collection and storage, including incurred problems, locations, problem categorizations, and solutions. However, BIM is not a data generation module, therefore it requires IoT sensor network or RFID systems to support its data collection functions.

The building conditions and components lack in overtime data, therefore applying linear time series trend may not be suitable. Instead ML algorithms, such as ANN, SVM, and Markov chains, can be applied to predict FM components conditions. Particularly ANN has potential to support predicting non-linear time series data trend. As noted by Cheng *et al.* (2020), ANNs differ from traditional statistical models for trend prediction. It performs better than known classical auto-regressive models for trend prediction of non-linear time series, and widely used in forecasting and life cycle of serviced products. On contrary, SVM model is widely used in classification techniques based on the statistical learning theory. Sousa *et al.* (2014) also evaluated the performance of ANNs and SVMs in predicting conditions of sewers and found particular advantages. However, the comparative results of both models are inconclusive, even though ANNs showed better results, whereas SVMs performed higher result in dispersion. Finally, Markov chain model, a stochastics model that describes a sequence of possible events with the probability of each depends on the previous events. The model has been applied to predict the life cycle of bridge and components. Thus, the limitation has been observed through the application of this model; (a) it used discrete parameters and (b) past conditions being ignored, and future conditions are calculated only based on present circumstance.

The proposed framework of Cheng *et al.* (2020) consisted of two layers – information including data collection and integration, and application, which multiple approaches of assess, predict, control, and monitor. The model then applied to three buildings of Hong Kong University of Science and Technology (HKUST). As a result of such extensive research application, the researchers discovered three significant implications, such as early stage of alarming to avoid failure and staffs achieved the prompt reaction, facility managers could know the condition of failure in advance and obtained better planning, and sourcing of maintenance materials and tools were ahead of the time. However, limitations of such applications in mind, the development for various field needs to be tested and validated.

Overall, benefits of utilizing AI/ML techniques and models can even help the floor staff and mechanics to understand the conditions of their equipment and machineries earlier before it fails. The proactive approaches from management to bottom level employees can benefit even in the long run, shaping SCM more agile and competitive. In further cases, quality of each module should consider dispersion of interconnected information moving throughout the SC, for instance, inventory management to production, supply base to channel monitoring, risk management to speed of operations and more.

Chapter4. Methodologies: AI and ML Focused Problem Solving

AI and cognitive computing are known for its ability to think like humans. With the respect of this distinctiveness, it can be further classified into a number of sub-fields based on the mathematical algorithmic approaches. These sub-fields, then, can be characterized based on the nature of their servings, (1) thinking humanly, (2) acting humanly, (3) thinking rationally and (4) acting rationally (Min, 2010). Each of these categories consists of multiple elements and we are going to examine the implication of selected concepts and evaluate their benefits toward to SCM philosophies and practices.

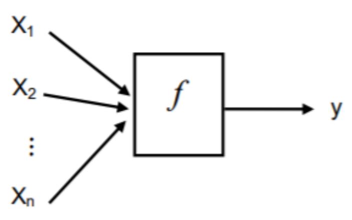
4.1 Thinking Humanly

Our mind, since childhood, start grasp on building personal beliefs, desires, emotions, and intentions. As soon we enter into the society, our brain begins to learn from others' behaviour and start simulating possible prediction, sometimes breaks down the actions into pieces. The vast simulation in itself allows us to develop cognitive abilities and social interaction skills. In the machine, the cognitive skill of humanly thinking will come from the ability to not only navigate through a straight line with trained dataset, it also simulates the right, left, up or down path to determine actions (Fan, 2018). But approach will not end its course in pre-programmed consequence engine, the development of series of artificial neural network allows deep learning like human behaviour. This aspect of the AI also includes rough set theory, which was introduced by Pawlak in 1982, and can be used for classification to discover structure relationship between imprecise or noisy data (Han *et al.*, 2012). However, under the characteristics of thinking humanly, we will further examine the ANN approach.

4.1.1 Artificial Neural Network (ANN)

The ANN system mimicked the brain cells, namely neurons, and its interconnectedness allowed computer memories to learn from its experience, distinguish features, recognize patterns, cluster objects, and process ambiguous or abstract information. It is composed of numerous nodes, each connected to each other through links with numeric weights assigned to it. The weights of each links are primary means of the long-term memory storage. The information processing in the network is organized in a way that on neurons output is another linked neuron's input. The weights are also important for prioritizing the information passed via link, and values of such weights are in a process of learning (Min, 2010). The mathematical expression of basic functionality of neurons and graphical representation showed in Figure 26.

Figure 26: Basic work principle neurons



Source: Liu (2015)

$$y=f(\sum w_i x_i)$$

y – output | w_i *– weight coefficient*

x_i *– input* | *f – characteristic function*

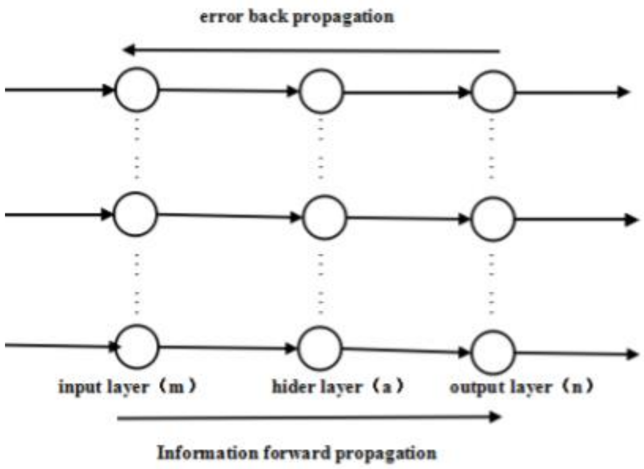
This reflects the mapping relationship between inputs and outputs, and it is usually a non-linear function (Liu, 2015). A neural network is just a collection of connected units, and its network properties are defined by its topology and the properties of the neurons (Russell and Norvig, 2010). While ANN can be taught to correspond to various data patterns and its hidden interrelations, it also can be modified to improve its performance through inductive learning algorithm with or without human supervision (McCulloch and Pitts, 1943, Min 2010).

Based on the mathematical modelling, the next step is to connect the nodes together to form a network. There are two fundamental forms of neural networks that can be mixed and matched, (a) feed-forward network – that is a non-linear learner when its fully connected, and can be used as a drop-I whenever a linear learning is used, (b) recurrent or recursive network – is designed to work with model sequences and generalizations (Goldberg, 2015).

A feed-forward network has connection only to one direction, which forms a direct acyclic graph. In other words, every node received information from input in the upstream, and produces output to the downstream nodes. There are no loops in the system. This network represents functions of its current input, whilst, it has no internal state other than the weights themselves (Russell and Norvig, 2010). Fully feed-forward network, as mentioned, is non-linear learner that includes binary, multiclass classification, and complex structural prediction problems, and can be integrated with pre-trained sets for superior classification accuracy.

A recurrent network, on the other hand, has feedback loop from its outputs into its inputs. This means that the activation levels of such network form a dynamic system, which reaches a stable state or exhibit oscillations or even chaotic behaviour. Unlike feed-forward network, a recurrent network can support short term memory. As a result of this feature, it makes it interesting yet more challenging model to understand. In other words, it is capable of self-learning, and generation mechanism. Figure 27 illustrates the basic business process network with the hidden layer of interrelationship;

Figure27. A classical 3-layer business process network



Source: Liu (2015)

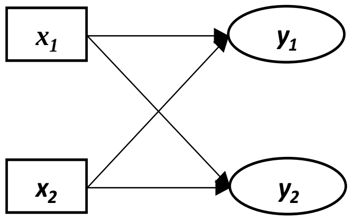
According to Min (2010) and Liu (2015), ANN in business process is simple and has easy implementation, while it has potential for complex learning tasks. ANN must have certain amount of twiddling to form right network structure and achieve convergence to something close to the global optimum in weight space. Starting with a single later feed-forward neural network system, or also called as a perceptron network, we will continue our journey to multi-layer network model and its algorithmic formation.

- *Single layer feed forward NN (Perceptron)*

A network with all its inputs directly connected to the outputs through a single layer of weights is known as a single layer feed-forward network, or a perceptron network. In the network, outputs do not interact with each other, thereof, a network with *N* outputs can be treated as *N* separate single output network. As an example, we can take a look at a simplest form of such network can contain 2 perceptron networks consisting 2 inputs and 2 outputs, as shown in Figure 28.

Figure 28. Single layer feed-forward network with its training data

x_1	x_2	y_1	y_2
0	0	0	0
0	1	0	1
1	0	0	1
1	1	1	0



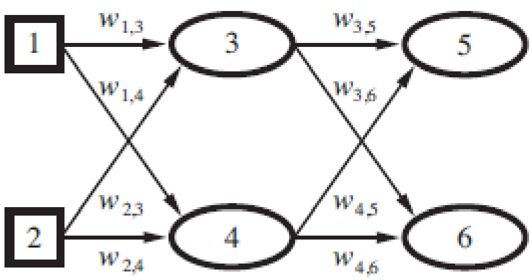
Source: Russell and Norvig (2010)

Since the perceptron network consists of y_1 and y_2 outputs, there are only 2 networks, because each weight of x_1 and x_2 affect only one of the outputs. Input layer of single feed-forward network does not count, because there is no computation performed in that layer. In other words, input layer is where data itself exists without modifications. Although problems in single layer perceptron network are simple to solve and easily represented in a decision tree graph, it does not necessarily mean that single perceptron network is suitable for all problems.

- *Multilayer feed forward NNs*

Opposed to single layer network is multilayer feed-forward network, where there is a hidden layer depicted between the input and output layers. According to Haykin (1999, Sazli, 2006), the functions of the hidden layer of this network is to intervene between the external inputs and the network outputs to extract higher order statistics.

Figure29. Neural network with hidden layer of units



Source: Russell and Norvig (2010)

In multi-layer feed-forward neural network, the function $h_w(x)$ parameterized by now the weight *w*. Consider that, Figure 29 training data has 2 hidden units added. Given an input vector $x = (x_1, x_2)$, the activation of the inputs is set to $(a_1, a_2) = (x_1, x_2)$.

The output at the unit 5 is given by;

$a_5 = g(w_{0,5},+w_{3,5}\ a_3 + w_{4,5}\ a_4)$

$= g(w_{0,5},+w_{3,5}\ g(w_{0,3} + w_{1,3}\ a_1 + w_{2,3}\ a_2) + w_{4,5}\ g(w_{0,4} + w_{1,4}\ a_1 + w_{2,4}\ a_2))$

$= g(w_{0,5},+w_{3,5}\ g(w_{0,3} + w_{1,3}\ x_1 + w_{2,3}\ x_2) + w_{4,5}\ g(w_{0,4} + w_{1,4}\ x_1 + w_{2,4}\ x_2)).$

A similar expression will be shown for unit 6. Because the function of network can be highly on linear – nested of non-linear threshold functions, the ANN can serve as an important tool for non-linear regression. In both Figure 28 and 29, networks are fully connected, due to the fact that in each layer is connected to every other neuron in the forward layer. If some case, the synaptic connections were missing, then the networks would be called as partially connected.

The final version we are considering is multi-layer network, which arises more complications and interactions among the networks. In this case, we need to think of the network implementation of a vector function h_w rather than a scalar function of h_w. In both a_5 and a_6 in Figure 29 depend on the input layer weights, thereof updates to those weights will depend on errors in both a_5 and a_6. This dependency is simple in the case of any loss function that is addictive across the components of the error vector y-$h_w(x)$, where L_2 loss are represented below;

$$\frac{\partial}{\partial w} Loss(\mathbf{w}) = \frac{\partial}{\partial w}|\mathbf{y} - \mathbf{h_w}(\mathbf{x})|^2 = \frac{\partial}{\partial w}\sum_k (y_k - a_k)^2 = \sum_k \frac{\partial}{\partial w}(y_k - a_k)^2$$

For any weight w, the index k ranges over the nodes in the output layer. In the final summation, each item is just a gradient of the loss for the k-th output, computed as if another output does not exist (Russell and Norvig, 2010). The major complication comes from the additional hidden input later, whereas the error y- $h_w(x)$ at the output layer is clear, the error at the hidden layer seems perplexing, because training set does not say what value the hidden nodes should have.

Backpropagation is the learning algorithm that is most popular and used for the training of feed-forward neural networks. By using backpropagation, we can examine the hidden layer through errors from the output layer. During learning phase of the machine, the network learns by adjusting the weights, so that it will be able to correct the class of label of the input tuples. The neural network learning is also known as connectionist learning, because of its connections between nodes and units (Han *et al.,* 2012). The algorithm processes the training data set, comparing network's prediction for each tuple with the actual target value. For each training set tuple, the weights are, then, adjusted to minimize the mean-squared error between the network prediction and the actual target value.

As mentioned, the modification starts from the output layer to backward direction to reach hidden layer. For a unit of j in the output layer, the error Err_j is computed as such;

$$Err_j = O_j(1 - O_j)(T_j - O_j)$$

Err_j *– errors in j unit of output layer*

O_j *– actual output for unit j*

T_j *– desired target output for neuron j*

Note that $O_j(1 - O_j)$ is the derivative of the logistic function during calculation. In order to calculate the hidden layer unit j, the weighted sum of the errors of the units connected to unit j in the next layer are considered, and shown below (Han *et al,* 2012), the error of a hidden layer unit j is;

$$Err_j = O_j(1 - O_j)\sum_k Err_k w_{jk}$$

w_{jk} *– the weight of the connection from unit j to a unit k in the next higher layer*

Err_k *– error of unit k*

When weights are updated in the equation, biases are updated to reflect the propagation errors, where Δw_{ij} is the change in the weight w_{ij}

$$\Delta w_{ij} = (l)\ Err_j\ O_j$$

$$w_{ij} = w_{ij} + \Delta w_{ij}$$

Δw_{ij} *– the change in the weight* w_{ij}

l – learning rate

The learning rate typically ranges between 0.0 to 1.0. This rate helps to avoid being stuck at the local decision space and encourage more findings in the global minimum (Han *et al*, 2012). The idea of learning rate is that when the value is too small then machine will learn slower, oppositely, when the rate is higher the learning is faster. However, keep it in mind that, too high rate my result in oscillation between in adequate solutions.

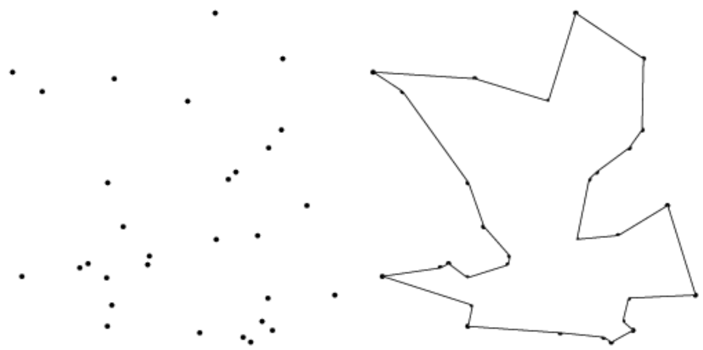
The efficiency of backpropagation depends on the time spent training the network and machines. Just like a human being, each epoch or tuples require time. It also depends on the number of input variables, thus, the time spent on each network varies. Fortunate enough, based on the circumstance, number of solutions to speed up the processes are available nowadays.

The most important feature of neural network is its learning capability, which can learn and improve its performance from its environment. There are many types of ANNs, which has different strengths and weaknesses in their applications. And its abilities of different networks also dependent on their structure, dynamics and learning methods (Soroush et al., 2009). The earliest kind of ANN is a single layer classic perceptron network, which is shown in the Figure 28. Other types include, feedforward neural network, radial basis function network, self-organizing map (SOM), recurrent neural network, Hopfield network and many more. And these types also characterized into the two main categories as mentioned earlier – supervised and unsupervised. Therefore, SCM environment is suitable for ANN, due to its multi-level system requirements with various methods, including procurement, production, distribution, warehouse, management to its final customers. There are main three areas that highly adopt this ML techniques are following.

- *Planning and Optimization*

Even though ANN is proven to be useful for semantic modelling, in a broader context, it has been applied to SC planning and optimization problems, such as time/capacity management and setups, lot-sizing, linked inventory and scheduling decisions at the lower level to higher level of management practices. In addition, another benefit of utilizing ANN is due to its strong ability to adapt, consider and accommodate the emerging constraints in real time processing. Fundamentally, it is designed to reflect interconnectivity and interdependence of SC planning processes better than traditional operational research techniques, which developed to solve less integrated and interrelated sub-problems in SCM (Min, 2010). In accordance with Hopfield and Tank (Soroush *et al.*, 2009), the classical exercise that can present the application of the model is Traveling Salesman Problem (TSP). It is a problem in discrete to combinational optimization and illustrates computational complexity theory. The requirement of the problem is to find the most efficiency Hamiltonian cycle or shortest path loop a salesman can take through each of given set of *n* cities (Weisstein, n.d). There are no general methods of known solutions, therefore it is a NP-hard.

Figure30. Traveling Salesman Problem Graphical Illustration



Source: Weisstein (n.d)

Based on the experience of SCM professionals, the approximate solutions are often accepted as good as optimal solutions, thereof ANN emerged as a most suitable approach to find sub-optimal or near optimal result.

- *Demand Forecasting*

Second common issue among SC decision makers is uncertainty. It primarily arises from changes in the product demand, logistics and distribution delays, shortages of supplies, and unforeseen mechanical failures. Just like a bullwhip, the changes affect the accuracy of demand planning of SC, as a result, often times management sees large fluctuations and volatility. Especially in integrated SC, inaccurate forecast can affect not only the firm, but also its suppliers. Over the time, minimizing these uncertainties became core focus of mid management, using available techniques such as statistical modelling and time series analysis. However, Liu (2015) noted that, the black box function in ANN can avoid these obstacles, since the system is essentially built for non-linear problems. Additionally, it is capable to draw non-linear mapping between marketing and sales demand and its affecting factors, learns from the incomplete and uncertain data, to provide rather appealing alternatives.

- *DSS*

Many supply chain experts and management often face either curse of too much information or, on the other hand experience incomplete information during decision-making process. Even though, they can apply expert systems or statistical models to understand a problem, it would be invalid and time consuming. Another advantage of ANN during decision processes is that it has somewhat creative thinking like humans, which embodied only to work with incomplete information. Henceforth, it's unique identification, data classification, self-organizing, and sorting capabilities, it has become ideal for traditional SCM philosophies. One of the key examples is a decision making in suppliers management and acquiring. The key decisions often made by human bidding and determination, which are limited in attributes and unstructured. However, by utilizing DSS and ANN techniques for outsourced manufacturing partner selections certain will help to enhance the decision functions and overall performance of the system (Soroush *et al.*, 2009).

4.1.2 ANN vs Traditional Approach in Forecasting – Case Study

Advantages of applying ANN in forecasting vs traditional approach will be discussed in this session. Due to limited experimentation possibilities, our research example will heavily rely on the research experiment of Kamruzzaman and Sarker (2003) on forecasting of currency exchange rates using ANN in comparison to traditional model of Auto-regressive integrated moving average (ARIMA).

The financial service industry is one of the early adopters of advanced forecasting models in their daily lives to control the dynamics of the exchange market. As a result, adoption and need for prediction, many businesses and economies success rate became highly dependent on it. Exchange rate prediction particularly is one of the most challenging field in modern time series forecasting analytics, due to its inherent noisy, high fluctuating and deterministically chaotic characters. For many years, ARIMA has been used for time series forecasting in financial field, and thus became benchmark tool for recent analytical models. The foundation of ARIMA is a general univariable model that is developed based on the assumption that time series forecasting is linear and stationary. To improve the financial forecasting models and analytics, ANN approach is applied on same training data with several different variation such as Standard backpropagation (SBP), Scaled conjugate gradient (SCGA), and backpropagation with Bayesian regulation (BPR) for Australian foreign exchange market, using 7 different currencies, including Australian dollar (AUD), US dollar (USD), British Pound (GBP), Japanese Yen (JPY), Singapore dollar (SGD), New Zealand dollar (NZD) and Swiss Franc (CHF).

Throughout the experiment, outcomes of all 3 variant models are compared with ARIMA models, according to Kamruzzaman and Sarker (2003), based on 5 different error indicators.

- *Learning Algorithms*

Standard BP (SBP): It uses steepest gradient descent technique to minimize the sum of square error E in the overall training data. Each target or desired output t_i is compared with actual output y_i and E_i is calculated as a sum of squared error at the output level. The weight w_i is updated in the n – training cycle based on following equation:

$$\Delta_{\omega_j}(n) = -\eta \frac{\partial E}{\partial \omega_j} + \alpha \Delta_{\omega_j}(n-1)$$

In this equation parameter η and α are the learning rate and the momentum factor.

SCGA: in conjugate gradient methods, a search performs following conjugate directions, that produces faster convergence than steeper descent direction with SBP utilizes. In SCGA, a new search direction spoils as little as possible the minimization achieved by previous one and the step size is adjusted in each iteration. The equation as follows:

$$\omega_{k+1} = \omega_k + \alpha_k p_k ,$$
$$p_k = -E'(\omega) + \alpha_k p_{k+1}$$

p_k and p_{k+1} are the conjugate direction in successive iterations, while α_k and β_k are calculated with each iteration. However, the drawback of this algorithm is the requirement of the line search in each iteration which is computationally expensive.

BPR: McKay (1992) proposed a method to constrain the size of network parameters by regularization technique, that forces the network to settle to a set of weights and biases having small values. This causes the network to respond to be smoother and less likely to overfit and capture the noise effectively. The cost function of F in regularization is defined as;

$$F = \gamma E + \frac{1-\gamma}{n} \sum_{j=1}^{n} \omega_j^{2}$$

In this equation E is the sum squared error and $\gamma(<1.0)$ is the performance ratio parameter, which dictates the magnitude of emphasis on the training. A large γ will emphasize the error E small whereas a small γ will drive the parameter size reduction at the expense of error and yield smoother network response. The optimum value of γ will be determined using Bayesian regularization in combination of Levenberg-Marquardt algorithm (Kamruzzaman and Sarker, 2003).

- *Model*

During the experiment, the researchers used time delay moving average as technical data, where the advantage of moving average lies in smoothing out number of irregularities between the market. Furthermore, moving average values of past weeks were set to feed to the ANN for predicting the following week's rate of currencies.

- *Performance Criteria*

The performance of above-mentioned model is evaluated against number of statistical metrics to see the accuracy of the forecasting. The smaller values of the metrics indicate higher accuracy in the forecasting. Following are statistical metrics used for comparative analysis of performance.

- Normalized Mean Square Error (NMSE)
- Mean Absolute Error (MAE)
- Directional Symmetry (DS)
- Correct up trend (CU)
- Correct down trend (CD)

- *Result*

In the experiment of forecasting 6 foreign currency rates against AUD, the researchers utilized 500 weeks of data for training the system, will 65 weeks of data have been evaluated.

They found that the performance of ANN approach depends on a number of factors, for instance, the initially chosen weights, learning parameters used for training, and number of hidden layers in the network. The hidden units varied between 3-7 in this case and training was terminated at iteration number between 5000 to 10000 units. The best results of each algorithms at the end of the experiment is shown below in Table 7, comparing the prediction for USD by ANN versus traditional ARIMA model.

Table7. Measured result of ANN model for USD

Prediction Period	Criteria	Neural Network Model			ARIMA (1,0,1)
		SBP	SCG	BPR	
35 Week	NMSE	0.5041	0.2624	0.2787	1.0322
	MAE	0.0047	0.0035	0.0036	0.0069
	DS	71.4286	80.00	82.8571	52.9411
	CP	76.4706	82.3529	82.3529	0
	CD	70.5882	82.3529	88.2353	105.882
65 Week	NMSE	0.0937	0.0418	0.0441	1.7187
	MAE	0.0043	0.0029	0.0030	0.0171
	DS	75.3846	81.5385	83.0769	42.1875
	CP	81.5789	78.9474	78.9474	0
	CD	69.2308	88.4615	92.3077	130.8462

Source: Kamruzzaman and Sarker (2003)

The result evidently shows that ANN models produce better performance and prediction than linear ARIMA, proving its suitability in financial modelling. In terms of most commonly used criteria, NMSE; MEA; SCG performed better than BPR in all currencies, in relation to observation reported by Kamruzzaman and Sarker (2003). Overall, ANN based models are performed far better than ARIMA model, which were measured on 5 performance metrics.

Even though the experiment was conducted in the financial market, it is also believed that this acquired knowledge, model designs, and experience can be transferred into various functions of SCM, such as inventory and warehouse management, demand and forecasting. While financial market has higher fluctuation rate on a day to day, on the basis of various externalities, SCM inventory management application, for instance, have fluctuated demands that serves similar behaviour. On the other hand, inventory management application may have more hidden layers in the network than financial service products. Considering of forecast and demand planning of SCM, it is highly dependent on the time series of historical information to arrive in probabilistic future outcomes. Therefore, similarities between financial market and traditional SCM may be more in this case than being different.

Thus, benchmarking these ANN approaches to support traditional SCM decision making in terms of materials procurement planning and production demand planning can be beneficial moving forward. The result and conclusion of these experiments display that ANN can improve the SC network disruption prediction effectively with given data set, whilst excluding negative externalities. Of course, we also need to keep in mind that more complex network problem with uncertainties should be examined in order to evaluate the true strength of ANN in SCM.

4.2 Acting Humanly

The concept of acting humanly represents machine acts like a human. The classical example of this characteristic is best described by the Turing test, named after British mathematician and computing pioneer Alan Turing in 1950. Turin defined the intelligent behaviour as an ability to human level of performance in all cognitive tasks, even under a fool interrogation (Russell and Norvig, 2010). During the test, human interrogates an entity without physical relations and examination, which considered unnecessary for cognitive intelligence. The test continues for 5 minutes and the result of interrogation is to determine if the examiner can differentiate machine from actual human-beings. The so-called total Turing test includes a video signal, where interrogator has the opportunity to test the entity's perceptual abilities and to pass the physical objects (Russell and Norvig, 2010). To pass the test, a program should succeed in speech recognition, natural language processing, speech synthesis, knowledge presentation, learning, and automated reasoning and decision making, which are represented by subfield of acting humanly – machine learning (ML) techniques, expert systems, and genetic algorithms. Especially in machine learning field of research, there are many models and techniques that tries to imitate human like reasonings and learning approaches, which we will examine further in this session.

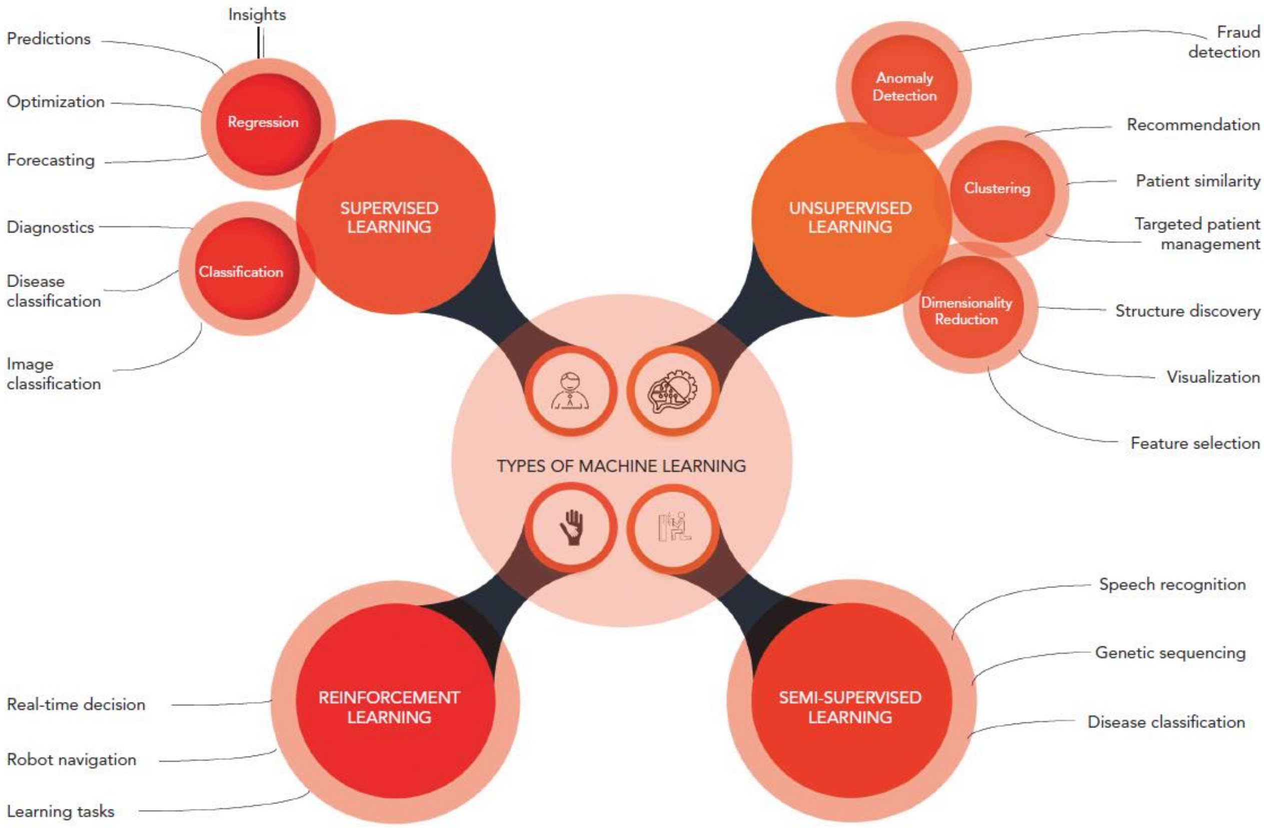
4.2.1 Machine Learning

ML is often considered as a subset of AI, where its algorithms automatically improve performance through experience. In other words, ML examines the ways which it can acquire knowledge directly and indirectly from data and thus learn to solve problems (Ratner, 2000, Min, 2010) The concept of learning, according to Russell and Norvig (2010), is to improve future performance after making observations about the world based on past and present data. So why do we want computers and agents to learn? Simply, it is due to the representation of growth in a broader aspect. However, there are three fundamental reasons behind.

First of all, the designers or programmers cannot anticipate all the possible situation to train the agent to begin with. Therefore, it is up to the agent to find alternative solutions to examine. Secondly, all changes overtime cannot be anticipated in current moment, rather it required to adapt when conditions occur. Lastly, humans have less understanding and power to find solutions by themselves. Thus, allowing agents to explore probabilities would help to see the problems from different angels.

Learning can be improved through its – components, prior knowledge, representation, and feedback. Especially, when digging further into the types of feed, the supervisory information forms back into the loop. There are three main determined types; (1) unsupervised learning, (b) supervised learning, and (c) reinforced learning. But the fourth type of the learning is also worth mentioning, which is known as semi-supervised learning. Each of these category serves specific goals and employs various different approaches.

Figure 31. Types of ML and examples of employed fields



Source: Seetharam *et al.* (2019)

Supervised and unsupervised learnings are most utilized approaches. Supervised learning deals with datasets with labelled variables or classified outcomes, where it is trained to build a model from a select feature derived from any imaging data sample, using logical regressions and analysis. Unsupervised learning, on the other hand, interpret the data without labels or interventions (Seetharam *et al.*, 2019). Semi-supervised learning is a type that work with both set of data and increasing role in speech and image recognition. Finally, reinforced learning uses rewards to articulate sense of passion to learn from trial and error approach.

Depending on the methods of learning, the ML techniques can be further categorized into; (a) concept learning – to recognize or construct concept that are relevant to the future decision processes, (b) decision tree (causation analysis) – to classify the objects by testing their values at certain properties, (c) Bayesian learning – to train the agents on probabilistic functions, (d) perception learning or perceptron learning – to learn and acquire useful knowledge, reduce errors, and solve problems via single layer network, and (e) reinforcement learning – to train the agents to perform at high level through constant feedback in the form of rewards (Min, 2010).

Nevertheless, regardless of its different approaches, the main goal of ML is to mimic natural decision based on acquired knowledge and experience of agents. There are several factors of motivation behind the approach, some may from sociological theory of human collaborative behaviour, some from mathematical modelling, some from imitating human brain, as well as human evolutions over time. Since the techniques are very diverse and foundation on human like factors, it is suitable for SC where it involves numerous partners that are sharing important information.

4.2.1.1 Concept Learning

Autonomous AI systems need to make decisions without immediate guidance or instructions of human facilitators. In order to make AI capable to producing morally correct behaviour and choices, it needs to have some level of human like understanding of relevant concepts like rights and well-being. The idea of concept learning comes from this need for training AI to behave correctly in situations that requires moral rightness, due diligence, reasonable doubts, or law enforcement context (Sotala, 2015).

Concept learning is defined as an inferring a Boolean-valued function from training examples of input and output. It also can be seen as a problem of searching through a predefined set/space of hypotheses for the hypothesis that fits the best fits as training examples. Generally, humans learn concepts based on the contexts that it belongs and follows rules and constraints given by their parents to arrive in final conclusions. Which reflects that in AI, we also can use similar idea by producing explicit algorithms that can produce similar results and/or classifications from given set of data. In other words, concept learning is the mechanism that trains the system for targeted concepts of FIND-S with multitude of possibilities. However, it should be noted that it may be very difficult to get the learning rules for machines exactly right at the first time, a minor error can lead to a crucial problem. Following example on a favourite sport that my father enjoys, can guide you through better understanding. Let's image that we have Target concept called Enjoyable Sport, which will be denoted by *c*. And set of instances denoted as *X*. So, the Boolean function defined over *X* is represented as such; $c{:}X \rightarrow \{0,1\}$

We have following training example available

Examples	Sky	Temperature	Humidity	Wind	Forecast	Result
1	Sunny	Hot	High	Strong	Same	No
2	Cloudy	Warm	Normal	Normal	Change	Yes
3	Rainy	Cold	Low	Weak	Change	No
4	Sunny	Warm	Normal	Normal	Same	Yes
5	Cloudy	Warm	High	Weak	Same	Yes

In this case, hypothesis will be represented by *h,* and the training set *i* will be illustrated as, $Hi(x){:}= \langle x_1, x_2, x_3, x_4, x_5 \rangle$ values that each correspond to the training set of Sky, Temperature, Humidity, Wind, and Forecast. Each attribute will consist of either "*?"* – representing any attribute value is acceptable, "*single specific value"* – such as sunny or cloudy, warm etc, and *"0"* – that indicates no value is acceptable for the attribute.

In the instance space *X* based on the above given training set, there are $3*2*2*2*2*2 = 96$ *instances*. However, in the hypothetical space of *H* there are $5*4*4*4*4*4 = 5120$ syntactically distinct hypotheses and $1+4*3*3*3*3*3 = 973$ semantically distinct hypotheses, because each *h* is represented as a conjunction of constraints.

As you can see, an algorithm that supports a concept learning should have:

- Training data consists of past experiences/information
- Target concept – a hypothesis to identify data objects
- Actual data objects – for testing the models

But concept learning alone cannot ensure the optimal result, instead inductive learning algorithms can at best guarantee that output *h* hypothesis fits the target concept over the training data. When there is an information gap, or lack in further data, our assumption is that the best hypothesis regarding the unforeseen instances is the hypothesis that best fits the observed training data. This is the foundation of inductive learning. It is to approximate the target function well over a sufficient training set examples and estimate the target function well over other unobserved examples.

To imitate such human like belief system, first and foremost, concept learning should utilize the version of space approach to equate the space of possible definitions of the target concept with element of concept language. The concept language is defined by a set of predicate vocabularies that can consist of a set of basic ground that being applied to objects in the universe of instances of the concept (Russell and Grosof, 1987). However, defining the concept language is often challenging for engineers, because it cannot accommodate noisy data, is hard to incorporate arbitrary background knowledge, and often highly demanding to come up with suitable concept language for unknown and complex concepts. Given some data, the feature space can be interpreted as a real space, where we can move and walk around in our *n* dimension of space. In other words, our data is a feature vector giving coordinates in *n* dimensional space, where *n* is typically the number of features, such as weight, height, width, age, and so on (Grigg, 2019). The key reasons using spatial representation is that it is useful to introduce an idea of distance and closeness between the hypotheses. Such that when defining the set of general categories for a dog, it is also important to feature a close data-point of another species, such as a cat. Thus, the conceptual distance helps to understand the target concept that we are trying to learn. Once the initial version of space is defined, we can employ several different sub-approaches to find the suitable hypothesis, such as Find-S algor1thm, List-then-eliminate, Candidate elimination algorithm, or rote learner. There are also few other techniques under concept learning, namely, general to specific ordering of hypothesis and more. Nevertheless, whatever approaches are being applied, the premises should provide good reasons, including whatever else the machine has learnt, such as belief in the correct concept, either inductively or deductively, arrive in conclusions.

Hence, the concept learning methodology is the key foundation of training human like machines to find the best fit hypothesis or solutions in the given set of examples, and moving forward with the concepts and techniques, it can learn from the previous actions to perform more independently without strict supervision. In current moment, the concept learning is widely used in the big data management, to explore massive amount of information without hesitation. As we look back into the thesis chapter 1, the artificial and natural process of thinking, big data is the very first step of initiating decisions – information search and interpretation. Big data often carries partial data analytics tools and designs, which we initially defined it as the intersect point of information input and analysis process of decision making.

But on the other hand, the constraints of previous knowledge can become limitation to AI under the term of bias. According to Russell and Grosof (1987), as long as the process of deciding on a bias is left to the programmer, the concept learning is not something that AI system can do by itself. Henceforth, Rendel (1986, Russell and Grosof, 1987) showed how typical AI concept learning systems perform where most information is contained in the choice of bias, rather than in observed instances. For human concept can be taught through rules, norms, beliefs, and the instances, however for machines, rule-based supervised learning or deep learning techniques are commonly used.

So how one could use this methodology in real business practices? Not many organizations directly apply the concept learning approach into their business decision makings, instead they use big data management technology and techniques to improve their decisions across their functions. The biggest application of big data management is performed in financial and economics, where most financial institutions like banks, insurance, and brokerage companies contain massive amount of transaction data and related activities. The success or the failure directly affects the way how the individuals in these fields manage the scarce resources, in relation to better utilizing their information. Another ever growing data sector is SCM, where large amount of transaction, productions and delivery information being created. Since big data is believed to bring new competitive advantages to firms, many large logistics service-oriented companies are exploring its benefits, such as UPS, DHL, Maersk, FedEx, Japan Post and many more (Zhong *et al.*, 2016). As for manufacturing side of operations in SCM, managers are leveraging Big data analytics to optimize operational capacity and capabilities, while developing strategic decisions real-time. The concept learning in big data plays important role, in this case, to identify, classify, integrate, and present a large number of moving objects in the SCM. This data modelling concept is able to precisely represent the location of information via generic presentation. Since manufacturing and logistics services in modern time employs robotics and sensors-oriented machineries, large sum of information should be formatted and standardized for further utilization. The concept learning, to this end then creates *n* dimensional model, twinning space, and time for labelling the behavioural and operational data in SCM, which then helps the analytical tool to process. Even though, the information storing, translating, and transforming stages are not directly linked with better decision making, it is the fundamental step to initiate the process. There are still more to explore in the future, in terms of, how concept learning can be utilized in businesses as a stand-alone methodology, rather than functioning under the umbrella of Big data. Furthermore, how other intelligent adaptive devices can apply the concept learning terminologies to improve their performance and facilitate its users.

4.2.1.2 Perception Learning

In AI, the perception study is mostly focused on the reproduction of human sensory perception, especially aural and visual signals. In a technical term, perception learning entails the process of acquiring, interpreting, selecting, and organizing sensory information. It presumes sensation, various types of sensors that converts a certain type of simple signal into data of the system. Putting data together and making sense out of this collected information is the main quality of perception mechanism in AI. More in detail, perception can be seen as a category of information, such as classification, patter recognition and others, where inputs are sensory data, while outputs are categorical judgments and conceptual relations (Atre, 2017). From the AI point of view, perception learning is considered as an active process that embeds particular abstraction, reformulation, and approximation within the framework (Bredeche *et al.,* 2006). The active process is the fact of machine searching correct data representation through several steps. And the key point of machine's perceptual learning comes from low level abstraction mechanism rather than relying on complex algorithmic inputs. In some cases, due to complexity of algorithm, machine may not be able to solve a problem without simplifying it. The perception algorithm of process, therefore, can be seen as abstraction and simplification of algorithms and complexity of representation within the system (Bredeche *et al.*, 2006). Abstraction is a change of representation within the same formalism that hides some important details and properties in order to make the initial problem simple and solvable

Since the perception is highly related to sensory data, data processing and representation, its application can be observed in autonomous robotic vehicles, where object detection, environment representation, scene understanding, human detection, activity recognition, semantic place classification, object modelling, and voice recognitions are present (Premebida *et al.,* 2018). This term of perception is classified as unsupervised learning, just like a human child learning, or supervised classifiers using handcrafted featured algorithm, just like when children attend school or learn new things from their parents. Another aspect that comes together with perception learning is deep learning neural network, where logic is no longer plays important role. There are 2 types of perception that are widely applied to robotics and machine learning: hearing – speech recognition and vision – visual detection. Differing from traditional sensory system, the recent robotic perception is more complex, embodied, and active in a goal driven robotic systems, where the outputs of the perception system will result in decisions and actions rather than set of organized data.

- *Natural Language Processing (NLP)*

There are two types of language in our world, natural and formal. Natural languages come from human societies throughout the development of using, repeating, and passing down generation after generation. Formal languages, on the other hand, have been designed for special purposes, specifically for computer programming and expressing logic (Gudivada and Rao, 2018). Natural language processing is concerned with the interactions between computer and human languages, communication between formal and natural linguistics, in particular how the computer program processes and analyses the large amount of data from natural language sources. The application of natural language processing started from automatic translation function on machines, which we widely use nowadays through search engine, such as Google. More the processing programs became available to the users, more software embedded such extensions in their services, allowing users around the world connected through a same platform like ERP tools.

In comparison to computing language, which can be defined by a set of strings as a legal programming and followed by specific set of rules, natural language is very rich and has various meaning even for single word. The set of computing language rules are also known as a grammar; though, it is totally different than natural language grammar as well. Moreover, natural languages evolve in time, which makes it more complex and ambiguous, therefore, it is best to utilize approximation techniques to accurately examine the meaning. As a result of such complexity and various characteristics, understanding natural language has become the most important subfield of AI. Because this field of AI is unlike any other areas, requires close empirical investigation of actual human behaviours and their environment/circumstance they are in, that makes it intricate process for researchers.

In 1957, Chomsky described four different classes of grammatical formalism that are classified by their generative capacity. The meaning of generative capacity is driven from the set of languages they can represent (Russell and Norvig, 2010). The types of grammatical formalism differ only in the form of the rewrite rules and arranged from the most powerful to least powerful class.

Table 8. Chomsky's Four Types of Grammars

Grammar	Language Class	Rule Constraints	Recognition automaton
Type 3	Regular	$A \rightarrow a$ and $A \rightarrow aB$	Finite State Automaton (FSA)
Type 2	Context-free	$A \rightarrow v$	Nondeterministic Pushdown Automaton (PDA)
Type 1	Context-sensitive	$xAy \rightarrow xvy$	Linear-bounded nondeterministic Turing machine
Type 0	Recursively enumerable	$u \rightarrow v$	Turing machine

Source: Gudivada and Rao (2018)

- Recursively enumerable grammars – a formal language or type-0 language, that can be accepted or recognized by Turing machines in their expressive power.
- Context sensitive grammars – it is a less general form of unrestricted grammar, in which all the left-hand sides contain many symbols and productions than its right-hand sides.
- Context free grammars – a set of recursive rules used to generate patterns of strings. In other words, left side contains single nonterminal symbol.
- Regular grammars – this is most restricted class that every rule has a single nonterminal on the left-hand side, followed by a nonterminal on the right -hand.

The usage of these types of linguistics formalization is often applied to detect programming errors ranging from incorrect characters of words, to bit more detail errors such as punctuations, parentheses, blank or tab errors, to more sophisticated details of constructing analysers on C++, Java, control and data flows in the system (Metzger, 2004). Furthermore, it is widely used in search engines to learn from users' behaviours, such as frequently mentioned or searched paraphrases and words, regularly cited articles and so on. However, how SCM can utilize these grammars to solve its issues and become more efficient?

One of the solutions recommended by Wichmann *et al.* (2018), was to use the techniques of NLP to automatically generate SC network maps for increased visibility and avoid uncertainties within the map. As mentioned in the previous chapter, SC network mapping is referred as a solution to SC limited visibility and its related risks. However, this transparency issue still exists today, due to the readiness and availability of data provided by suppliers with its partners (Sheffi, 2005). While data can be scarce in supply chain mapping, the web originated NL form of data can contain valuable information that can bridge this gap. To understand and translate these texts, NLP methods can be applied and eventually help to generate rudimentary supply network automatically, while cross checking existing models or augment it with additional information (Wichmann *et al.*, 2018). With defined grammars and information extraction techniques, NLP can process naturally unstructured texts. Information extraction can be divided into named entity recognition (NER) – the subtask of locating and classifying instances, and relation extraction (RE) – the task of detecting and classifying the semantic relationship between known entity in the system. The case study conducted on the Toyota supply chain, identifying chosen 12 suppliers out of its 3431 direct suppliers, were success and 100% accurate. However, the difficulty arose from the repetitive brand names in different part suppliers among in 3431 suppliers. One of the requirements the case result meet was the transitivity – where only direct relationship between buyer and suppliers are mentioned but rarely the end-use of the part or material in the news or the reports on web. As a result of this problem, the initial data needs to be evaluated against the web data, secondly the incomplete information on web, and finally the training purpose needs to be generated manually beforehand running any tests.

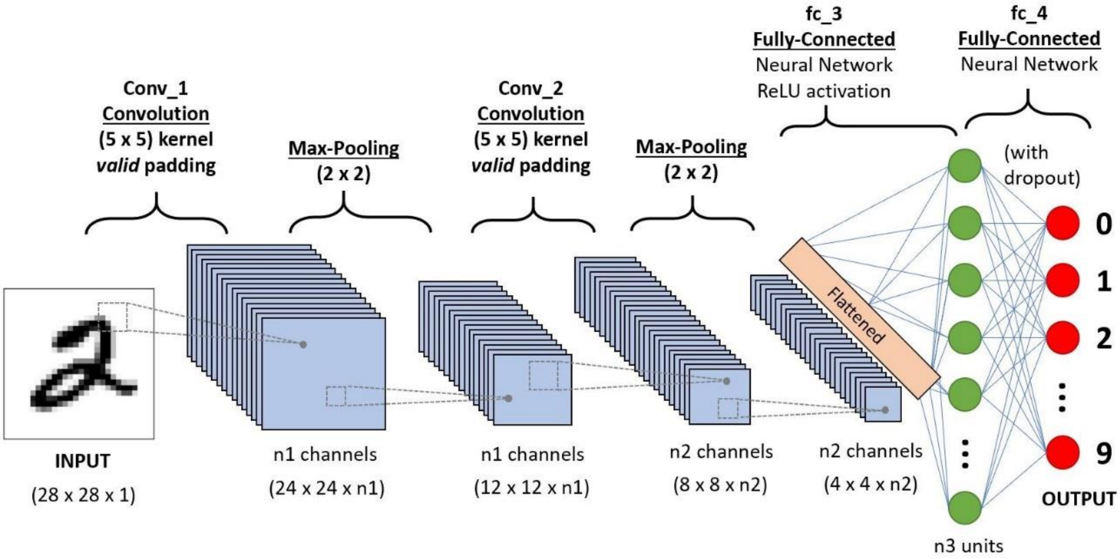
In many cases NLP is often utilized in data collection and queries posed languages, which is a part of data processing. However, none of its limitation is further explored enough in automatic mapping, problem solving in information extraction and connecting dots. The case study of SC mapping showed another possible approach to NLP, which can support better managerial decision making in visible network. We may continue to see better input information, and influence of industrial involvement to achieve increased mapping performance of automated machines in the near future.

- *Image Processing and Robotic Perception*

Perception provides agents with information about the world they inhabit by interpreting the response of sensors. Unlike humans' sensory abilities, the machines and robots have limited physical abilities in terms of perceiving the environment around them. The object model describes the objects surrounding the machine through its visuals, allowing them to extract the features, recognize and reconstruct the data from the images. In the case of moving images and/or objects, the optical flow needs to be installed to describe direction and speed of motion of features measures in pixels per seconds. At basic, robots can recognize and classify images into several different categories, which is considered first phase of learning. Unlike human perception and experience that allowed us to instantly recognize the objects without difficulties, machines require training data to learn. Even though images are easily obtained for training, the diversion of single image cannot be recognized. Therefore, the training set needs to be very large for machine to learn, such as any kind of roses are classified as a flower, but not all flowers are roses.

Unfortunately, some images are hard for human to classify, which makes it harder to machine learning to identify it better than humans. The specific type of learning that accomplish these complex tasks is known as convolutional neural network (CNN), which works by breaking an image by smaller bit of pixels, called filters. CNN is a Deep Learning algorithm that can take-in an input image, breaks it down to smaller pieces to process, assign importance to various aspects of the object, and makes it easier to differentiate from one another without losing the critical features for getting good prediction (Saha, 2018).

Figure32. Convolutional Neural Network Sequence



Source: Saha (2018)

CNN operation does not limit its function on high-level features extraction, such as edges from the input image. The first layer of CNN is responsible for capturing basic feature – edges, colour, gradient information. Then further layers add the architecture of high-level features as well, giving the network to have wholesome understanding of the image in the data set. The accuracy of CNN is based on the large amount of labelled training data, with error and loss functions, which helps the network to perform better every time it runs the functions again on the images. The end layer is also known as a fully connected layer, basically it takes an input volume and outputs an *N* dimensional vector where *N* is the number of classes that the program has to choose from. The network looks into the previous output layer to determine which features are most correlated in a particular class with weights to compute and finalize the prediction. But how does the machine adjust its filter values or weights?

The process emerges from the derivation of the overall error gradient. It can be divided into four sections, forward pass, the loss function, the backward pass, and the weight update (Pande, 2016). Since there are multiple output units, the Err_k becomes the k^{th} component of error vector y-h_w. It will be then convenient to define a modified error through $\Delta_k = Err_k \, x \, g'(in_k)$, which makes the update rule as (Russell and Norvig, 2010).

$$w_{j,k} \leftarrow w_{j,k} + \alpha \times a_j \times \Delta_k \ .$$

Of course, not to forget about the learning rate, where programmer needs to choose from. As mentioned before several times, higher rate represents bigger steps to be taken in the weight updates, may result in imprecision. The next step in CNN is how can we utilize this learning process to improve decision-making in SCM? Where can we apply and what are the other advantages?

One of the main areas that can better utilize image recognition function of advanced technology and deep learning is definitely logistics and inventory management field of SC. For those advanced technology to perform better, the optical processing also requires additional support from other form of sensors, like location sensor via GPS, proprioceptive sensors – informing robots about its own motion, and force sensors to handle fragile object, and integrated camera monitoring systems in the physical facility. On the other hand, the prediction analysis of raw materials using CNN, especially in food materials is received more attention. Currently food industry uses human detector to analyse on the conditions of raw materials, which are considerably laborious, tedious, costly, and time-consuming process. To overcome this bottleneck of processes, Chen *et al.* (2017) examined computer-based image processing techniques together with full CNN models to predict the freshness of raw materials in food industry. The proposed model starts with raw images of items, ending with multi-class prediction of clean images, allowing the model to learn and classify the images into clean or dirty, respectively.

The joint features generated from the last convolutional layers will be then connected to first full connect layer and fed into the two loss layers. The weight parameters matrix learned from two loss layers will be decomposed into bottom shared layers. This model can also be viewed as the specific SoftMax loss of clean task with a fully connected layer and a SoftMax loss of multiclass with two fully connected layer shared the same bottom layers. After optimization of joint loss layers, two tasks CNN model will backpropagate to the specific parameters in the backward pass system. And collected images, which are annotated as clean or dirty label and multiclass label, will train the whole network and parameters until it converges (Chen *et al.*, 2017). The CNN did not perform single handed, the system also performed together with other deep learning neural network like Caffe Net, Alex Net, and VGG-16 software, and showed significant efficiency and accuracy at the end of the day. By utilizing CNN in raw material examination, the quality evaluation and system efficiency can be improved in the SC, directing supervisors and managers to have better visibility in their inventory conditions. Furthermore, this method also can factor into the suppliers' evaluation and management of SC, allowing overall network to perform efficiently together, while reduce the cost of quality and procurement and time.

4.2.1.3 Reinforced Learning

This is a separate category of learning in ML, that employs unique strategies to enhance performance and outcomes. It explores the task starting with a complete, interactive and goal seeking system, which can sense its environment and choose actions to influence their environments and goals (Barto and Sutton, 1997).

The type of learning is an AI technique that has been successfully utilized for solving complex problems under Markov decision process in realistic systems. Markov decision process (MDP from hereon) is a sequential decision-making stochastic process that characterized by five components, decision epochs, states, actions, transitions probabilities, and rewards (Giannoccaro and Pontrandolfo, 2002). The decision maker takes control over the path of the stochastic process, where at certain point in time he/ she intervenes and take decision that affect the future path. These points are often known as epochs and decisions are called actions. At the stage of decision epoch, the system occupies a decision-making state, and after taking the action in the state, the decision maker receives a reward. Often time, MDP problems are to choose a policy to maximize a function of the reward sequence, which is optimality criteria. Following expression shows the average reward or gain of a stationary policy π;

$$g^{\pi}(i) = \lim_{N \to \infty} \frac{1}{N} \sum_{i}^{\pi} \left\{ \sum_{t=1}^{N} r(X_t, Y_t) \right\},$$

i – starting state

r – reward received

X_t – reward state

Y_t – action state to arrive at reward

MDPs have been used widely in SC inventory management and ordering policy related problems. While decision rules specify the quantity to be ordered at the time of review, the policy consists the mapping of replenishment orders onto the possible inventory positions. Evidently, decision-makers, usually managers seek for an optimal policy that maximizes the profits over the decision period. But MDP only allows the decision maker to select an action at predetermined discrete point in time.

The extension of MDP is Semi-MDPs, where decision makers are allowed to choose any actions in any given time the system state changes. In SMDPs, the action choice is not only determining the join probability distribution of a subsequent state, but also the time between decision epochs (Giannoccaro and Pontrandolfo, 2002). In other words, it combines both evolution of the system at the decision epochs and natural process of evolutionary state over time. The reward function associated with SMDPs is also more complex and accrue as long as the natural process occupies, thereof the average reward gain started at the state *I* and continuation with the policy π can be represented as;

$$g^{\pi}(i) = \frac{\lim_{N \to \infty} \{E[\sum_{k=1}^{N} (r(i_k, i_{k+1}, \mu_k | i_0 = i_1))]/N\}}{\lim_{N \to \infty} \{E[\sum_{k=1}^{N} (t|(i_k, i_{k+1}, \mu_k | i_0 = i_1))]/N\}}.$$

For $i \subset S$ when action $a \subset A_i$ is chosen and if the next state is *j*, let r *(i, j, a)* represent the reward obtained and *t (i, j, a)* represent time spent during the state of transition.

i_k – state visited in the k^{th} epoch

μ_k – action taken in the k^{th} epoch

When SMDPs employed to solve inventory control related problem, it provides several advantages more than MDPs, such as inventory policies are considered without constant review time intervals and system is possible to accrue rewards or costs.

The reinforcement learning comes in play, when teaching agents, the optimal control policy based on simulation and the value iteration, rather than using traditional methods to solve MDPs or SMDPs.

Reinforced learning utilizes both exploitation and exploration mechanisms internally. Meaning learning agents select the actions/decisions by trial and error – exploration and the previous knowledge and environment – exploitation (Giannoccaro and Pontrandolfo, 2002). However, challenges appear in this model mainly come from the trade-off between these two dimensions. When agent choose the best action, also called as greedy action, the next step the probability of exploration decreases as the probability of exploitation increases. In each step, however, the combined value of both probabilities will be equal to 1.

$$Pr_{exploration,t} + Pr_{exploitation,\, t} = 1$$

When system visits a state, the learning agent lists and chooses the actions with highest value of *R*, which also explored further with all given states. Once all *R* values are appeared, then decision-maker can clearly choose the best action in each state without trouble. The learning model does not tell the machine what to do, instead it finds the actions yields most reward by trying them in each state, and pass that control over to the final decision maker. Referring back to chapter 1 of decision-making process, this model actually combines analysing inputs of information and problem definitions, and possible outcomes of each and every single strategy that could be predicted and leaves the judgment to the decision maker. So how this model works on real life problems in SC inventory management problem?

As we know, SC model consist three main stages, supply, production, and distribution. Assuming, a single decision-maker exists in all stages, who has a responsibility to manage certain inventory related to each stage. The key parameters of the model, including state variable, reward function, value function, and system policy need to be specified. The environmental response for each action is captured from simulating the system with different actions using Semi-Markov average reward technique (SMART). The updating of the knowledge must happen between the shift of one decision making state to new decision state. Another implementation needs to be considered it the learning rate, which is gradually decreased to 0, as the learning progresses over time. Following is the expression of decaying scheme;

$$a_m = M/m$$

a_m – value of the learning rate or exploration probability at the m^{th} iteration

M – predetermined constant

Traditionally, at the fixed time interval, each agent can review the stock level and decides where he/she requires to place an order to the up or downstream. It is sufficient when upstream has sufficient stock to fulfil their needs and delivery time period does not fluctuate. However, each time agent in any stage issues an order, it incurs ordering cost S_i that includes transportation costs as well. The inventory cost of holding the items h_i per time. Given the demand D, the optimal ordering quantity is expressed;

$$Q = \sqrt{2DS_i / h_i}$$

Though with SMART policy, it focuses on minimizing the total SC costs. Such policy is defined by two vectors that specify stock review time intervals (T_1, T_2, T_3) and the target levels (S_1, S_2, S_3) at each stage. Stock review time interval T_i increases the stock level up to the target level S_i. Especially, the time vectors are determined by solving non-linear programming problem of minimizing the average cost of SC, subject to;

$$T_1 \geq T_{i-1} \geq 0 \qquad \text{for} \qquad i= 1, 2, 3.$$

So, the average cost of SC is given by;

$$C_t = \sum_{i=1}^{3} \left[\frac{\mathrm{Co}_i}{T_i} + \frac{1}{2} \mathrm{d} H_i T_i \right]$$

And target stock S_i is defined by;

$$S_i = (T_i + \mathrm{LT}_i)d.$$

The demand during the reorder time interval T_i $(T_i\, d)$ plus the stock necessary to cover the demand during the transportation lead time (LT_i). Considering all these, safety stock SS is added at the last stage to cope with uncertain demand of customers, therefore, order quantity QQ at every stage becomes;

$$\mathrm{OQ}_1 = (S_1 + \mathrm{SS}) - \mathrm{IP}_1; \quad \mathrm{OQ}_2 = S_2 - \mathrm{IP}_2;$$
$$\mathrm{OQ}_3 = S_3 - \mathrm{IP}_3.$$

Based on the quantitative research conducted by Giannoccaro and Pontrandolfo (2002), the SMART model presented higher efficiency, whilst resulted robust actions whenever demand showed slight changes. The higher efficiency may be resulted from the fact that decision rules and replenishment order of inventory positioned as complex functions. Furthermore, the stochastic characteristic of the model considers the lead time and demand variability in comparison to traditional approaches, makes it superior. However, given the fact that all agents have different reward policies, having them to share and split the higher rewards fairly may require higher integration of SC network and may present behavioural issues among agent, which could be examined in the future.

4.3 Thinking Rationally

As we step back to the Chapter 1, we discussed rationality in human decision-making process. Field of AI research studies are often conducted and examined in nature of human intelligence, which does not necessarily follow strict rule or structure. However, it tries to imitate the logical reasoning behind our thought processing. Thinking rationally, in human, means the ability to consider the relevant variables of a situation and to access, organize, and analyse this information to arrive at a conclusion using logic. In AI, the thinking rationally follows the laws of thoughts approach, which is based on the hope to build logical thinking process, where conclusions are drawn based on some type of symbolic logics. Reasoning of machine involves manipulating the symbols according to well-defined rules and notations. The result of such function is an idealized model of human reasoning, which then can be implicated to AI. The logical sequencing and humanly thinking in machines are mimicked through fuzzy logic theory and algorithms.

4.3.1 Fuzzy Logic

The first and most applied method of resembling human reasoning is known as fuzzy logic. It can be a powerful tool to build knowledge bases for particular domains and acquiring knowledge from experts, through opinions as form of inputs to specify “good” versus “bad” areas of each variable and determine the likelihood of goodness and badness in the level by comparing the variables with expert opinions (Min, 2010). Fuzzy logic conceptualizes partial truth and characterized as an extension of Boolean logic. In conventional logic block that computer can understand takes place in precise input and producing definite output such as YES or NO, TRUE or FALSE. But in fuzzy logic, just like human decision making, all outcomes can be range between two certainties. Answer YES can be ranged from Certainly, Possibly, Maybe, and Uncertain, which are applicable to NO answers.

In other words, it is not a method for uncertain reasoning at all. For instance, when we refer to someone as *Tall*. The certainty of the tallness in person sometimes agreed as “sort of”, which is not sharp yes or no. Even the linguistic term of “tall” does not refer to a sharp demarcation of objects into the class we need to determine. The degree of tallness also depends on the actual measure of the person in comparison to the social medium he/she is at. In this case, fuzzy logic treats definition of *Tall* as a fuzzy predicate and the truth value of *Tall* is a number between 0 and 1, rather than classified as True or False (Russell and Norvig, 2010). When we introduce second character into the first sentence, He/She is *Tall and Slim* -> *Tall* ∩ *Slim*, then the fuzzy truth value becomes a function of truth values of its components. The standard rule for evaluating fuzzy truth *T* in the complex sentence is shown below;

$$T(A \cap B) = min\ (T(A), T(B))$$

$$T(A \cup B) = max\ (T(A), T(B))$$

$$T(\neg A) = 1 - T(A)$$

Therefore, fuzzy logic is a truth functional system that causes serious difficulties. Because, taking an example as mentioned above, if $T(Tall(Woman))=0.6$ and $T(Slim(Woman))=0.4$, then we have $T(Tall(Woman)) \cap T(Slim(Woman))=0.4$, which seems reasonable, but we also will have a result where $T(Tall(Woman)) \cap \neg\ Tall(Woman)=0.4$, which does not. As a result, it is clear that the problem arises from the inability of a truth-functional approach to consider the correlations or anticorrelations among the component propositions (Russell and Norvig, 2010). If it does not provide absolute answer, then why should we use fuzzy logic in forming decision in machine? The reasons of using this method in commercial and practical purposes is to understand and handle ambiguity, imprecision, and uncertainty of objects, without setting a clear-cut boundary. It may not give accurate and absolute reasoning, but it provides acceptable reasoning, mimicking human like reasoning.

Fuzzy logic usually consists of five components:

- Linguistic Variables – it is a fuzzy expression for input and output parameters, which consists of imprecise or vague terms that appears in our languages. The range of possible values of a linguistic variable represents the variable's universe of discourse (Guo and Wong, 2013).
- Linguistic Values – range of possible values that assigned to present the linguistic variables. For instance, *A* and *B* are linguistic values defined by fuzzy sets on the ranges of *X* and *Y* (universes of discourse) respectively.
- Fuzzy Sets – in mathematical terms, fuzzy set is an uncertain set. The fuzzy set theory, by contrast, permits the gradual assessment of the membership of elements in a set. The representation as follows;

Fuzzy set of *A* of *X* is defined by its membership function: $\mu_A(x)$

$\mu_A(x)\colon X \rightarrow [0,1]$

where

$$\mu_A(x) = \begin{cases} 1, if\ x\ is\ totally\ in\ A; \\ 0, if\ x\ is\ not\ A; \\ u\ (0 < u < 1), if\ x\ is\ part\ in\ A. \end{cases}$$

The fuzzy set operations are;

- The union of two fuzzy sets $C = A \cup B$ is defined by

  $\mu_C(x) = max\ [\mu_A(x), \mu_B(x)]$

- The intersection of two fuzzy sets $C = A \cap B$ is defined by

  $\mu_C(x) = min\ [\mu_A(x), \mu_B(x)]$

- The complement of fuzzy set *A*, *C* is defined by
  $\mu_C(x) = 1 - \mu_A(x)$

These are the functions we have defined as the standard rules, as discussed earlier. The operators are not limited to union, intersection functions, but also includes equality, complement, and containment.

- Membership Functions – is a function in [0,1] that represents the degree of belonging. The most commonly used membership functions are triangular, trapezoidal, piecewise linear and Gaussian functions, because they are easily prepared and computationally fast (Guo and Wong, 2013). Thus, the choice of membership functions is largely arbitrary because there is no theoretical justification for using one rather than another, allowing more flexible approach. As a result, it can enable either greater resolutions or greater computational complexity.
- Fuzzy IF-THEN rules – are used to define the relationship between variables based on the defined logic and membership functions. It is created in the form *IF x* is *A* then *y* is *B* (Mohammad and Fuchs, 2015). Following are the examples.
  - *IF* temperature *IS* very cold *THEN* stop fan
  - *IF* temperature *IS* cold *THEN* turn down fan
  - *IF* temperature *IS* normal *THEN* maintain level
  - *IF* temperature *IS* hot *THEN* speed up fan

Notice that there is no "ELSE" function. The temperature in a same condition of cold or normal can be different degrees at the same time. The AND, OR, and NOT are operators of Boolean logic, also exist in fuzzy logic that usually defined as min, max, and complement. They are also known as Zadeh operators, named after its inventor, so for fuzzy variables;

$x\ AND\ y = min\ (Truth(x), Truth(y))$

$x\ OR\ y = max\ (Truth(x), Truth(y))$

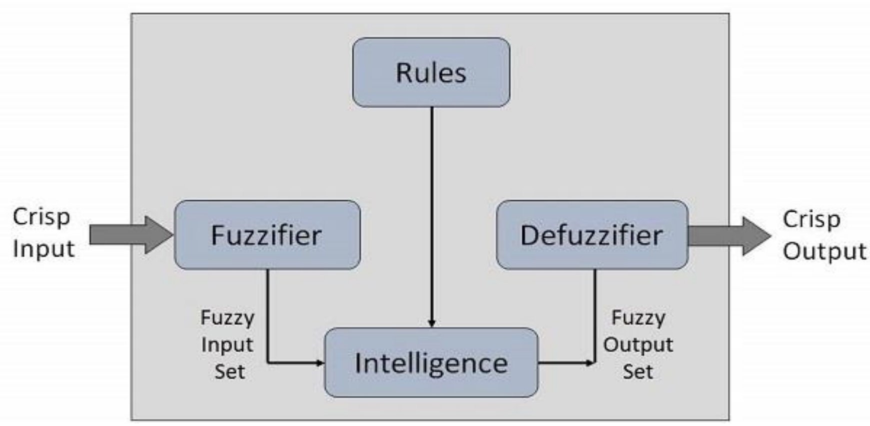
$NOT\ x = 1 – Truth(x)$

Fuzzy logic is conceptually easy to understand and tolerates imprecise data, in comparison to any other AI algorithms. Especially, expressing a common-sense knowledge and/or expert opinions it is very convenient to utilize. It is often intuitive and utilized universal approximation, rather than absolute resolutions, though, it does not solve everything as precisely. Sometimes, theoretically, and practically precise models are more convenient, depending on the situation and approaches.

The fuzzy logic system architecture has four main parts:

- Fuzzification Module – transforms the system inputs into fuzzy sets by categorizing the input signals in five steps, such as large positive, medium positive, small, medium negative, and large negative (Tutorial Point, 2020).
- Knowledge Base – it stores *IF-THEN* rules provided by the experts
- Inference Engine – stimulates the human like reasoning in the machines by making fuzzy inference on the inputs and expert knowledge using given rules
- Defuzzification Module – transforms the fuzzy set obtained by the inference engine into a crisp value or output. There are three most common types; centre of gravity or centroid, maximum, and mean of maxima defuzzifier

Following Figure 33 depicts the basic fuzzy logic architecture.



Source: Tutorial point (2020)

Membership functions perform on the fuzzy set variables. The use of fuzzy set provides a basis for systematic way of manipulating the vague and imprecise concepts, especially to represent linguistic variables. Take an example on the temperature again, the linguistic variable of temperature will be set as,

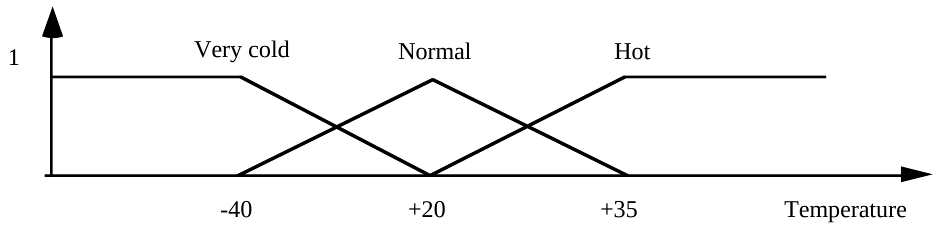
T = {hot, warm, normal, chilled, cold, very cold…}

Where each term in *T* is characterized by a fuzzy set in a universe of discourse *U = [-50; +50]*.

Therefore, we may interpret,

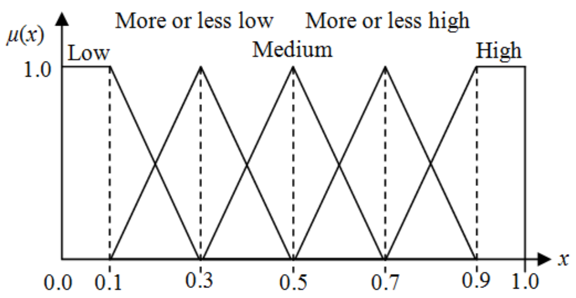
- *Very cold* as temperature below -40
- *Normal* as temperature close to +20
- *Hot* as temperature above +35

Figure34. Values of linguistic variables *Temperature*



In many practical applications, multiple membership functions can be applied to fuzzify a numerical value and use the type of fuzzy partitioning as briefly shown in Figure 35.

Figure35. Membership functions of Fuzzy Logic



Ibrahim and Sorensen., (2010)

It is evident that same five fuzzy modules are applied to present the accuracy, the time rate, difficulty, complexity, and the adjustment of questions in the fuzzy domain. Nonetheless, using more functions do not guarantee precise results, though, it complicates the computation.

The application of fuzzy logic can fall into two main categories, (a) fuzzy control applications – simple and efficient rule-based system, and (b) complex system aiming to support or even replace human expert, such as medical diagnostics, financial portfolio and investment systems, traffic control systems and more (Klement and Slany, 1994). The practical application of fuzzy logic in SC decision environment, however, is proven to be useful over the years and employed to various subjective performance criteria. It also can be applied to well-known traveling salesman problem in a SC setting, supplier performance evaluation, inventory cost control, measurement of bullwhip effects, agro-industry SC planning, supplier selection and order fulfilment (Min, 2010). Although fuzzy logic is not a philosopher's stone in solving all problems in management practices today, it has considerable potential to be applied to managerial uncertainty, due to lack of knowledge or evidence, abundance of complexity and information, fast and unpredictable development of SC projects.

4.3.2 Bullwhip Effect - Case Study

One of the key concerns of managers in complex SC is to understand the relationships between various agents and its effects on other parts of the network. The Bullwhip effect, that we will examine in this session, refers to the phenomenon where orders to suppliers tend to have larger variance than the sales to the buyer, similarly order to the producers, which is generally known as demand distortion or distorted information from one end of SC to another end. Often time, this distortion amplifies to upstream, leads to tremendous inefficiencies, excessive investment, poor services, loss in revenues, misguided capacity plans, ambiguous transportation and production planning (Lee *et al.*, 1997). A few major causes of the bullwhip effect have been discussed throughout different research journals, such as;

- Demand forecast updating – it appears to be major source of bullwhip or whiplash effect. Parties in the supply chain build their forecasting based on the historical demand of their immediate customers. While retailers build their forecast, based on the actual customers demand, and other parties adjust to fluctuations in ordering policies of these preceding in the SC (Carlsson and Fuller, 2000). If everybody reacts to this constant adjustment with smoothing techniques, the fluctuation within the SC network will amplify. For instance, assuming that retailer experiences a higher demand in period 1, which will be then interpreted as a signal for higher demand in the future period. Accordingly, future demand forecast gets adjusted, therefore, retailed places a larger order with wholesalers. Since the demand is non-stationary, the optimal ordering policy will get adjusted, as a result. A further consequence is that the variance of order grows, which starts the bullwhip effect. Especially, when the lead-time between reordering point and the delivery is too long, the uncertainty increases. Thus, retailed increases its safety stock level by adding marginal safety in the order, which will further increase the variance to the bullwhip effect.
- Order batching – When demand comes in with updated figure, the managers need to handle the supply part of the SC. Since not many companies acquire orders every day, instead they order weekly, biweekly, or even monthly, the supplier faces a high erratic stream of orders. There is a spike once during the month, the variable will be much higher than the company itself (Lee *et al.,* 1997). Periodic ordering amplifies variability, which directly contributes to the bullwhip effect, in general. Even if the company want to order frequently, the characteristics of economics of transportation will need to be measure and played against, because there is huge difference in cost between FTL and LTL rates. As a result, it pushes the companies to full a truckload with useful materials with economic price than ordering unnecessary materials and holding it off at their warehouse. In contrast to periodic ordering policy, companies with push ordering policy experiences regular surges in demand, whenever it fluctuates radically over the given period. Hence the salespeople are often measured on their periodic performance quota, suppliers, and manufacturers experience surges during period end when the orders pushed-in from customers. Though, this order pattern may or may not reflect the actual demand pattern of end consumers, which then reflect in the bullwhip effect.
- Price fluctuation – when high-low price occurs in the form of price discount, coupons, rebates and so on, the forward buying and stocking options, or advance buy-in for stock up may be the better option for customers. However, in terms of demand, it does not reflect the actual consumption pattern of customers, which creates faulty variation in the consumption rate – the bullwhip effect. When sales hits higher seasonally, some manufacturers required to run their production overtime to catch up with the demands, while other time it has to idle its facility activities. Evidently, companies foresee the demand pattern built in the historic data and get prepared for the increase. Building stocks higher than its normal volume can result in fully occupied warehouse and inefficiency warehouse capacity utilization and increased holding costs per products at the same, not taking account into possible damages to the products during handling and stocking. In relation to Lee *et al.* (1997), using trade promotion can backfire due to the fact that it will impact on manufacturers' stock performance.
- Rationing and shortage gaming – when product demand exceeds the supply, manufacturers often rations its products to customers, meaning manufacturers will ration when the products in short supply, customers exaggerate their real needs for the goods. But in reality, real consumption of products is not increased, but retailers' anticipation, on the other hand, increased the demand to manufacturers. When the demand cools off, manufacturers receive more cancellation of orders than it actually received, leaving them with overstock problem. This overreaction by customers anticipating shortages in the market pushes manufacturers to deal with unrealistic demand, which constitutes to further problems.

Understanding bullwhip effect and it causes can help SC manager to find strategies that can mitigate such risks. Furthermore, it is important for companies, who are wanting to control such effect, have to focus on modifying the chain's infrastructure and processes, rather than the decision maker's behaviour (Lee *et al.,* 1997). So, how fuzzy logic can help to solve this problem of bullwhip effect in SC and improve managerial decision-making processes?

First and foremost, we understood that the core component of bullwhip effect is an inaccurate demand and forecast management, which has been affected by numerous agents within and outside of the SC network. Since there is no absolute forecast to begin with, fuzzy logic can be useful to understand such imprecise information. Let's assume that retailer gets higher demand in one period, which signals higher demand in the future period, and forecasts get adjusted, and retailer reacts by placing a larger order to its supplier. Hence demand is non-stationary, the optimal policy of order is up to *S*, which also becomes non-stationary. The further consequences occur when variance between two elements becomes bigger, the bullwhip effect starts. If we concentrate on a single item in multiple periods of inventory, we can construct and follow equation with trapezoidal fuzzy members.

Let us denote the elements as following.

t – inventory period
z_t – decision order quantity at period t
υ – some period ago the good ordered
S_t – amount in stock plus on order (including in-transit inventory)

If the retailer faced serially correlated demands, the process follows below representation.

$$D_t = d + \rho D_t - 1 + u_t$$

D_t – demand at period t
ρ – constant satisfying $-1 < \rho < 1$
u_t – independent and identically normally distributed with zero mean and variance σ^2

In this case, σ^2 – assumed to be significantly smaller than d, so that the probability of negative demand is very small. The existence of d is a constant basic demand to a producer to avoid any granted demand. After the formulation, Lee *et al.* (1997, Carlsson an Fuller 2000) examined and proved following theorems.

(a) If $0 < \rho < 1$, the variance of retailer's orders is strictly larger than the retailer's sales, thereof;

$$Var(z_1) > Var(D_0)$$

(b) If $0 < \rho < 1$, larger the replenishment lead time, the larger the variance of orders, $Var(z_1)$ will strictly increase in υ

$$\begin{aligned} z_1^* &= S_1 - S_0 + D_0 \\ &= \frac{\rho(1-\rho^{\nu+1})}{1-\rho}(D_0 - D_{-1}) + D_0 \end{aligned}$$

and

$$\begin{aligned} \mathrm{Var}(z_1^*) = &\left[\frac{\rho(1-\rho^{\nu+1})}{1-\rho}\right]^2 \mathrm{Var}(D_0 - D_1) + \mathrm{Var}(D_0) \\ &+ 2\left|\frac{\rho(1-\rho^{\nu+1})}{1-\rho}\right| \mathrm{Cov}(D_0 - D_{-1}, D_0) \\ &> \mathrm{Var}(D_0). \end{aligned}$$

z_1^* - optimal amount to order, which collapses into

$$Var(z_1^*) = Var(D_0) + 2\rho \text{ when } \nu = 0.$$

The optimal order quantity is the optimal ordering policy. In any cases, it does not help to avoid the bullwhip effect in SC inventory and order management. However, with the research examination conducted by Carlsson and Fuller (2000), incorporating above theorems with Hausdorff fuzzy number metric, while considering probabilistic variances over the replenishment lead time proved that the bullwhip effect can be eliminated completely.

From above case example, we need to understand and see the significance of the designer of a fuzzy system, must make several important choices in the selection of membership functions. Especially in SCM decision-making, there are many components that need to be considered and built into the system, to allow fuzzy logic to provide humanly support to the decision-makers in discontinued, flexible, and non-linear ways.

4.4 Acting Rationally

The rational agent approach or acting rationally means that machine is acting to achieve one's goals, given one's belief or understanding about the world. An agent is a system that perceives and acts within the environment. An intelligent agent is the one that acts rationally with the respect to its goals. In the stage of designing, instead of constructing theoretically it concentrates on best decision-making procedure possible within the circumstance in which the agent is acting. Logical approaches that we have examined earlier provides best action, but perfect rationality – making the best decision theoretically possible that requires more complexity in a real environment, such as time, memory, computation power, uncertainty and more. The rational agent approach has two advantages, over other approaches. It is more general than the "laws of thoughts" because correct inference is just one of several possible mechanism for achieving rationality. Secondly, it is more amendable to scientific development than other approaches based on human behaviour or human thoughts (Russell and Norvig, 2010). However, it is also crucial to note that there is no absolute rationality, even for human beings, such that always doing the right things is not feasible in complicated situations.

4.4.1 Agent-based model

An agent-based system is an approach that distributes problems into sub-problems and solves it through independent entities known as agents. Each agent then can use different methodologies, knowledge, and resources to process the assigned tasks (Min, 2010). According to Newell (1989, Min, 2010) an agent refers to an autonomous entity that has characteristics of exploiting significant amount of domain knowledge, overcome erroneous input, use symbols and abstraction, learn from the decision environment, operate in real time and communicate with others in natural language. Agent-based model is capable of combining elements of game theory, complex systems, emergence, computational sociology, multi-agent systems and evolutionary programming, which makes it highly trained and intelligent system.

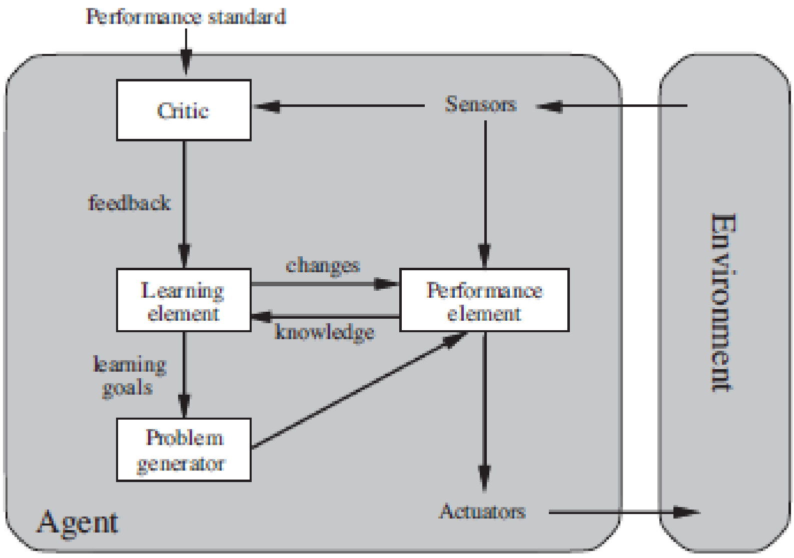
It has been often been applied to handle various complex tasks in SC, including shop floor control, logistics planning, aggregate planning and forecasting, joint production planning, new product development, order monitoring, B2B negotiation, outsourcing relationship management, customers relationship management, SC performance assessment, SC coordination and collaboration under uncertainty, information exchange among partners, purchasing e-procurement, e-supply chain, maintenance and repairing and many others (Min, 2010).

The main reasons of employing an agent-based system is that its methodologies and algorithm mimics the social behaviour of ants, who often find shorter path to their food sources, innate capability to follow pheromone trails, and work together and contain collective memory. This colony optimization algorithm is meta-heuristic inspired by knowledge-sharing behaviours to solve combinatorial and complex problems in different dimensions. Due to its past success, the agent-based approach has been employed to solve many sequential and/or selection problems in SC; whilst it became extremely popular in software engineering field in the last few decades. It has also infiltrated the area of operating systems, where the autonomous computer system and network that has ability to control and monitor themselves with perceive-act loop and machine learning methods (Russell and Norvig, 2010). Noticeably, the repetitive competitive interactions between agents are the core of agent-based modelling, allow them to search for explanatory insight to the collective behaviour than solving specific practical problems. As a result, it may experience learning, adaptation, and reproduction, mimicking human behaviours in advanced technology like AI. Therefore, agent itself is a system of body that consists of, according to Russell and Norvig (2010), architecture and program or goal. In general, there are four types of agents outlined, as following:

- Simple reflex agents – is the simplest kind of agent that selects actions based on current percept, ignoring rest of the percept history, reducing the number of possibilities, in comparison to alternative agent models. Even in a complex situation, simple reflex agent output can be performed, due to the connection between the agent program and the action, which is called as condition-action rule. It is similar to human reflex or learn response to certain actions, such as initiating braking when drive closer to a car.
- Model-based reflex agents – it is the most efficient way to handle partial observability and keep track of and maintain internal state, which depends on the percept history and current unobserved state. Over the time, the agent requires to update the internal information based on external changes, and result of its own decision making to outside world, which are encoded in the agent program. Although there is an unobserved state in the agent, it is still required to make decision, which result in best guess rather than exact measures.
- Goal-based agents – knowing the current state is not enough to make decision. Most of the time, agent needs some sort of goal information that describes the situations that are desirable, just like humans. Agent program can combine this two information together to find ways to achieve the desired end results. Even though the goal-based agent seems inefficient in some way, it is more flexible because the knowledge that supports its decisions is represented explicitly and can be modified.
- Utility-based agents – finally, goal alone with current state does not ensure the quality of behaviour. As we make more decisions, it results in certain condition that affects other people. It is often measured in emotions and feelings. However, it is hard for machines to learn and feel these emotions. Instead, a performance measure assigns a score to any given sequences of the environment state to distinguish different levels of desirability. This is also known as internalization of the performance measure.

There is another agent that has been introduced overtime and performing great deal of responsibilities in machines, is a learning agent. It provides advantage of operating in unknown environment and become more competent than its initial knowledge. The learning agent can be divided into four conceptual components, illustrated in Figure 36. First is a learning element, that is responsible for making improvement in the machine internally. A performance element, in contrary, selects external actions in a given situation. Critic is the third component, which represents the feedback element that determines how the performance should be modified to be better in the future. Finally, the problem generator, for suggesting actions that will lead to a new and informative experience (Russell and Norvig, 2010).

Figure36. General Learning Agent



Source: Russell and Norvig (2010)

In the case of updating the system of knowledge, the learning element can make changes to any of the components shown in the diagram. The choice and design of an agent rely on the functions and objectives of the project leader. One of the vivid examples can be seen from robot navigation, rather than following a discrete set of routes, a robot can move in continuous space with an infinite set of possible actions and states, draw function of states and learn from the outcomes. If the robot is just there to follow an instructed route, therefore it is no longer a learning agent, but a tool with objective to perform with less error, essentially to reduce the cost of operations. Meanwhile not every business requires to reduce cost, sometime while robot is learning, engineers can discover better resolutions that have been overlooked, which is the description of learning organization. But how the performance of the robot can be measured in reality?

Since algorithm is the one, which is commanding the robot to perform, it can be evaluated in four ways:

- Completeness – is the algorithm guaranteed to find a solution when there is one?
- Optimality – does the strategy find the optimal solution?
- Time complexity – how long does it take to find a solution?
- Space complexity – how much memory does it need to perform?

Time and space complexity measure solely depend on the difficulty of the problem, while completeness and optimality eventually represent effectiveness and cost of the function. However, agent-based model is more than just a technology, it is elaborately a mindset. The popularity of such system is not only because of its ease of implementation, though, it also provides further benefits, such as agent-based system captures emergent phenomena, provides a natural description of a system, and has flexible approaches (Bonabeau, 2002). As we mentioned earlier, it is very flexible system that allows it user to change the goal anytime and perform accordingly after the changes. Emergent phenomena result from the interactions between individual agents. By its nature, the when system is running, it builds up its interaction and collects emergence of information from bottom up, which mimics simple social behaviour of human beings. Secondly, the model makes the behaviour of agents closer to reality. The model looks at the organization from the viewpoint of activities, not of business processes angle, hence examines what people do (Bonabeau, 2002).

4.4.2 SC Integration - Case Study

Due to dramatic advancement in IT, various functions of SC have become dependent on its settings. SC strategies are currently reorganized through information integration, which becomes challenging for many organizations. IT allows greater amount of information to be distributed among network parties, which results in increased accuracy and collaborations (Kwon *et al.*, 2007). Furthermore, it brings superior efficiency and synchronized activities in the business, leading organizations into pursuing tightly integrated SC. Many scholars have taken various approaches over the years to investigate and improve the quality of information sharing and coordination within SC. But with the development of agent-based modelling enabled further exploration of creating multiple agents in the system to tackle collaborative environment. Hence, challenges regarding deployment of agent-based model in SC was, it was difficult to make the network to adapt a new products or trading partners, because agent system was usually fixed in the traditional transaction sequence. However, in this case study, we will further examine the adaptable and flexible agent-based model to dynamic changes of structure.

The agent-based system, first, requires heterogeneous agents which act in virtual environment. Evidently, it also requires central agent to coordinate and reconcile conflict among other agents. Especially, since SC consists of different parties on the network with different goals, it is important to dedicate roles to each agent to specifically serve to the entity's purposes. Agent with different knowledge can produce different products. Assuming that the network architecture will consist of retailer, manufacturer and supplier, the agents can be denoted as following.

- *R-Agent* – Recipient agent that collects customer's orders and cross-sell it against available inventory. If inventory is insufficient to fulfil the orders, then it places an order by communicating with M-agent and the order is backlogged in the system (Kwon *et al.*, 2007). The main goal of R-agent is to increase profit by reducing costs associated with inventory, backlog, and ordering. Automatically, it calculates the order quantity to manufacturer while optimizing the costs.
- *M-Agent* – manufacturing agent by assembling final components. Its main goal is similar to R-agent, in addition to production setup. It also needs to decide whether to expand its supplier base if it faces supply uncertainty (Kwon *et al.*, 2007).
- *S-Agent* – supply agent, which serves for similar profit maximizing goals to suppliers of component in the network. It determines the final production quantity.
- *MACE (multi-agent case-based reasoning) frame* -

After determining the agents in the system, the model then facilitates additional levels of coordination and information sharing among the agents. The main priority of general agent is to maximize the overall SC profit via improved coordination and cooperation. Which means, the general agent can support the strategic level of relationship among parties in the SC network. Furthermore, the central agent performs better in conflicting situations through better SC transparency. As a result of such coordination, it created agent-based web services, that equipped to facilitate exchange of semantic information among agents in the SC.

The main concern of the manufacturer is to maximize the revenue, while minimize the cost of inventory, backlog, and ordering. Furthermore, the manufacturer concerns to understand quantity to be produced and how much to order from its supplier. Therefore, mathematical representation of the manufacturer's objective will be the goal of maximizing the profit at the time *t.*

$$Profit\ (m, t) = P(m, t) * X(m, t) - p(m, t) * Prd(m, t) - Inv\_cost(m, t) - Backlog(m, t) - Order\_cost(m, t) - Setup\_cost(m, t)$$

Profit (m) – profit of manufacturer at the time of *t*
P – sales price
Q – order quantity

Prd – production quantity at the time of *t*
X – sales quantity to the retailer.

$$Profit\ (m, t) = f(P(m, t), Q(m, t), Prod(m, t))$$

Meaning manufacturer's profit is the function of the sales price, order quantity, and production quantity at the time of *t*.

In the development of a model, autonomy, integration and enhanced integration level of agents and partners are also defined closely.

- Autonomy level: agents are only transactional information, such as order quantity. They cooperate minimally and pursue individual goals. If three agents, as we defined earlier R-agent, M-agent, and S-agent involved in such level, they are no longer relay on case base coordination mechanism.
- Integration level: strategic relationship among partners are highlighted at this point. They collaborate extensively and share both operational and strategic information. They pursue the optimal solutions for the entire supply chain and collaborative environment (Kwon *et al.*, 2007). In this case, fourth agent is introduced into the model, which is known as MACE – multi-agent case-based reasoning agent. MACE acts as a central coordinator, and possesses sole authority for decision making, and conflict solutions. However, agents do not follow the case, instead they follow MACE orders.
- Enhanced integration: similar to integration level, but it uses unique agent CBR – case-based reasoning agent to find globally optimal solutions. In this case, agents have access to additional information on market, price levels, and corresponding demand quantity. They rely on the case basis and follow the MACE coordination mechanism (Kwon *et al.*, 2007).

The coordination mechanism MACE can function better when all agents focusing on achieving a global/central goal, by sharing operational and strategic information. However, it is also important to note that, not all parties in the SC network will be defined as strategic partners. Therefore, before utilizing such methods, SC managers need to closely identify their strategic allies to feed into the systems. Secondly, the agent, then tries to identify the local goals while seeking global solution to the problem. These two approaches may lead to trade off, a solution that meets either the local or global goal, but not both.

$$\text{Maximize} \quad Profit\ (c, t) = \alpha * (Profit\ (r, t) + Profit(m, t) + Profit(s, t) + (1 - \alpha) * ms(r, t)$$

$$\text{Subject to} \quad Profit(r, t) \geq Min\_Profit(r)$$

$$Profit(m, t) \geq Min\_Profit(m)$$

$$Profit(s, t) \geq Min\_Profit(s)$$

$$0 \leq \alpha \leq 1$$

The objective function of MACE (*c*), its profit is expressed, as above, summation of the profits of R-agent (*r*), M-agent (*m*), and S-agent (*s*), and the market share (*ms*) at the time of *t.* The market share is determined by the customer's preference whose value is the function of sales price, quality and marketing investment and others. For simplicity, the customer reference is defined as a function of price, which can be, then represented as $y = ae^{(b/x+c)}$, to derive price where *x* and *y* indicate the price and customer preference, and parameters *a, b,* and *c* are randomly determined (Kwon *et al.*, 2007).

The minimum profit is introduced to the system as criteria, where local goals to be achieved. In other words, MACE accomplishes the profit maximization goals while meeting the local goals of 3 agents simultaneously. Under the supply and demand uncertainties, such as customers demand volatility, distributors lead time, production capacity, change in number of suppliers, and relationship types, the mean performed fixed and changed only standard deviations of all uncertainties mentioned. As a result of Kwon *et al.* (2007) research of multiagent-based system integration in SC, they found that this system structure is intuitive to formulate and case-base function can easily be built by monitoring past transaction and records of SCM. Thus, the method is highly flexible, the structural changes have been accommodated by the engineers and the system relatively faster in the emerging situations. Furthermore, introducing central agent in the system to coordinate the global and local goals was proven to be effective to avoid further behavioural problems.

However, there are a few limitations to agent-based model. First, it is often hard to define the relationship between customers and suppliers as it can change over time. Therefore, it needs to be examined carefully and fed into the system. The case study is performed only on 3 agents in the system, which is simplistic in comparison to realistic and complex SC. Thus, introducing more entities in the system can change the adaptation of such system in real life. The system is often studied from the view of decision-support, rather than stand-alone function, thus, there are more to explore. Having said that, one must not make decision based on the quantitative outcome of the systems that should be interpreted purely at the qualitative level. As we all know, based on the quality of the input data, the outcome will vary in both quality and quantity characteristics, which may or may not be useful for decision and implementation at the end.

Chapter5. AI in Supply Chain Management

In this part of the thesis, we would like to shift our attention into the overall implementation of AI in SCM, how does it change or improve the traditional decision-making business environment. First and foremost, the thesis will continue its course in research regarding external environmental changes, moving towards its impact on general SCM. The key reason of involving externalities is to, then, understand, how AI can incorporate corresponding information to improvise on its performance to support decision-makers in the network. Once the answer becomes clearer, then the further discussion will head to future of SCM.

5.1 Uncertainties and Changes in Supply Chain Management

As business environment changes in unprecedented ways due to external influences, SC managers are also required to adapt new norms and be concurrent. There are many externalities, as traditionally we often examine those surroundings of business on the basis of PEST or PESTEL model. However, we would like to shift our attention on limited number of current events that affected various industries in distinctive ways. Think of externalities, it is often out of one's immediate control and has big impact on both consumption and production. As a result of externalities, it creates several uncertainties in the atmosphere and makes business environment more complex.

5.1.1 Legal and Political Issues

To take an example of Brexit, where it created massive uncertainty among European manufacturers before and after it has taken place. In a such sudden change, how does one manage just-in-time deliveries? How did it affect one's contractual agreements and system implementations? Not limited to business operations and partners relationships, how did it affect overall employment movement in European Union? As a result of UK leaving EU, number of organizations imposing high risks of leaving the country for good. The withdrawal of UK from EU started in June 2016 with public referendum and began the process in March 2017. The finalization of this process took place in January 2020, which shows the lengthiness of such uncertain environment. In some big corporations, the movement of leaving UK already started ever since 2017, commenced from big companies like Tesla, who is building its next factory in Germany, Sony is moving its European headquarter to Netherlands, while Nissan and Siemens are holding off their funding respectively toward their UK operations (Giambrone, n.d).

Not to mention, the trade war between one of the biggest economies in the world, USA and China has speculated more tensions in global supply chain. Uncertainty about its depth and duration of such war, even after the presidential discussion, pressing firms to rethink their extended supply chains inside out. Since tariffs are being imposed on Chinese produced goods, companies are forced to revisit their long-term strategies to reposition their factories elsewhere. Even though, an agreement has been put in place to balance the tension between the countries, there are more ambivalence on its way in relation to a notion of US departing from its strategic trade relationship with Canada and Mexico. The NAFTA is now revisited as to modify as bilateral instead of multi-lateral agreement.

In general, we can characterise these risks into several different categories, such as political instability, regulations and policies changes, protectionism, and conflicts. These trends of uncertainties can impact the operations of SC by altering the terms on which the market can be assesses. Considering not only global political events, national level risks also need to be examined closely by managers, which are including;

- *Regulatory arbitrage* – this risk is concerning and criticising the fact that global SC circumventing a form of social norms and ethical behaviour through hiring or sourcing labour, materials, and equipment cheaply overseas than locally. Historically, this is due to the nature of the business, where it is often required to reduce the cost by selecting and sourcing less pricey items. With the extension of global sourcing platform, more job vacancies and manufacturing facilities have been created third world countries than developed countries. As a result of such movement, this created a whole new chapter of global risks of power manipulation among large corporations.

- *Unethical/criminal practices* – related to the first point, complex global SC also created an unethical or criminal channel for certain businesses. This reinforces the point of outsourcing aspects of production and manufacturing, with abdicated responsibilities of businesses (Cicero, 2017). Especially, in the case of raw material sourcing, many companies do not aware of the processes how they are being treated, grown, or what kind condition does the facility have.
- *Corporate reputation* – it is highly linked and openly accessible in modern age of communication and social media, which is why managers of any SC needs to be updated to date on the matter. A simple mistake or ignored facts can be treated and used against the corporation reputation, that can result in tragic events of business boycotts or bankruptcy. Therefore, legalistic response or standards need to be prepared and imposed on international suppliers of any kind to ensure integrity of the brands.
- *Shifting polarities* – with global changes and attitude toward to multilateral agreement among leading countries, it is not undermined as it seems. Many other internationalist countries like Canada, Australia, New Zealand have continued to advocate for international outlook of trading benefits and continue creating and promoting engaging promises. Regardless of sceptic leadership by US or China, or the respective shift of focal points elsewhere, such as Canada, EU, Australia, the status quo will herald significant uncertainty for business owners and principal stakeholders (Cicero, 2017). In the event of such regulatory changes on governing international trading, SC is often expected to alter substantial amount activities and adapt accordingly by devising new systems, changes of market or routes.

So how all these changes will affect the internal SC network? First and foremost, it will require businesses to find additional capacity to change and redesign their SC according to the changes in the nation. Some suppliers in countries like China and Mexico are, no longer, considered competitive in terms of their price due to increased tariffs. As we discussed briefly on bullwhip effect, such changes in price can also affect the effectiveness of location, and facility decision-making in SC, that includes suppliers' lead time, inventory responsiveness, and transportation methods etc, and not be swayed by the cost savings alone (Bhatnagar and Sohal, 2005). Whilst reducing a demand for one supplier, will require the remaining requirements to be fulfilled by other partners. As a result, SC managers either need to look for new partners to expand its relationship or increase demand to other closely related suppliers. Raw material availability is another uncertainty by manufacturers, especially industrial size producers and its market. Thus, changes in the government regulations can highly fluctuate the trading market of raw materials quantitatively and qualitatively. Thereof, companies ought to emphasize risk capitalization and forward contracting methods to mitigate related risk, which may or may not be sustainable in the long term.

5.1.2 Environmental & Social Issues

Another most discussed issue is global environmental concerns and its effects on businesses. A significant number of researches have been conducted over the years on conceptual and practical matters of how to integrate sustainability into global supply chain. Especially in economic sense, there is a continuous debate of profitability against environmental sustainability among businessmen and practitioners. Among most concerned global environmental challenges are global warming, which forced global SC to rethink and redesign its network to reduce its negative effects on environmental, social, and economic implications. It challenges managers to rethink about the investment, long term strategies under uncertainty of financial return (Bals and Tate, 2018).

- *Natural disasters* – varying types of such event can happen all around the world, leaving the network of links broken for certain period. Most SC businesses stay highly vulnerable to uncontrollable and unforeseen disasters. One of which was occurred in Thailand, where continuous rain flooded southern side of the country 2011. It caused major factories to shut down, costing billions of dollars in damage and put over 600,000 people out of work (BSI, 2020). Other disastrous events like earthquake and tsunami, can cause ripple effects from one chain to other chains in the network and remain its impact more than a month. Thus, the natural disasters strike with seemingly low warning, the risk occurrences are highly unpredictable. Nevertheless, chain of organizations can have risk mitigation strategies to reduce the effect and quickly respond to such disaster at the same time.

- *Infectious diseases* – SARS; MERS, Ebola and Covid-19 have imposed huge risks all around the world. In medical supply chains, outbreaks of epidemics would account of great presume to keep up with emergency demand, while people's lives on the stake. On the other hand, other types of SC are severely slowed down due to restricted activities and reduced consumer demands. Hence, the imbalance in the economy will bring the worst-case scenario of global economic recession, which can continue for several months to years to regain its strength to support all businesses and lives, in general.
- *Consumer preference & Sustainability practices* – with the respect of consumer behavioural changes, recent trend shows that more and more consumers are likely to support businesses that engage corporate social responsibilities, such as environmental sustainability acts. Without adopting socially responsible model for sustainable business, companies would end up losing its customers and brand recognition, which was not the case many years ago. On top of offering reasonably priced, quality products, the companies are now forced to produce ecological items, rather than mass produced products. As a result, most of the traditional businesses functioned concentrating on cost and outcomes, though, the current organizations increasingly recognizing increasing need for significant trade-offs between social and sustainable objectives and financial longevity.

Thus, consumers have become more and more aware of the environmental and social issues, the demand for responsible organizations grew into a foundation for successful business. So how does consumer movement concerning environment and society will influence the current SC designs and decision-making?

Without proper guidance and inputs, advanced systems like AI and ML cannot function at its full potential to solve the issues. First of all, sustainable supply chain requires strategic sourcing to meet environmental standards. Therefore, instead of selecting suppliers based on the costs, locations and availability, managers now need to add new parameters such as quality, responsiveness, social practices. Furthermore, these changes also require transparent information and integrated communication throughout the supply chain network. Secondly, quality of production in the manufacturers. Traditional low-cost manufacturers are now facing not only ethical behavioural problem, but also compelled to practice desired cost structure with improved workforce conditions. Meaning that quality of product does not only represent the physical material, but also became the representation of full network practice, including labour force. The demand for sustainable SC does not end here. The next condition for responsible organization is fulfilment of international standards, which is an extension of stakeholders in the network. These external organizations are important for examining the current organizational practices throughout the entire chain of relationship and pledged to evaluate the performance based on the internationally approved principles. Expansion of stakeholders often expects managers to be aware of the complex network and take desired actions. Without proper training, design, and input data AI/ML inspired technology cannot support such compound and heterogenous decision-making, at the end.

5.1.3 Technological Changes

With the expansion of Internet and availability of advanced technology, customers have become very information in their decision making. The rise of external issues brought information disruptions among consumers, and forcing companies to shift toward convenient, yet responsible model of doing business. Not only informational disruption among consumers, technological disruptions are changing the traditional SCM significantly. Newer technologies such as Blockchain, 3D printing, and IoT promise further disruptions with different time horizons for implementation in this rapidly changing business environment (Zinn and Goldsby, 2019). Since customers demand and its complexity are playing major field in changing of business models, the advance technology also allowing the production of such businesses to be faster and efficient.

- *Additive manufacturing* – is allowing reduction in total number of components and assembly for final products, while changing the nature of competitive field. The further advantages of 3D printing are rapid prototyping and reduced new product development cycle time, decreased inventory, and raw material requirements, allowing high customization with increased responsiveness to the market demand (Waller and Fawcett, 2014). With other IoT driven robotic technology, small SC businesses will have most responsive and flexible network of chains, in comparison to larger incumbents. However, these advantages may have reserved effects on SC managers who are responsible to deal with rapid environmental changes and consumption uncertainty. Having small SC network, also, does not define the extensive investment decision of applying advanced AI/ML driven systems, which will bring us to the second point.
- *Inexpensive software* – small business owners mostly could afford inexpensive computer aided design software (CAD) and spreadsheet to manage their businesses, leaving managers with less advanced computer system-based supports. Moreover, the SC map or network is non-existent among small businesses, because it only has limited number of suppliers and customers, due to its capacity. As for medium to large industries, inexpensive software is not suitable to support their dynamic SC needs. Therefore, they often prefer to hire customized solutions provider that can design and implement systems to accommodate complex needs at higher expense.
- *e-Supply chain* - is another emerging phenomenon among businesses, signifying integration of activities between SCM and modern Internet services. Manages have realized that enabling Internet can enhance SCM decision-making by providing real-time information and enabling collaboration between trading partners (Gimenez and Lourenco, 2004). This change of technology is more in line with current advancement in SCM field, however driving middlemen like retailers out of business. Successful businesses like Amazon and Alibaba are leading e-supply chain players, who significantly traded-off their possible retail chain network with direct e-commerce channel. This process shifted all traditional activities such as fulfilment, inventory warehouse, and logistics into internet-sourced activities, though allowing real-time feedback. To have strong e-supply chain network, the owners and managers must establish medium to high level of information and knowledge-sharing system. Apart from system implementations, selection, preparation, and training competent workforce is key to successful businesses, like Amazon and Alibaba.
- *Automation* – since start of the industrial revolution, there has been steady and continuous stream of labour-saving advanced technologies in the market. With the recent advancement of robotics technology in the SC, especially, in the inventory and warehousing areas, created certain controversial discussion among users and practitioners. Evidently, the use of automation reduces labour costs, time spend on monotonous jobs, while improving efficiency and errors. However, it also means that headcount required for manufacturing production related vacancies are reduced due to the adaptation of such technologies. With the automation and adaptation of such system will also shift the traditional way of management to whole new chapter of leadership style. This allows businesses to be highly responsive and agile and assist with removing human errors from the bottom level of operations. Though, now the pressure and errors may rise from supervisors and mid-level management, with more heterogeneous issues.
- *Overexposure* – beyond these automation and high efficiencies, the regulatory landscape of current advancement in technology is still catching up with slowing pace. Since internet technology has its own hidden layer, catching criminal acts like hacking, cannot be contained easily. Especially, speaking of IoT based SC is fuelled by cloud-base IT system, which is often very vulnerable against security attacks.

Hence, how do these changes in technology will influence the current SCM decision-making and its structure? Evidently, first and foremost, it brought the curse-of-unlimited information to every manager. To be up to date, managers are expected to be informed by most current market and consumers trends, and other related events to capture the right essence and apply the knowledge to benefit the final outcome at the end of the day. However, it is not easy to process all this incoming information, which may or may not be useful. Thereof, secondly, technology can be used to filter these data inputs and make it easy for managers to process, as well. In a better way, web-based or advanced technology will help managers to simplify their tasks and manage their time efficiently. However, on the contrary, it can also bring sense of insecurity, inattentiveness, and neglectful act due to too much dependency. Not to forget, before adapting and/or integrating such technologies, IT infrastructural developments need to be designed, performed, and tested in order to allow secure connection and information transparency.

5.1.4 Competitive Environmental Changes

The competitive environment is changing in relation to customers demand and preference shift. It defines and success or failure of the business and became the soul of capitalism. Traditionally, relationships identified by Porter five forces model still provide useful structural model by which to understand how the economic value of product or service is distributed between the different players in the market. Thus, due to recent disruptive innovations and high connectedness, it is important to examine how internet changed the playing field of competitive environment.

- *Internet* – the uniquity of internet technology means that competitiveness is heightened for many firms, and intelligence of competitors is more easily available in modern time. This contributes and increases the bargaining power of suppliers (Levy and Powell, 2005). Thus, suppliers eventually can create its own direct channel of sales with customers, leaving businesses vulnerable in the market. New substitutes are created through different manufacturing and delivery mechanism generated by highly linked webs, which made it easier for customers to switch from one supplier to another, to obtain better cost, is another remarkable change of internet. Hence customers switching cost is low, many companies suffer to stay competitive in the market. Such pressure of lowering cost while providing better quality pushes many managers and business owners to make wrong strategic moves. Price pressure also affect the bottom line of operations in the SC. Meaning every mistakes and downtime is treated as a serious contribution to company's loss. As a result, it is highly preferred to apply advanced technologies to reduce human made errors at the cost of high investment structure and new process development. Another way of staying connected with customers is opening up an e-commerce channel. While increasing geographic reach opens new market, but it also puts firms in highly competitive environment with each other. However, downside of depending too much on internet brought more fixed cost than variable. Not to mention the shipping options on the side, firms are unlikely to utilize benefits of internet, if they could recognize its full potential as a complementor to traditional activities, rather than replacing them (Levy and Powell, 2005).

5.1.5 Internal Structure of SC

As a matter of fact, changing routes, establishing advanced system alone does not label strength of SCM. What matter to firms in such uncertain environment is their unique characteristics development in relation to monitor, predict, control and take responsive actions in the SC accordingly. In other words, internal attributes of a firm, such as how fast can a supply chain be redesigned to meet the environmental changes? Is it capable of responsive changes? Can it be fast enough to fulfil market requirements? Can a sustainable competitive advantage be achieved through heightened internal structure?

- *Plasticity VS Flexibility* – given the rising level of uncertainty, plasticity is a growing need for SCM. Differ from flexibility, plasticity conveys the capability to rapidly make changes to an existing SC to respond or drive changes in the environment, in which the business operates (Zinn and Goldsby, 2019). In order words, major network changes signify the rate of plasticity, for instance, investing into omnichannel capability, and/or creating online business channel. Flexibility, on the other hand, signifies the manufacturing systems and methodology to easily adapt to changes in the demand, type and quantity of products being produced. However, it has limited ability to convey as a strategic outcome. The idea of flexible manufacturing became more and more popular by understanding and adjusting manufacturing processes; however, it is not a management practice. Henceforth, SC plasticity also takes consideration into strategic approaches like the traditional operational goals and management focus on customer services, costs and risk management, according to Zinn and Goldsby (2019). The principle of plasticity also can use adaptability, flexibility, fluid networks and roles, goals, and innovation to achieve operational excellence, while removing organizational siloes to create creative and vibrant enterprise in general. Based on the view of Chevreux *et al.* (2014), plasticity should be practiced as a third dimension in any organizations to become more versatile and successful.

- *Agile VS Lean manufacturing* – this is not a recent phenomenon. Concept of agile business, manufacturing and/or organization has been discussed by many researchers over the years. This is another key attribute of successful SC is continuously solving the problems when the market mutate itself. Unlike lean manufacturing, agility is also another organizational capability that emphasizes on dynamic strategic management. In this current turbulent condition, manufacturing firms will need to innovate, not occasionally, but continuously, either by deploying better technology to gain first mover advantages or by responding quickly and effectively to demand signals (Bessant *et al.*, 2001). In fact, the definition of agility applies differently to the size of firms. But many researchers would agree that, agile manufacturing means firm's capability and capacity to adapt and innovate on a continuous basis. Furthermore, it does not exist only in the SC side of the firm, it consists of four main contributors, namely, strategy, processes, people, and linkages. Each of the component associated with special set of routine activities, respectively, to create and support agile organization. However, this often requires huge organizational changes from the people to processes to physical systems, which makes it hard. To keep in mind that, agility does not offer a route to strategic competitive advantages, but it comes from not only reacting quickly and appropriately to demands from the market, but also in pro-active organizational behaviour, trying to change and share the rule of the game (Bessant *et al.*, 2001). Many people may confuse agility with lean manufacturing, however, the main difference is that agile methodology concerns the optimization of development process, while the lean method concerns the optimization of production process. The distinction of such differences lies on the size of framework it covers. In a way, agile has wide application than lean manufacturing approach. Another contrast comes their nature, while lean concept was born in the industrial sector with the intention to make production system more efficient and reduce less waste, the agile approach was born in the creative and software development environment, to embrace continuous flow of feedback and changes (Anon, 2018). However, it is difficult to say, which method is superior than another. In some cases, both methods can be practices in a single firm. Hence the requirement and rules of the game changing in the marketplace, it certainly makes sense to blend some of traditional thinking with modern approaches.
- *Platform ecosystem* – like every other technology, the ecosystems of applications and technology have their lifecycle. Like most technological innovation, platform ecosystem regresses from pre-or post-dominant stages, while progressing along the maturity curve (Tiwana, 2014). In the initial stage, both customers and producers meet at the optimal design, eventually then adopted by the majority in the market. Sometimes, the design of the solution can become dominant design, but does not necessarily constitute the technologically superior solutions. Since, the market often evolve overtime, firms practically required to be up to date, in terms of their implemented systems. Hence forward, this is another reason why we need to update our computer software occasionally. But depending on the business size and previous implementations, sometimes software become obsolete or insufficient to support internally expanding functions. When the database or platform necessitates an update, it takes time for managers to examine the current solution vs market innovations. In the past, number of innovative solutions were less than today, therefore it was easier for managers to select from one of the well-known brands like SAP and Microsoft Dynamics. Thus, the price for such solutions were not cheap in comparison to modern age. Now that, the amount of technological solution providers has increased dramatically, while offering reasonable to lower price with customized products, it made the selection processes more complicated. But the core value of platform ecosystem stayed the same overtime – competitive durability. Meaning that, in contrast with applications and software, competitive durability of platform ecosystem or infrastructure continues to be used by the firm, even when implementing a newer function or integrating other solutions. Software platform ecosystem must be orchestrated rather than managed. Because much of their strength comes from diverse external innovators but their work

must also be integrated internally with all processes and practices, when strategies of firm changes, it also appropriately assimilates the platform ecosystems and lifecycle.

All in all, these changes and uncertainty affect investment in the current SC's potential factor. Most conversion requires significant amount of time, evaluation, and costs. Especially when the firms significantly invested in the assets like warehouses and transportation, redesigning the SC will be likely to be supported by the management (Zinn and Goldsby, 2019). Even internally, other than processes, procedure and human resources, the ecosystem of systems needs to be taken into consideration under market uncertainties and changes. Losing sight of both external and internal impacts on business outcomes will impact negatively on entire SC network and its partners one way or another.

5.2 Applications of AI on Current Supply Chain Management

Overall Chapter 4 of the thesis was designated for the specific algorithms and models that applied in SCM to solve relevant issues. The approaches that examined are subbranches and components of ML, which is a part of AI. If we imagine AI as a human brain, the right side of the brain would be represented by cognition, ML models and logical function algorithms that are covered in the earlier chapter, while left side of the brain would contain the natural language processing (MLP), speech recognition and vision oriented activities and techniques of AI.

What is more exciting is that AI has seemingly unlimited potential application in businesses. When bundled with other associated technologies, its implications become more powerful, such as IoT, predictive analytics, and algorithms. Not only enhancing the operational capabilities, it is also changing the way of thinking and transparency in SCM field. In addition to Chapter 1, Figure 4 decision making model, AI can be applied in decision-support functions in two ways. According to Gartner Analysts Noha Tohamy (Anon, 2017), AI can be broken down for two main categories.

- Augmentation: which assists human with their day to day activities, including personal and commercial needs. Such AI is present in virtual assistant, data analysis, software solutions, and the focus of augmentation is used to reduce human errors and bias.
- Automation: which works completely autonomously in any field of application without human interactions. The main implementation of such technology can be seen in robotic manufacturing.

Thus, major companies like Siemens, Amazon, and Alibaba have already begun implementing AI into their supply chain networks, primarily in robotics and software to fully monitor the production, inventory, and delivery activities. First, by shifting their functions into AI based operations, they have effectively reduced their average time spent on paper-based processes, checks, invoices, related discrepancies, and errors down (Anon, 2017). Such as chatbots on procurement activities in SCM, would be one of the key implementations of AI within the industry. This does not mean that chatbots will replace the human candidates within the industry. Instead they are eligible to reduce the redundancy of repetition. Chatbots are capable of handling cold calls, instructed and narrated by specific rules and recorded conversations. It can also handle low value transactions, paperwork, sending orders with or without supervision, find and build a list of potential suppliers, and many more (Smith, 2016). Henceforth, the most important part of chatbots is to collect and record timely information, monitor the performance of suppliers, and present the KPIs are met, if not procurement officers would be notified. Such streamlining tasks related to mundane SCM activities can help employees, supervisors, and managers to concentrate on the details of how to achieve overall goal of the organization.

On the other hand, according to Cordon (2019), AI can broadly support three important business needs, such as automation of processes, gaining insights through data analysis, and engaging end to end users in the network. One of the best examples of automated operations and warehousing can be seen from Amazon, where it employed more than 200,000 robots in their warehouses across nations. As a result of such restructuring of its operations, Amazon has reportedly improved its safety and productivity of both physical warehouses and their employees.

Companies like GE; Intel, Funac, Kuka, Bosch, NVIDIA and Microsoft are also making significant investment on ML powered approaches with robotic technology to improve all aspects of their manufacturing. These technological changes are being used to bring down labour costs, product defects, shorten unplanned machine downtimes, improve transition times, and increase production speed (Soleimani, 2018). Furthermore, robotic technologies in manufacturing will help production team to obtain better insights on products traceability and production efficiency, while recording, documenting, and storing data real time.

Another successful implementation of AI and its methodologies in SCM is application of genetic algorithms in variety of challenging supply chain network problems, such as vehicle routing and scheduling. Traditionally, finding a set of minimum costs vehicle routes which starts and ends at the central depot, after serving a set of customers, without violation of constraints (Soleimani, 2018). Especially courier services and logistics delivery companies, understanding and solving this set of problem is very essential for their financial performance, which must function harmoniously amid high volumes, low margins, lean assets allocation and time sensitivity. One of the key examples here is UPS, who employed Orion, a GPS tool that helps drivers to make sure to do their deliveries in timely and cost-effective manners. The tool helps to plan the routes, optimize the timing based on the traffic conditions in the areas, and other related factors. As such, Orion helped UPS to save nearly $50million annually (Khasis, 2019).

In traditional SCM, inventory management represents idle resources and high costs that are required to main high levels of customers services. However, high inventory is not always guaranteeing the right mix of products, therefore, customers satisfactions. Furthermore, the firm's success in a competitive market often depends on the ability to control and plan inventory at minimal cost while ensuring products availability to the customers. AI tools such as ANN and agent-based modelling can help improving predictive analytics by forecasting of customers behaviours in relation to business environments in which they are operating. Demand forecasting of AI is not a new idea, though, implication allows for far higher level of accuracy with continuous adjustment to forecasts in real time. Many industry players in crude oil, financial trade, weather forecast, and energy supply, today utilize AI driven solutions to predict the future demand more accurately.

The application of AI does not stop at the operational level. For example, through collecting and analysing its customers' needs and purchase behaviours, Amazon has made its e-commerce platform success around the world. With the development of the very first commercial deep learning model to the expansion of ML, Amazon also managed to diversify its business portfolio to cloud-based data warehousing services to other businesses, also known as Amazon Web Services (AWS). Whilst serving other corporations to securely monitor and maintain their databases, Amazon has also innovated the Alexa voice platform to put more insights and accessibility to AI in the hands of every users. Amazon has tailored its AI and ML offering to match both types of customers at their end channel – businesses and individual consumers. Some of the users may have deep experience and ability to build their own ML models, while others just want to take advantage of those are already exist (Terdiman, 2018). With its successful implementations of AI driven innovations, the core business of Amazon now evolves around AI, which is the key reason why the company hit over $1trillion in the capital market.

So now the question would be, how can we apply this entire system in SCM decision-making process?

First and foremost, with the increased need for data analytics, it is safe to say that AI and ML would be a necessity in current business environment to process and analyse the real-time information efficiently and effectively. In comparison to time consuming traditional practices of understanding available information and preparing reports manually, which may or may not ensure the validity and credibility, AI can save time and costs while guaranteeing better accuracy and reliability of data. Thus, the need for data analytics is on the rise, whilst overall rising the demand for Big data management, it is also safe to say that without real-time information, AI is just a tool for making bad decision.

Secondly, the redundancy of time spent on decision making and information search will be reduced with the help of AI. According to recent research published by McKinsey, around 61% of executives reported decreased costs and 53% reported increased revenue as direct result of employing AI into their SC network. Most areas that applied AI were sales and demand, forecasting, spend analytics and logistics network optimization (McKendrick, 2020). Of course, there is also growing concern and challenge regarding increasing volume in SKUs due to customization, thus, AI can help managing such mayhem through reducing duplications and system errors. AI is best suited for SCM cognitive automation, which essentially can eliminate the issue of increased data storage and manual approaches of creating SKUs, by aggregating and normalizing the data in standardized format.

Supply chain planning is another crucial part within SCM strategy, and it requires consistent amount of information, expertise, and time. Having intelligent tools, such as ML, to be applied well into SC planning could help planning accurate forecasting, and inventory, which then revolutionize the agility and optimization of supply chain decision making through understanding, acquiring and managing the supply and demand better. By utilizing ML tools and techniques, SC managers and professionals could have better access to best possible scenarios, calculated based on superior and intelligence algorithms to find optimal solutions. The only duty of managers, then, to select relative options, add personal experience and knowledge, and compare it with other external and internal source of information to confirm the output and implement the final choice. Furthermore, the ML provides endless self-improving options and capabilities, that can reshape the traditional management practices as we know.

Through this thesis analysis and review on several different scenarios on utilizing ML techniques showed that there is an increasing need for proper IT infrastructure in SCM. Without is, it is difficult to achieve the speed, agility, and integration that characterize the very foundation of AI. Evidently, building suitable form of IT infrastructure would take long time and considerably high expense, though, having proper and elaborate system would enable firms to gain enhanced SC monitoring and eventually lower down the costs of operations in the long term. Furthermore, AI is able to close gaps between end-to-end supply chain processes, to create consistent services and manufacturing overtime with less errors. Today’s complex environment, having end-to-end visibility of SC network also will ensure better flow of services, through revealing cause and effects, bottlenecks, and opportunities for improvements.

Up until now, these components would fall under augmentation of AI and how it could help SCM practices and decision-making via better quantitative techniques. The next would be how NLP and voice recognition part of AI can help SCM managers to make better choice? NLP has enormous capacity for deciphering large amount of foreign language data in a streamlined manner (Anon, 2017). If it is applied correctly to build data sets, regardless of language differences, any information could be tapped into the database for further usage. The language barriers become no longer a limitation to those in-need of making decisions. From both suppliers and buyers point of views, the language boundary no longer presents a threat to both end creating endless opportunities, though, it can open more competition in the market. Supplier selection process would become more predictive, and intelligent than ever, whilst all information would be easily accessible for personal inspections, it also could create increasing concerns in safety and security related issues, as mentioned in earlier chapter of the thesis.

After combining and examining all these methodologies will bring us to the era of intelligent manufacturing, a broad concept of manufacturing with the purpose of optimizing productions and products transitions by making full use of advanced technologies and methods like AI (Zhong *et al.*, 2017). It is regarded as an upgrade of traditional manufacturing models, in terms of designs, production, management, and integration of whole lifecycle of products and services from end-to-end. As a result, the entire network can be communicated and analysed using various smart sensors and technologies, adaptive decision-making models combining both human and intelligent devices. In general, the decision-making process itself is very dynamic, factoring many different elements of SCM. The main reason for applying AI in SCM is to obtain informed decision making through strengthening all the other parts of SC networks, namely infrastructure, data management, physical automation, and policies, finally to improve the performance, despite of current business environment changes and needs.

5.3 Future of Supply Chain Management

Thus, we are in the fourth industrial revolution, the disruption and innovations are occurring at larger scale and at a faster pace. This is the main reason why the traditional industries are required to evolve over time to stay competitive and present. In additional to evolution within the business environment, the market also positioned the need of customers in different focal point. As a result, the question of “what is the right supply chain for companies” has changed to “what is the right supply chain for customers” (Min *et al.*, 2019). In the age of digital and sustainability economy, there is no ideal way to find and manage optimally balanced SC across companies. Ideally, understanding and fulfilling the current and future needs of customers may help to configure SC in relation to further development in the technological field.

As we know, a standard form of SC consists of at least one supply and a customer, with simple configuration of main and supporting activities internally. In this digital age, however, following factors strongly influence and change this composition and management style of SC; (1) the demand for microsegments for personalized products, (2) emergency of additive manufacturing due to need for past paced flexible production, (3) the reduction in resources constraints with advanced technologies.

First and foremost, diverse consumer demand and global competition intensified the nature of playing field, where it caused companies to develop varying degrees of products that are suitable for both personalized and general interests. As customers get accustomed to same day deliveries and highly customized products, the manufacturers recognized the need to produce, assemble, and store goods closer to the point of delivery, while dealing with uncertain demand. One of the key shifts happened as a result of macro trend is when companies started adopting new structure of management strategy, forming not only among vertical members, but also began to integrate among its horizontal channel relations. Putting volatile interest rates, tax regimes, trade tariffs changes, inflation and deflation on the side, it made future-ready SC to be ready for active response not only towards macro economy, but also to customer centric disruptive demands (Foster, 2020).

So, it is also evident that strategic partnership will likely to remain unchanged as a core of SCM, even in the future. However, the ways of interacting and managing the partnership may change due to other environmental factors, such as technology. First, an open platform access enables a focal company to build and directly interact with its strategic partners, customers, and suppliers at large base, making the SC even more complex and exposed (Min *et al.*, 2019). On the customer side, the loyalty and building trust often necessitate high quality customer services and its promptness of delivery, which makes it even harder for the focal company. Even though having massive number of SC participants and customers, traditional arm-length relationships can still be valuable for maintaining proper control over its speed and quality for firms.

Secondly, additive manufacturing and other sources of technological approaches may shrink and reconstruct the need for small sized manufacturers. Even though it will likely to reduce the advantages of attributes to economies of scale that large companies used in sourcing, production and distribution, additive manufacturing will continue to promote simple SC structure with even more simplified decision-making processes. Furthermore, in relation to changes in customers preferences and requirements for sustainable economic performance, this type of manufacturing may bring solutions to the raising concern of sustainable consumptions and resources redistribution.

Meanwhile further technological innovation allowed data transparency and agile decision-making among SC managers to build, maintain, and improve relationships with a larger number of network members, which in turn, further expands its product and service quality and diversity, and cost reductions (Min *et al.,* 2019). Undoubtedly, the limitation of current legacy system and development of information security will give way to data driven future, where AI based systems will run smooth management over the flow of goods and service. Some of current SC networks are already expanding its horizon to robotics technologies and replacing many of their human involved activities to software-based systems. Essentially mundane, repetitive tasks are being automated, granting employees and managers to concentrate on more sophisticated problems in exchange. Hence, the efficiency of processes is measured rapidly and easily throughout the SC, the effectiveness of decision-making is, yet to be assessed. Perhaps, this is one of the reasons why AI/ML-based methodologies are far from replacing the human cognitive functions, instead playing a major role in supporting activities. In the interval, blockchain technology or IoT will continue enabling transparency in SC processes by recording and verifying movement of products, and associated parties' involvement.

In the form of system-based approaches and development, the AI and ML-based methodologies are believed to further explored and advanced in relation to the usage and presence in SC and its management practices. Based on recent International Data Corporation (IDC) Digital Economy Model, by 2023 over 50% of all worldwide nominal gross domestic product will be driven by digitally transformed enterprises. By 2025, at least 90% of new enterprises apps will have embedded AI capabilities (Balte, 2020). In fact, according to research conducted by McKinsey & Company believes that businesses to gain between $1.3 and $2trillion a year in economic value just by using AI in their supply chains. On the other hand, PricewaterhouseCoppers (PWC) predicted that AI could contribute about $15.7trillion to the global economy by 2030 (Khasis, 2019).

Especially in the area of intelligent warehousing and inventory management, AI is expected to be fully present in upcoming years, creating automated warehousing that utilizes storage space efficiently at minimal supervision. Take Lineage Logistics as an example, which transformed its cold storage and logistics firm into AI algorithm driven warehousing. Lineage patented algorithm that forecasts when goods and orders will arrive and leave, which allows them to arrange the warehouse pallets efficiently and effectively. This smart placement driven by AI helped Lineage to boost warehouse capacity and efficacy by as much as 20% (Shaw, 2020). By implementing AI together with warehousing robotic technology will further increase the performance and capacity in the near future. Not to mention, logistics and transportation network of SC is believed to become more data driven and integrated than ever. Many logistics companies around the world are embracing the digital transformation of information technology, transitioning away from traditional legacy ERP systems to advanced analytics, automation, and robotic solutions.

The application of quantitative and qualitative methods will contribute to the key success factors of SCM, in the structure of combining variety of disciplines of SCM theories to solve relevant problems and predict outcomes, while taking into account of data quality, and availability issues both internally and externally (Schoenherr and Speier-Pero, 2015). However, with the new demand, it will also create a stiff competition among firms on the basis of finding and hiring right talents, who can assist and drive the changes in the technology. While digitization is on the rise, evolving faster than traditional forms of education and training, the number of those possessing acquired skills and knowledge will remain small. To keep up with the trend and reduce the risk of human resources talent, organizations must identify specific capabilities first, and focus on their energy on developing further effective knowledge-oriented and talent preparing pipeline, such as third party knowledge providers like external training courses and education organization partnership (Williams, 2019). Therefore, the future of SCM not only consists a mere form of monetary exchange, thus, it may become a valuable information and knowledge exchange economic activity at large.

As a result of such movement and automatization, the digital and sustainable economy also may necessitate flat structure of management, bringing different tiers of SC members closer to the focal company. Choi and Linton (2011) also noted that tiered approach in managing SC partners may lead to risk of losing control over critical resources and information availability in lower tiers, risks that may associated with first tier partners' opportunistic behaviour, which can drive focal company away from its lower tiers. Therefore, more and more companies are encouraged to practice information share even with lower-tier partners in the near future, practicing close contacts. Under the growing pressure from government and non-governmental organizations, SCM needs to be more connected to share common objectives and encourage collaborative decision-making. Essentially, the final customers are getting more and more knowledge, the focal firms should not limit its managerial boundaries at their organizational level. Indeed, closer communication with lower tiers can bring more relevant and up to date information about movement and transformation of materials and labour conditions, which then can help the managers to avoid predictable future events.

Finally, the recent supply chain risks and uncertainties forced firms to rethink and redesign their SC. Since beginning of 2000s, the companies who have pursued achieving a lean manufacturing and SC in the form of supply rationalization and process integration, may continue lead the industry. However, with the current externalities, as we discussed earlier, such as trade wars, natural disasters, political turmoil, and other factors will persuade those companies to continue redesign the SC to be more resilient, and elastic. Resilient in a way that it should set up alternative strategic plans to mitigate uncertainties and SC related risks, while integrate and analyse the market intelligence to stay pro-active and elastic. It also requires the SC to be more international market-oriented than managing risks locally. As a result, there would be no dominant design of SC network, instead primarily customized structure and solutions might take over the industry. Importantly, the future SC seem to become more entrepreneurial style oriented, which in reality represents a significant opportunity and challenge. As such, it is clear that the scope and boundaries of SCM and partnering will likely to expand and shift as never before together with development of new innovative technologies.

Conclusion

Since SCM requires the comprehensive and complex, integrated, and interrelated decision-making processes and the creation of intelligent knowledge by its agents for joint problem-solving, AI has been put forward as useful decision-aid tool that helps organization to connect with its customers, suppliers, employees, and SC partners. As this thesis devoted exploring and studying the potential applications and impacts of AI and its sub-field techniques on SC decision making processes, activities and network structure, it is evident that models that are applied have presented intriguing effects and promising returns.

However, discovering implications of AI in SCM has not been fully performed because it is either too expensive or too difficult for existing professionals and researchers. In line with its physical limitations to reach its peak, thesis has also presented possible ethical and moral dilemmas and biases regarding AI applications, to show the differences between human thinking versus artificially induced humanly thinking. In the recent years, the recognition of not just the theoretical discoveries, however industrial benefits of AI models are peaking with the surge of information and big data. To fully comprehend this recent event, the problem scope of the thesis then has proposed to assess two hypotheses and openly debated throughout the Chapter 3. The main finding of this discussion was that AI and its sub-fields techniques are no longer a fad, instead, it has become a legitimate business practice. Though, it is not enough to prove how and why it has become the current business practices that are especially suitable for SCM decision-making.

The complexity of decision process and variety of applicable field in SC is the very first reason why it has become most suitable environment for AI methods to be tested. Throughout the analysis of general industrial applicability of AI approaches in SCM, we have seen how diverse techniques and methods can be applied to different parts of SC under three timeframes. By looking and categorizing the SCM issues in a timeframe-oriented grouping, it showed how management decisions can be formed and influence overall performance of the organization. While defining and recognising common issues in SC, the implication in natural characteristics of decision has been classified into four categories using AI functions, such as thinking humanly, acting humanly, thinking rationally, and acting rationally. Starting with ANN method of thinking humanly nature of AI, we examined its functionality and algorithmic capacity in planning optimization, demand planning, and decision support fields. The most important feature of ANN method is its learning capability to improve the performance in the existing environment. However, there are many different types of ANN techniques available that makes it suitable for performance and planning optimization settings. Especially in forecast and demand planning, the performance of ANN approach produced prediction better than traditional statistical model. However, the study was limited to the case study that is deterministic time-varying demand pattern rather than real business practice. Although, we have examined the secondary application of the methodologies using predetermined case in the financial market environment, the proposed ANN can be generalized to real SCM environment and improved by performing network training and demand series with increase and decrease with seasonality.

Another big finding of the methodologies section contains the various techniques of ML, which is under the category of acting human division of AI. ML alone also has rich categories of models, which makes it stand alone module in real life. It can be subdivided into supervised, unsupervised, and reinforced learning. However, in this thesis, it concentrated on the learning focused measures, such as concept learning, perception learning, and reinforced learning. In comparison to other techniques, ML mainly focus on mimicking natural abilities of humans, such as robotic sensitivity, language reception and processing, and visual insights. With such abilities, ML techniques are examined in a SCM network mapping, robotics manufacturing, inventory and warehousing, and big data management cases. The further potential of ML is varied on case by case basis; however, it has proven to be advantageous in collecting, processing, and solving issues using real-time data, and propose number of possible resolutions to managers.

Under the umbrella of thinking rationally category of AI, the thesis has explored the fuzzy logic theory. Unlike ML and ANN methods, fuzzy logic produces and proposes alternative solutions that are nearly optimal under the time pressure. As a result of such quality, it is the closest to how natural decision-making forms. The application of fuzzy logic is believed to be beneficial for suppliers' selections and relationship management, and decision support functions. Therefore, we further provided a case of using this methodology in bullwhip effect of SC. The algorithm was provided to find the nearly optimal solutions to avoid bullwhip effect generated from faulty forecasting and inventory management. However, in any case fuzzy logic alone could not help avoiding the given problem. Instead, combining the research examination conducted by Carlsson and Fuller (2000) with Hausdorff fuzzy number metric, while considering probabilistic variances over the replenishment lead time proved that the bullwhip effect can be eliminated completely. This means, the traditional way of thinking, the bullwhip effect cannot be removed from SCM is no longer the case. Seemingly, more research experiments need to be conducted to fully understand the humanly support of fuzzy logic theorem to the decision-makers.

In the acting rationally part of AI, the thesis has expressed its interest towards agent-based model. It employs numerous types of agents depending on the scenario; thus, its benefit is best seen in the integration function of SCM. Moreover, agent-based system is suitable for performance and coordination assessment analysis across different departments of the organization, because all single agent can seek and perform to fulfil its individual goal, while centralized objective is ensured by other collaborative agents in the network. To prove its benefits, we have utilized a multiagent-based model in the profit maximization and integration case study. As a result, it was evident that system was intuitive to formulate flexible structural changes in the emerging situations, while carrying out both individual and central goals in the system. However, there are a few limitations to agent-based model; due to the relationship changes and need for new entity adaptations.

Overall, the thesis concentrated on the partial application of AI models and tools in different cases, but the last chapter reviews its complete implications and impacts on entire SCM. Even though scholar findings are limited on this topic, instead of highly emphasis on detail utilizations, the industrial surveys and responses suggest that using AI is highly beneficial not only to the overall outcome of the organization, but also valuable for individual performance within the entity. The most impacted part of SC is still the demand planning and forecasting, and inventory and warehouse management, which often relied heavily on historical data for future predictions. However, with the help of AI, it can outperform its traditional methods by including current industrial data and consumer market analysis, under various advanced algorithm with better accuracy. Moreover, with the integration of IoT and robotic manufacturing, current and future SCM will be more automated, agile, and customized. Although, the critical need for experimental research still exists to clarify the scope of this thesis activities, the implication can be done in the future under inductive and detailed exploratory approaches separately.

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