İSTANBUL TECHNICAL UNIVERSITY ★ INSTITUTE OF SCIENCE AND TECHNOLOGY

MILITARY LOGISTICS NETWORK DESIGN VIA AXIOMATIC DESIGN PRINCIPLES

M.Sc. Thesis by
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Department : Interdisiplinary Program

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AKSİYOMATİK TASARIM İLKELERİ İLE ASKERİ LOJİSTİK AĞI TASARIMI

YÜKSEK LİSANS TEZİ

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FOREWORD

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ABBREVIATIONS

IW **:** Information war
EW **:** Electronic war
HW **:** Hi-tech war
PW **:** parallel war
C^4I **:** Command, control, communications, computers and intelligence systems
WWII **:** World War II
DoD **:** Department of Defence
TSS **:** Theatre sustainment stock
MYP **:** Multiyear procurement

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MILITARY LOGISTICS NETWORK DESIGN VIA AXIOMATIC DESIGN PRINCIPLES

SUMMARY

As long as there is a conflict of any kind, and weapons are being used by the parties, the military is the only organization that can secure interests. In war, the victory does not always go to those having the largest army or the most sophisticated equipment. It goes to who has more efficient strategic plan. Everything depends on strategic plan: when, where and with what forces a battle is to be delivered; in other words on logistics how and where to locate. In this study military logistics network is designed via axiomatic design principles. In axiomatic design, functional requirements, technical side of customer expectations, design parameters to achieve functional requirements and mathematical relation between two are studied.
During logistics network design, it is divided to 4 steps: acquisition, storage, distribution and maintenance.

In acquisition it is important to buy products in required amount and desired features to minimum cost at the right time. Cost includes variable product costs, shipping cost and fixed costs. In order to decrease cost, consolidation, outsourcing or any step that will decrease demand can be used. Price analysis should be made and inventory visibility should be maintained. In acquisition, besides cost, it is important to buy products in desired features- desired quantity and quality. Demand quantity depends on safety stock in peace time and probability of war. Quality not only depends on what is available in the market but also depends on enemy's' quality standards. Forecasting, spying and updating product information are necessities. In order to buy products at the right time order-management procedures should be developed and lead time should be decreased.

Second design step is storage. For strategic mobility framework, some equipment should be prepositioned. Instead of long movement of needed equipment, by prepositioning it allows combat-ready forces. Managing inventory is one of the key features of logistics. Inventory management includes minimization of costs and maximization of usage of inventory. Profit maximization and risk minimization strategies should be developed to better management. In order to minimize costs, fixed costs including fixed assets, administration and selling costs should be decreased; inventory levels and movement of inventory in depots should be minimized by eliminating non-value added functions as much as possible, inventory accuracy and developing inventory allocation strategy. Inventory level minimization means minimization in depot inventory, minimization of non-stable inventory (under maintenance and in-transit), clarification of pre-positioned equipment quantity and minimization of in-theater inventory. Another concern in storage design is to keep assets in safe and good conditions.

Third design step is distribution design. The military distribution system has two distinct segments: strategic-national and theater. The strategic-national segment

consists of moving supplies from points outside a theater of military operations into the theater. The theater segment consists of distribution that occurs within a theater of military operations. In distribution it is aimed to increase efficiency and decrease risk of failure. Performance indicators for transportation are throughput maximization, time definite delivery, cost minimization and flexibility. Fundamental economic principles impacting transportation economy are economy of scale and economy of distance. Transportation costs are driven by distance, volume, density, stowability -how product case dimensions fit into transportation equipment-, handling, and liability. By flexibility, it is aimed to define a transportation mode having high maneuverability, large freight volume, can be used in all weather and climatic condition. In order to increase efficiency transportation methods should be optimized. Transportation optimization methods are consolidation, outsourcing, route optimization and selecting right transportation mode based on product features, quantity and critique. Another important point in distribution is to decide shipping priorities: which one, in which order, what quantity, in which conditions, what frequency. To solve the problem shipping procedures should be developed based on defined criteria.

The last design step is maintenance design. Maintenance is an important aspect of military logistics and includes those activities needed to keep weapons, vehicles, and other materiel in an operable condition; to restore them to a serviceable condition when necessary; or to improve their usefulness through modifications. The Army calls maintenance as reset as the repair, recapitalization and replacement of equipment to equip units preparing for deployment and improve next-to-deploy unit’s equipment on hand levels. In order to have a customer satisfied maintenance function, total cost, risk and required time should be decreased. Cost for repairing are shipping, material and personnel costs. Outsourcing, consolidation and decrease breakdown-frequency can reduce costs. Speed and the accuracy of repair are other issues.

In the study as an example to military system design, documents published by USA Department of Defense are used.

AKSİYOMATİK TASARIM İLKELERİ İLE ASKERİ LOJİSTİK AĞI TASARIMI

ÖZET

İnsanoğlu çıkarlarını devam ettirebilmek, korumak ya da yeni kazanımlar elde etmek adına, sürekli savaşmıştır. Teknoloji en çok savaş zamanlarında gelişmiştir. Teknoloji geliştikçe, değiştikçe, kendisiyle beraber savaşma yöntemlerini şekillerini de değiştirdi. Fakat bu değişimlerin nasıl kullanıldığı savaşı kazananı belirlemektedir. Özellikle sahip olunan kaynakları nasıl, nerede, ne miktarda ve ne zaman kullanılacağı başarıyı getirmektedir. Askeri lojistik kuvvetlerin ve silahların temini, sevkıyatı, koşullandırılması, bakımı ve geri çekilmesini ifade etmektedir.

Bu çalışmada aksiyomatik tasarım ilkeleri ile askeri lojistik ağı tasarımı yapılmıştır. Aksiyomatik tasarım, müşteri ihtiyaçlarının fonksiyonel gereklilikler şeklinde ifade edilmesini, fonskiyonel gerekliliklerin gerçekleşmesi için gereken tasarım parametrelerini ve bunlar arasındaki matematiksel ifadeyi göstermektedir. Askeri lojistik insan ve ekipman lojistiğini içermesine rağmen bu çalışmada sadece ekipman lojistiği tasarımı yapılmıştır. Ayrıca savaş meydanındaki lojistik yerine, ulusal lojistik olarak da tanımlanan, savaş alanına kadar olan lojistik üzerinde durulmuştur. Tasarım dört alt baslıkta yapılmıştır: temin etme, depolama, dağıtım ve bakım-onarım.

Satın almada önemli olan müşterinin gereksinim duyduğu ürünü doğru zamanda, doğru miktarda uygun fiyata ve istenilen özelliklerde satın almaktır. Maliyet kalemi değişken ürün maliyeti, taşıma maliyeti ve sabit maliyetten oluşmaktadır. Maliyeti düşürmek için, konsolidasyon, dış kaynak kullanımı ya da talepleri azaltma yollarına başvurulabilir. Fiyat analizleri yapılarak ürün değişken fiyatı optimize edilmeye çalışılmalıdır. Ayrıca stoktaki ürünlerin özellikleri tam bilinmelidir. Ürün özellikleri derken miktar ve kalite kastedilmektedir. Yeni alımlardan önce depodaki ürünler kullanılmalı, üründe modifikasyonlar yapılarak istenilen kalite standartlarına getirmeye çalışılmalıdır. İstenilen kalite standartları ise olası düşmanın ekipmanlarının kalitesine ve miktarına bağlıdır. Bu bilgilerin elde edilmesi için casusluk yapılmalı ve elde edilen bilgilerin doğru kullanımı için de çok hassas biçimde tahmin etme metodlari geliştirilmelidir.

Askeri lojistikte en önemli sorunlardan bir tanesi depolama standartlarının sağlanamamasıdır. Depolamada maliyetleri düsürmek ve envanter kullanımını arttırmak amaçlanmaktadır. Maliyeti azaltmak için dış kaynak kullanımı ya da konsolidasyon yöntemleriyle sabit maliyetler ve yönetim maliyetleri düşürülmeli; envanter seviyesi ve envanter hareketleri azaltılmalıdır. Envanter seviyesi sadece depoda bulunan envanteri değil, taşıma halindeki envanteri, tadilattaki envanteri ve savaş alanındaki envanteri de içermektedir. Askeri sistemlerde savaş olasılıklarına karşı bazı ekipmanlar tehlike bölgelerine yakın yerlere konumlandırılırlar. Önemli olan ne miktarda hangi üründen nerede depolanacağı, bu ürünlerin ne sıklıkta bakıma tabi tutulacağı, saklama koşullarının neler olacağıdır.

üçüncü basamağı ulaştırma tasarımı oluşturmaktadır. Askeri dağıtım; savaş alanı dağıtım ve savaş alanına kadar dağıtım olmak üzere iki kısımdan oluşmaktadır. Dağıtımda önemli olan zamanında ve düşük maliyette olmasıdır. Ölçek ekonomisi ve mesafe ekonomisi dikkate alınarak maliyet azaltılabilir. Rota optimizasyonu ve taşıma yönteminde esneklikler arttırılarak zamanında ulaştırma sağlanabilir.

En son tasarım basamağı bakım onarım faaliyetleridir. Askerler tarafından sahada bakımı yapılamayan ürünler belirli bakım merkezlerine gönderilmektedirler. Bakımda önemli olan maliyetlerin düşürülmesi ve riskin azaltılmasıdır. Riskin azaltılması için ürünler kısa surede bakımdan geçirilmeli ve tamir edilmeli, tamir prosesleri oluşturulmalı ve kontroller sıkı yapılmalıdır. Maliyetleri azaltmak için önleyici ve tahmin edici bakim yöntemleri ile ekipmanlardaki bozulmalar azaltılabilir. Dış kaynak kullanımı ile yönetim maliyetleri ve personel maliyetleri sıfırlanabilir.

Çalışmada örnek askeri sistem olarak Amerika Birleşik devletleri savunma bakanlığının yayımlamış olduğu kaynaklardan faydalanılmıştır.

1. INTRODUCTION

History is full of wars and inventions and methods to gain it. War is an act of violence intended to compel opponent to fulfill wills. The aim of all action in war is to disarm the enemy [1]. In past general wars were based on human forces. After Second World War, as a result of advance in military technology [2], the form of wars has changed. Technological advances show themselves in information, command& control, penetration and precision [3], weapons, cost effectiveness, target acquisition and designation [4]. With all these advances, wars are based on logistics, weapon technology, quality of personnel instead of quantity, and true and recent information. With new form of war, victory goes who gets forces to be right places at the right times, and ensuring that they have the resources needed at the same time cutting enemies', in other words who has better logistics network.

1.1 Purpose of the Thesis

In this study, it is aimed to design a military logistical network: acquisition, inventory management, transportation& distribution, and maintenance functions with axiomatic design, which is a systems design methodology using matrix methods to systematically analyze the transformation of customer needs into functional requirements, design parameters, and process variables.

1.2 Definitions of Military Logistics

According to Council of Logistics Management, logistics is the part of supply chain processes that plans, implements, and controls the efficient effective forward and reverse flow and storage of good, services and related information between the points of consumption [5]. Specific definitions for logistics of war:

-Logistics concerns movement and supply: getting forces to the right places at the right times, and ensuring that they have the resources needed [6].

- According to Department of Defense (DoD), logistics is those aspects of military operations which deal with: a) design and development, acquisition, storage, movement, distribution, maintenance, evacuation and dispotion of materials b)movement, evacuation and hospitalization of personnel c)acquisition or construction, maintenance operation, and disposition of facilities d) acquisition or furnishing services [5].

-Logistics consisted of moving and loading the army, and procuring and supplying it with all of its needs: food, construction materials, uniforms, arms, munitions, animals, major items of equipment, camp equipage, spare parts for all items supplied, replacement personnel and medical support [7].

-According to NATO, logistics is the marshalling and employment of the military resources of Nations in support of military operations; embraces the five functions of: supply and maintenance, casualty evacuation and hospitalization, movement and transportation, construction and facilities, and communications and administrative management [8].

1.3 History of Military Logistics

History is full of wars and inventions and methods to gain it. War is an act of violence intended to compel opponent to fulfill wills. The aim of all action in war is to disarm the enemy [1]. In past general wars were based on human forces. After Second World War, as a result of advance in military technology [2], the form of wars has changed. Technological advances show themselves in information, command& control, penetration and precision [3], weapons, cost effectiveness, target acquisition and designation [4]. With all these advances, wars are based on logistics, weapon technology, quality of personnel instead of quantity, and true and recent information. By the word information it is denoted all the knowledge about the enemy [1].

The earliest known standing army was that of the Assyrians at around 700 BC. They had iron weapons, armor and chariots, were well organized and could fight over different types of terrain -the most common in the Middle East being desert and mountain- and engage in siege operations. The need to feed and equip a substantial force of that time, along with the means of transportation (i.e. horses, camels, mules and oxen) would mean that it could not linger in one place for too long. The best time to arrive in any one spot was just after the harvest, when the entire stock was available for requisitioning. Obviously, it was not such a good time for the local inhabitants. One of the most intense consumers of grain was the increasing number of animals that were employed by armies of this period. In summer they soon overgrazed the immediate area, and unless provision had been made beforehand to stockpile supplies or have them bought in, the army would have to move. Considerable numbers of followers carrying the materiel necessary to provide sustenance and maintenance to the fighting force would provide essential logistic support[9].

Both Philip and Alexander improved upon the art of logistics in their time. Philip realized that the vast baggage train that traditionally followed an army restricted the mobility of his forces. So he did away with much of the baggage train and made the soldiers carry much of their equipment and supplies. He also banned dependants. As a result the logistics requirements of his army fell substantially, as the smaller numbers of animals required less fodder, and a smaller number of wagons meant less maintenance and a reduced need for wood to effect repairs. Added to that, the smaller number of cart drivers and lack of dependants, meant less food needed to be taken with them, hence fewer carts and animals and there was a reduced need to forage, which proved useful in desolate regions. He also made extensive use of shipping, with a reasonable sized merchant ship able to carry around 400 tons, while a horse could carry 200 lbs. (but needed to eat 20 lbs. of fodder a day, thus consuming its own load every ten days). He never spent a winter or more than a few weeks with his army on campaign away from a sea port or navigable river [10, 11]. He even used his enemy's logistics weaknesses against them, as many ships were mainly configured for fighting but not for endurance, and so Alexander would blockade the ports and rivers the Persian ships would use for supplies, thus forcing them back to base. He planned to use his merchant fleet to support his campaign in India, with the fleet keeping pace with the army, while the army would provide the fleet with fresh water. However, the monsoons were heavier than usual, and prevented the fleet from sailing. Alexander lost two-thirds of his force, but managed to get to Gwadar where he re-provisioned. The importance of logistics was central to Alexander's plans, indeed his mastery of it allowed him to conduct the longest military campaign in history. At the farthest point reached by his army, the river Beas in India, his soldiers had marched 11,250 miles in eight years. Their success depended on his army's ability to move fast by depending on comparatively few animals, by using the sea wherever possible, and on good logistic intelligence [12].

The Roman legions used techniques broadly similar to the old methods (large supply trains etc.), however, some did use those techniques pioneered by Phillip and Alexander, most notably the Roman consul Marius. The Romans' logistics were helped of course, by the superb infrastructure, including the roads they built as they expanded their empire. However, with the decline in the Western Roman Empire in the Fifth Century AD, the art of warfare degenerated, and with it, logistics was reduced to the level of pillage and plunder. It was with the coming of Charlemagne, that provided the basis for feudalism, and his use of large supply trains and fortified supply posts called 'burgs', enabled him to campaign up to 1,000 miles away, for extended periods. The eastern Roman (Byzantine) Empire did not suffer from the same decay as its western counterpart. It adopted a defensive strategy, which Clausewitz recognized as being easier logistically than an offensive strategy, and that expansion of territory is costly in men and material. Thus in many ways their logistics problems were simplified - they had interior lines of communication, and could shift base far easier in response to an attack, than if they were in conquered territory, an important consideration, due to their fear of a two-front war. They used shipping and considered it vital to keep control of the Dardanelles, Bosphorous and Sea of Marmara; and on campaign made extensive use of permanent warehouses, or magazines, to supply troops. Hence, supply was still an important consideration, and thus logistics were fundamentally tied up with the feudal system - the granting of patronage over an area of land, in exchange for military service. A peacetime army could be maintained at minimal cost by essentially living off the land, useful for Princes with little hard currency, and allowed the man-at-arms to feed himself, his family and retainers from what he grew on his own land and given to him by the peasants[13].

The fighting ships of antiquity were limited by the lack of endurance while the broad beamed seaworthy merchant ships were unsuited to the tactics of the time that were practiced in the Mediterranean. It wasn't until the Europeans put artillery on-board such vessels that they combined the fighting and logistic capability in one vessel and thus became instruments of foreign policy with remarkable endurance and hitting power. They reached the zenith of their potential during the Napoleonic Wars, but with the conversion to coal and steam power, a ship's endurance was once again limited. But they could still carry their ammunition and supplies farther and faster,

and were thus more logistically independent than horse-powered armies, despite the need for coaling stations. Fuel oil increased endurance by forty percent, but that was due to its greater efficiency as a fuel source. The coming of the fleet train and underway replenishment techniques during the Second World War enhanced the endurance of modern navies massively, and ships could thus stay at sea for months, if not years, especially with the reduced time between dockyard maintenance services. The coming of nuclear power once again extended the sea-going life of a vessel, with endurance limited to that of the crew and the systems that need a dockyard to be overhauled.
The appeal by Emperor Alexius to the Pope for help in clearing Anatolia of the Turks in 1095 paved the way for a series of Western European military expeditions which have become known as the Crusades. As a result of these, the Western Europeans significantly advanced their practice of the military arts [15].

The First World War was unlike anything that had gone before it. Not only did the armies initially outstrip their logistic systems with the amount of men, equipment and horses moving at a fast pace, but they totally underestimated the ammunition requirements. On average, ammunition was consumed at ten times the pre-war estimates, and the shortage of ammunition became serious, forcing governments to vastly increase ammunition production. In Britain this caused the 'shell scandal' of 1915, but rather than the government of the day being to blame, it was faulty pre-war planning, for a campaign on the mainland of Europe, for which the British were logistically unprepared. Once the war became trench bound, supplies were needed to build fortifications that stretched across the whole of the Western Front. Add to that the scale of the casualties involved, the difficulty in building up for an attack (husbanding supplies) and then sustaining the attack once it had gone in (if any progress was made, supplies had to be carried over the morass of no-man's land). It was no wonder that the war in the west was conducted at a snail's pace, given the logistic problems. It was not until 1918, that the British, learning the lessons of the last four years, finally showed how an offensive should be carried out, with tanks and motorised gun sleds helping to maintain the pace of the advance, and maintain supply well away from the railheads and ports. The First World War was a milestone for military logistics. It was no longer true to say that supply was easier when armies kept on the move due to the fact that when they stopped they consumed the food, fuel and fodder needed by the army. From 1914, the reverse applied, because of the huge expenditure of ammunition, and the consequent expansion of transport to lift it forward to the consumers. It was now far more difficult to resupply an army on the move, while the industrial nations could produce huge amounts of war matériel, the difficulty was in keeping the supplies moving forward to the consumer.

This of course, was a foretaste of the Second World War. The conflict was global in size and scale. Not only did combatants have to supply forces at ever greater distances from the home base, but these forces tended to be fast moving, and voracious in their consumption of fuel, food, water and ammunition. Railways again proved indispensable, but sealift and airlift made ever greater contributions as the war dragged on. The large-scale use of motorised transport for tactical re-supply helped maintain the momentum of offensive operations, and most armies became more motorised as the war progressed. The Germans, although moving to greater use of motorised transport, still relied on horse transport to a large extent - a fact worth noting in the failure of Barbarossa. After the fighting had ceased, the operations staffs could relax somewhat, whereas the logisticians had to supply not only the occupation forces, but also relocate those forces that were demobilising, repatriate Prisoners Of War, and feed civil populations of often decimated countries. The Second World War was, logistically, as in every other sense, the most testing war in history. The cost of technology had not yet become an inhibiting factor, and only its industrial potential and access to raw materials limited the amount of equipment, spares and consumables a nation could produce. In this regard, the United States outstripped all others. Consumption of war material was never a problem for the USA and its allies. Neither was the fighting power of the Germans diminished by their huge expenditure of war material, nor the strategic bomber offensives of the Allies. They conducted a stubborn, often brilliant defensive strategy for two-and-a-half years, and even at the end, industrial production was still rising. The principal logistic legacy of the Second World War was the expertise in supplying far off operations and a sound lesson in what is, and what is not, administratively possible [16].

With the end of the Second World War, the tensions that had been held in check by the common goal to defeat fascism finally came to the fore. The Cold War started in around 1948 and was given impetus by the Berlin Blockade, the formation of NATO and the Korean War. The period was characterised by the change in the global order, from one dominated by empires to a roughly bipolar world, split between the Superpowers and their alliance blocs. However, the continued activity by both blocs in the Third World meant that both sides continued to draw on the experience of power projection from the Second World War. East and West continued to have to prepare for both limited conflicts in the Third World, and an all-out confrontation with the other bloc. These would vary between 'low intensity' counter-insurgency conflicts (Vietnam, Central America, Malaya, Indochina and Afghanistan) and 'medium intensity' conventional operations (Korea, the Falklands) often conducted well away from the home base and an all-out Third World War involving high-intensity conventional and / or nuclear conflict. Both sides had to deal with the spiralling rate of defence inflation, while weapon systems increased in both cost and complexity, having implications for the procurement process, as defence budgets could not increase at the same rate.

The principal concern for the defence planners of the two blocs involved the stand off between NATO and the Warsaw Pact in Europe. The history of the two alliances is closely linked. Within a few years of the end of the Second World War, relations between East and West became increasingly strained to the point of becoming the Cold War and a dividing line being drawn across Europe. The Soviet inspired coup in Czechoslovakia, the Greek Civil war and the Berlin Blockade all suggested to the Western nations that the Soviets wished to move the Iron Curtain westwards, which was combined with the Soviet failure to demobilise on a par with the West. Initially, the North Atlantic Treaty was signed in April 1949 building upon the Brussels Treaty of 1948, and was signed by the United Kingdom, France, United States, Canada, Belgium, Netherlands, Denmark, Norway, Portugal, Iceland, Italy and Luxembourg. The outbreak of the Korean War (in June 1950) and the early test of a Soviet nuclear device in August 1949 led to fears of a major expansion in Soviet activity. This prompted the Alliance into converting itself into a standing military organisation, necessitating the stockpiling of large amounts of munitions, equipment and spares; "just in case" it was needed. The original members were joined in 1952 by Greece and Turkey, by West Germany in 1955 and by Spain in 1982.

NATO strategy, by the late 1980s, was based around the concepts of "flexible response", "forward defence" and "follow on force attack". The key element of NATO strategy, that of "flexible response", was adopted in 1967, and took over from "massive retaliation". This strategy demanded a balance of conventional and nuclear forces sufficient to deter aggression, and should deterrence fail, be capable of actual defence. The three stages in response to aggression were "direct defence" (defeating the enemy attack where it occurs and at the level of warfare chosen by the aggressor), "deliberate escalation" (escalating to a level of warfare, including the use of nuclear weapons, to convince the aggressor of NATO's determination and ability to resist and hence persuade them to withdraw) and "general nuclear response" (the use of strategic nuclear weapons to force the aggressor to halt his attack). A key commitment has been to "forward defence" (in deference to German political interests), that is, trying to maintain a main front line as close to the Iron Curtain as possible. To this had been added "FOFA" (follow-on-force attack), derived from the US Army's "AirLand Battle 2000" strategy where "smart" and "stealth" weapons are used to attack enemy rear areas and approaching forces. For forty years, the main threat to NATO's territorial integrity was the armed forces of the Soviet Union and Warsaw Treaty Organization, more commonly known as the Warsaw Pact. This organization came into being on the 14th May 1955 with the signing of the Treaty of Friendship, Cooperation and Mutual Assistance by Albania, Bulgaria, Czechoslovakia, East Germany, Hungary, Poland, Rumania, and of course the USSR. This was supposedly a response to the rearming of West Germany and its incorporation into NATO. The treaty reinforced a number of bilateral mutual aid treaties between the USSR and its allies, which was also complemented by a series of status force agreements allowing for the positioning of substantial Soviet forces on the allies' soil. The original treaty was valid until May 1975 where it was renewed for ten years and again in May 1985 for twenty years. The purpose of the Pact was to facilitate the Soviet forces to defend the Soviet Union and to threaten Western Europe, while extracting military assistance from the East European states. The East Europeans were "reluctant to make all the military efforts demanded of them, and have from time to time, resisted Soviet attempts to extract more resources, and refused to undertake all the exercises demanded or even on occasions, to lend full blooded diplomatic support" [9]. As a consequence, the dependability of the Pact forces in a war may have been open to question. Much would have depended upon the nature of the conflict.

Warsaw Pact doctrine called for a broad frontal assault while securing massive superiority at a few preselected points. The attacking forces would be echeloned, possibly three or more echelons. To the Pact, only the offensive was decisive. The concept of defence was used as a means to shield reorganising forces getting ready to launch another offensive. Pact formations were modular all the way up to Front level (each Front consisted of two to five Armies, but generally consisted of three). One Pact Army was configured similarly to another Army (each Army was made up of from three to seven Divisions but generally consisted of four or five Divisions). Forces in the front echelon would punch holes in NATO's front line for the Operational Manoeuvre Groups and the second echelon to exploit through and hopefully lead to the collapse of the NATO main line position. The third echelon would then pursue the fleeing enemy forces and complete the assigned objectives [17, 18, 19].

It must be noted however, that as structured, the Pact was not intended to be used in wartime. The Pact was meant to support the stationing of the various Groups of Soviet Forces, control training and exercises, assist in operational effectiveness and supervise and control military policy. The East European national armies were trained and equipped on the Soviet model because in war they would have been fully integrated into the Soviet Command structure as parts of the various Fronts. The logistic implications of a clash between these two giants would have been enormous. Despite its high ideals, NATO had a number of drawbacks, the most serious of which was its lack of sustainability. In a major shooting war, so long as the Soviets performed reasonably well, NATO would probably have lost due to the fact it would have run out of things with which to fight. In a static war, logistics is somewhat simpler in the modern age, as ammunition can be stocked and fuel expenditure is limited. In a highly mobile war, the main consumable used will be fuel rather than ammunition, but in a highly attritional conflict, the reverse will apply. Ammunition will be used to a larger extent than fuel. For example, Soviet tank armies advancing at a rate of between sixteen and forty-five kilometers a day in 1944 - 5 suffered far lower losses in men and tanks and consumed a third less fuel and one sixth the ammunition of tank armies that advanced at a rate of between four and thirteen kilometers a day [10]. Of course, this requirement will have to be modified to take account of what Clausewitz termed the 'friction of war' - terrain, weather, problems with communications, misunderstood orders etc. not to mention the actions of the enemy.

NATO reinforcement and resupply had been coordinated under SACEUR's (Supreme Allied Commander, Europe) Rapid Reinforcement Plan, and could be expected to work if given adequate time. However, there were possible clashes in that, for example, if the United Kingdom decided to exercise its national option of reinforcing BAOR (British Army of the Rhine) with the 2nd Infantry Division, its arrival may coincide with the arrival of the III US Corps from CONUS (Continental United States) to draw their equipment from the POMCUS (Pre-positioned Overseas Material Configured in Unit Sets) sites and thus cause major logistic problems given the lack of rolling stock to go around. So, paradoxically, the greater the success the United States had in reinforcing Europe, the greater probability there would have been clashes in priority. The plan depended upon NATO forces limiting the expected interference from theb enemy (something the Warsaw Pact definitely planned on doing) and kind weather - only then would the plan have had a good chance of succeeding. Given the extended supply lines from the Channel ports across the Low Countries and the lack of operational coordination, either in defensive tactics or logistics one is left to wonder. For example, if one corps' national logistic capability became critical, the Army Group headquarters may have recommended a transfer of stocks between National Logistic Support Commands. If the national authorities refused to transfer stocks then the Army Group Commander would have to refer the decision to the Commander-in-Chief Central Region (CINCENT) who would then negotiate with the Ministries of Defence concerned. Tactical and logistic responsibility was thus separated and command was divided. CINCENT or the Army Group Commanders had no power to reallocate nationally provided operational support capabilities or resources, and did not have access to logistic information that would have helped them make decisions on redeployment or reinforcement. As logistics was a national responsibility, each national corps has a set of 'tramlines' that ran westwards. Cross corps-boundary logistics was difficult, if not impossible. While routes for such operations had been thought out, there were three different tank gun ammunition types, different fuzing and charge arrangements for artillery ammunition, different fuel resupply methods and no interoperable logistic support system for airmobile operations. All this would mitigate against a cohesive Army Group battle, particularly in the Northern Army Group. Thus sustainability would have been the NATO achilles' heel. While the agreed stock level was to thirty days, many nations did not stock even to this. All have different ways of arriving at Daily Ammunition Expenditure Rates. Most members had either non-existent or not published plans to gear up their industrial base to replace the stocks once used. As experience in the Falklands War points out, actual ammunition expenditure rates would have been far above those planned [10]. It is also worth remembering that one British armoured division would have needed around 4,000 tons of ammunition of all types per day.

The Soviets (and hence Warsaw Pact) view was that while a short war was preferable, it was possible that the conflict might last some time and stay conventional. There is no such word as 'sustainability' in Russian, the closest being 'viability'. This has a much broader context, and includes such matters as training, the quality and quantity of weapons and equipment, and the organization of fighting units, as well as supply, maintenance, repair and reinforcements. The Soviets also relied on a scientific method of battle planning; one that took into account military history, to reduce uncertainty to a minimum and to produce detailed quantitative assessments of battlefield needs. They also had a common military doctrine throughout the Warsaw Pact and standard operational procedures. Soviet forces still relied on a relatively streamlined logistic tail as compared to their Western counterparts. The bulk of logistic resources were held at Army and Front level, which could supply two levels down if required. This gave a false indication to the West of the logistic viability of the Soviet division. Thus senior commanders had a great deal of flexibility in deciding who to support and who to abandon and which axis to concentrate on. Soviet priorities for resupply, in order, were ammunition, POL, spares and technical support, food and medical supplies and clothing. They regarded fuel as the greatest challenge, but their rear services could still make maximum use of local resources, be it clothing, food or fuel. It is probable though that the Soviets would not have had things all their own way. Keeping a high tempo of operations would consume large amounts of fuel and ammunition. Thus almost every town and wood in East Germany and Czechoslovakia would have become a depot and every road or track would have been needed to transport it and every possible means to carry it utilised, including captured vehicles. NATO would of course be trying to interdict these supply routes and the density of forces would have made traffic control problematic, not to mention the fact that any significant advance would place the leading forces well away from their supply bases and railheads behind the initial start line. However, the Soviets would endeavor to maintain strict control over supply priorities and a ruthless determination to achieve the objective. To this end, surprise would have been vital, and thus the objectives should have been achievable with forces in being, with the minimum amount of reinforcement. Also, the first strategic echelon would have been required to maintain operations over a longer period of time. There would thus be no secure rear areas, no forward edge of the battle area or front line. The repair and medical services would thus be positioned well forward, giving priority to men and equipment that can be tended to quickly and sent back into action. The Soviets did not have a 'use and throwaway' attitude to men and equipment, but intended to keep the fighting strength of the unit as high as possible for as long as possible. Once the formation had become badly mauled however, it would be replaced by a fresh one - they did not believe in the Western method of replacing unit casualties with reinforcements thus keeping the unit in action over a prolonged period.

The ending of the Cold War has had profound effects upon the philosophy of, and approach to military logistics. The long held approach of stock-piling of weapons, ammunition and vehicles, at various strategic sites around the expected theatre of operations and in close proximity to the lines of communications was possible when the threat and its axes of attack were known. It is no longer the optimum method in the new era of force projection and manoeuvre warfare. 'High tech' weapons are also difficult to replace, as the US Air Force demonstrated during the 1999 attacks on Yugoslavia, when they started to run short of cruise missiles. With pressure on defence budgets and the need to be able to undertake a (possibly larger) number of (smaller) operational roles than had previously been considered there has been a closer examination of the approach of commercial organizations to logistics. For the UK, this pressure has been particularly intense and as part of the Strategic Defence Review (1998) the Smart Procurement Initiative was announced. This was designed not only to improve the acquisition process but also to bring about more effective support in terms of supply and engineering. However, it is pertinent at this point, to briefly examine what commercial practices are being considered. Just after the Second World War, the United States provided considerable assistance to Japan. Out of this, the Japanese have become world leaders in management philosophies that bring about the greatest efficiency in production and service. From organisations such as Toyota came the then revolutionary philosophies of Just In Time (JIT) and Total Quality Management (TQM). From these philosophies have arisen and developed the competitive strategies that world class organisations now practice. Aspects of these that are now considered normal approaches to management include kaizen (or continuous improvement), improved customer-supplier relationships, supplier management, vendor managed inventory, customer focus on both the specifier and user, and above all recognition that there is a supply chain along which all efforts can be optimised to enable effective delivery of the required goods and services. This means a move away from emphasising functional performance and a consideration of the whole chain of supply as a total process. It means a move away from the 'silo' mentality to thinking and managing 'outside the (functional) box'. In both commercial and academic senses the recognition of supply chain management, as an enabler of competitive advantage is increasingly to the fore. This has resulted in key elements in being seen as best practice in their own right, and includes value for money, partnering, strategic procurement policies, integrated supply chain / network management, total cost of ownership, business process reengineering, and outsourcing.

The total process view of the supply chain necessary to support commercial business is now being adopted by, and adapted within, the military environment. Military is different from private sector [17]. Although it uses best practises of private sector, economy concept and risk meanings are different. In private sector economy is gained via cost and time minimization. Quality is one of the determinants. It is aimed to minimize storage. On the other hand, because of life risk in military, in order to preserve sustainability and continuity, some items are stored. Economy is in the second order. Quality is having the materials to continue to survive.
Hence initiatives such as 'Lean Logistics' and 'Focussed Logistics" as developed the US Department of Defense and acknowledged by the UK Ministry of Defence in the

so-called Smart Procurement, recognise the importance of logistics within a 'cradle to grave' perspective. This means relying less on the total integral stockholding and transportation systems, and increasing the extent to which contractorised logistic support to military operations is fanned out to civilian contractors - as it was in the eighteenth century.

Force projection and manoeuvre warfare blur the distinction between the long held first, second and third line support concept of the static Cold War philosophy and link the logistics' supply chain more closely with the home base than ever before. One of the reasons for the defeat of the British in the American colonies in 1776 may have been the length of, and time involved in, replenishing the forces from a home base some 3,000 miles away. The same was true in the Russo-Japanese War with a 4,000-mile supply line along a single-track railway [20]. Whilst the distances involved may still be great in today's operational environment, logistic philosophies and systems are being geared to be more responsive in a way that could not have been previously envisaged.

1.4 Advances in Form of War

All of the advances mentioned above showed themselves as war-form changes. For nearly 400 years, large scale conventional war has been the most strategically significant form of arm conflict [20]. Now we are talking about information war (IW), electronic war (EW), hi-tech war (HW), parallel war (PW) and unconventional war.

In hi-tech warfare, tactical effectiveness no longer depends on the size of forces or extends of firepower and motorized forces; but more on control systems over the war theater and efficiency in utilizing information from the theater [3].

Electronic war is any military action involving the use of the electromagnetic spectrum to include directed energy to control electromagnetic spectrum or to attack enemy. It is a force multiplier. When its actions are integrated with other military operations, a synergistic effect is achieved, losses minimized and effectiveness enhanced [21].

In parallel war all forces simultaneously attack enemy centers of gravity across all levels of war (strategic, operational and tactical) at rates faster than the enemy can repair and adopt. The overall goal is paralysis of the enemy through shock. It requires highly precise weapons directed against vital targets [3].

Aim of information war is to destroy the national information network of the enemy. Certain innate features of IW are battlefield transparency, overall coordination, operations in real time and precision strike [22]. To be able to fight in IW nations should improve and protect C^4I systems (command, control, communications, computers, and intelligence systems) by decentralizing [3, 4, and 22] and destroy enemies'. In Desert Storm first command and control structure was systematically destroyed, followed by attacks against critical elements of the infrastructure. In short order Baghdad could not communicate with the troops in the field and the supply lines were cut off [23]. Information age armies will know where their own forces and enemies are and distribute this information among the forces of all dimensions- sea, land, air and space [3]. In order to be successful in IW, destroying enemies' information system is not enough, but also having a mobile and flexible database is a must. To adopt IW needs, changes in military makeup will experience the following trends [22]:

- naval and air force troops will grow
- the ratio of army troops will decline
- technical support will grow, while rear logistic support will decline
- new staff like computer soldiers

In conventional war, enemies are peers. But because of technological advances like mass destruction weapons, small parties levy war on bigger countries [2, 3]. Unconventional war is the war not against military forces of one country but an irregular war against terrorist cells [24]. Guerilla wars can be given as an example. Troops in Aphganistan operates in small units to function behind enemy lines, develop and coordinate guerrilla force, conduct direct action strikes against designated targets [23]. Guerilla tactics generally have objectives: 1) they sap the strength of a regular army until they can defeat it in conventional war 2) they aim to provoke the government into retailing indiscriminately, harming innocent civilians in the process and so increasing popular support for insurgents [25].

In fact, all form changes make wars become more deadly, more capital intensive and longer range [4] by changing the way of fighting [22]:

- battle space will be extended to hundreds or several thousand kilometers
- the front and rear of the battle field will be attacked simultaneously
- the strategic rear area might be first target to attack
- time and speed will have new meanings
- enemy C^4I systems and high threat weapons will be the main targets
- information attacks and firepower will be combined
- The destructions of numerous enemy forces will no longer be the primary task.
- Warfare cannot be carried out by a simple adjustment in the structure of the army but will be a network formed by land, sea, air and space forces. Space forces are ultrasonic weapons, laser weapons and high frequency weapons.

1.5 Military Logistics Literature

Although there are lots of books written about military, a minority of them give importance to logistics. After Iraq War, by the transformation of USA military logistics, new books and academic papers are published:

- The oldest information is belonged to Sun tzu. It gives general tactics to warriors that can be used in business world [26].
- Leonard studied on Clausewitz book [27].
- In his book, Huston studies how logistics strategy of NATO is planned [28].
- Pillsburg published papers of Chinese commanders written about future warfare: technology, military structure, logistics and weapons [29].
- In his book, Pitney expresses how to use politics to win wars [30].
- Megargee works on Hitlers commanders and structure [31].
- In his paper Kiley gives example how USA military uses private sector supply tactics [32].
- Colonel John Alexander studies which and how advanced weapons should be used after September 11 in Iraq and Afghanistan [33].
- Gansler and Luby studied about USA military supply chain transformation to meet new age request [34].

- In his book Mockaitis examines Iraq war, what the failures were, what should be done for future security and warfare [35].
- On his paper, Cardinali asks what is best for military logistics: outsourcing because of its economy and efficiency or privatization because of security. [36]

Thesis studies and their topics are:

- Smith studied the logistical support to the US army during the war with Mexico 1845-1847 [37].
- Arikan studied the Israel Defense Forces' (IDF) transformation in the context of the U.S. military transformation [38].
- Alcide examined the U.S. Army's Single Stock Fund (SSF) program, which is a business process initiative designed to reengineer the inventory management, finance, and accounting systems and to enable 49 general ledgers accounts Army-wide [39].
- Maddox focused on what strategic organizational structures should exist within the Department of Defense to facilitate further integration of the defense supply chain. [40]

After 1995, USA military department of defense started to study on its logistics process and published events and ideas quarterly.

1.6 Design Methodology

In this study, logistics is designed via axiomatic design principles under these subtitles: acquisition, storage, transpotation& distribution and maintenance.

During design there are some important points:

- Logistics is designed by the assumption of knowing the geography of war well, because it is the geography that shapes logistics. Geography consists of natural features such as rivers, climatic circumstances such as temperature, and artificial structures such as roads and buildings. It also includes human circumstances where different kinds of people live and work [41]. Different geography requires different kinds of equipment and poses different challenges to supply lines. For example during World War II, because of different structure of Russian Railways, Germans had difficulty to move supply trains [42].

- Logistics begins with time and money. In the study it is assumed that the forces have enough time and money.
- War is conventional. Although the future battlefield expands the concept of armed conflict by placing the operational aspects within a broader context to include political, economic, social, ecological, demographic, legal, normative, diplomatic and technological [20].
- Logistics design is made for material. It does not include human factor.
- Active defense is taken as defense wars. It requires the organic integration of offense and defense, and achieving the strategic goal of defense by active offense, when the condition is ripe, the strategic defense should be led to counter attack and offense [22]
- Only outbound logistics is studied due to fact that battle field supply line is shortened while the strategic supply line is relatively extended [22].

During design process, it aimed to have rapid delivery, light government inventories, operational integration, functional integration, enterprise integration, predictive intervention, robust information security, customer driven processes, continuous review and improvement [5].

2. AXIOMATIC DESIGN & PRINCIPLES

2.1 Principles of Axiomatic Design

Axioms are general principles which are evident actualities that cannot be proven to be correct but which do not have counter examples [43]. AD principles developed to form systematic scientific basis for designers, especially in the design processes of product, production systems, and software design are widely used to solve many design problems. These principles present better design solutions in the shortest time as they provide a systematic research process in a design space which becomes complicated with customer needs. Design axioms provide a rational means for evaluating the quality of proposed designs, and the design process which is used guides designers to consider alternatives at all levels of detail and to makes choices between these alternatives more explicit [44].

The world of design is made up of four domains: the customer domain, the functional domain, the physical domain, and the process domain. The domain on the left relative to the domain on the right represents "what we want to achieve", whereas the domain on the right represents the design solution of "how we propose to satisfy the requirements specified in the left domain".

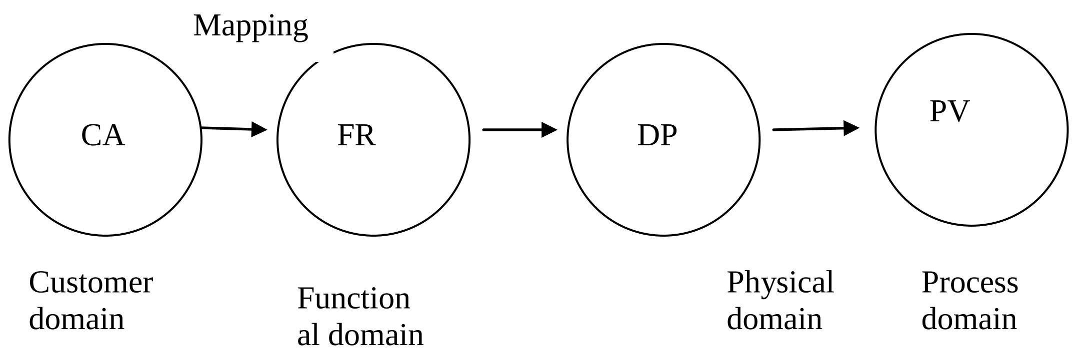


Figure 2.1: Design mapping process

The customer domain is characterized by customer needs (or the attributes) the customer is looking for in a product, process or system. In the functional domain, the customer needs are specified in terms of functional requirements (FRs) and constraints (Cs). In order to satisfy the specified FRs, we conceive a design described by design parameters (DPs) in the physical domain. Finally, to produce the design product specified in terms of DPs, we develop a process that is characterized by process variables (PVs) in the process domain.

Axioms are widely accepted principles which are the fundamental concepts of mapping process. The first design axiom is known as the Independence Axiom and the second axioms is known as the Information Axiom; and are stated as follows [43]:

Axiom 1. The Independence Axiom: Maintain the independence of functional requirements.

Axiom 2. The Information Axiom: Minimize the information content.

Independence axiom states that, during the mapping process from the functional requirements (FRs) in the functional domain to the design parameters (DPs) in the physical domain, a change in a particular DP must affect only its referent FR. According to the information axiom, among all the feasible designs that satisfy the independence axiom, the one with the minimum information content is the best design [44] .

The mapping process between the domains can be expressed mathematically in terms of the characteristic vectors that define the design goals and the design solutions. At a given level of the design hierarchy, the set of functional requirements that define the specific design goals constitutes a vector {FRs} in the functional domain. Similarly, the set of design parameters constitutes a vector {DPs}. The relationship between these two vectors can be written as:

$\{FRs\} = [A]\ \{DPs\}$ where [A] is defined as the design matrix that characterizes the design and shows the relationships between the FRs and DPs at a given level of the design hierarchy.

To satisfy the independence axiom, the design matrix must be either diagonal or triangular. When the design matrix [A] is diagonal, each of the FRs can be satisfied independently by means of one DP. Such a design is called uncoupled design. When [A] is triangular, the independence of FRs can be guaranteed if and only if the DPs are changed in a proper sequence. Such a design is called decoupled design. Any other matrix is known as a coupled design. In equations 2.1, 2.2, and 2.3, an X represents a strong effect by a DP on a FR, while a zero indicates a weak effect, relative to the tolerance associated with the FR.

$$\begin{bmatrix} FR1 \\ FR2 \\ FR3 \end{bmatrix} = \begin{bmatrix} X & X & X \\ X & X & X \\ X & X & X \end{bmatrix} \begin{bmatrix} DP1 \\ DP2 \\ DP3 \end{bmatrix} \quad coupled\ design \tag{2.1}$$

$$\begin{bmatrix} FR1 \\ FR2 \\ FR3 \end{bmatrix} = \begin{bmatrix} X & 0 & 0 \\ X & X & 0 \\ X & X & 0 \end{bmatrix} \begin{bmatrix} DP1 \\ DP2 \\ DP3 \end{bmatrix} \quad decoupled\ design \tag{2.2}$$

$$\begin{bmatrix} FR1 \\ FR2 \\ FR3 \end{bmatrix} = \begin{bmatrix} X & 0 & 0 \\ 0 & X & 0 \\ 0 & 0 & X \end{bmatrix} \begin{bmatrix} DP1 \\ DP2 \\ DP3 \end{bmatrix} \quad uncoupled\ design \tag{2.3}$$

Information Axiom which is the second axiom of AD principles is about minimizing the information content of the design. In other words, among all the proposed solutions that satisfy independence axiom, the best design is the design that has the minimum information content. Information axiom provides a conventional method to asses the designs to select the best one. The selection process is based on criterion which states that the design resulting in the highest probability of FR success is the best design [45]. If the probability of success for a given FR is p, the information content is calculated by

$$Ii = \log_2 \frac{1}{pi} \tag{2.4}$$

If there is more than one FR, the information content is calculated as follows [43,45]:

$$Isystem = \sum_{i=1}^{m} log_2^{1/pi} \tag{2.5}$$

The methodology of axiomatic design can be summarized as follows [43]:

Step 1. Determine the experts. While determining the expert group, the potential user population of the designed product must be taken into consideration.

Step 2. Define FRs in the functional domain. In this step, to define design parameters, functional requirements are determined to satisfy customer needs.

Step 3. Define DPs in the physical domain. Design parameters/ criteria are defined to satisfy the defined FRs.

Step 4. Decompose of FRs and DPs. FRs and DPs at the top level are decomposed until to obtain applicable design parameters.

Step 5. Construct the design matrix and evaluate the relations between FRs and DPs.

2.2 Literature of Logistics Design via Axiomatic Design Principles

The method is developed by Suh. Based on the literature review studied by Kulak et al, it is mentioned that [46]:

- High majority of studies is based on indepence axiom instead of information axiom.
- Axiomatic design principles are generally used for product design.
- Instead of fuzzy evaluation, crisp design is preferred.

The list of logistics and supply chain related axiomatic design publications are:

- On their graduation project, Ozel and Ozyoruk used fuzzy axiomatic design principles for supplier selection [47].
- Favaro used indepence axiom by crisp evaluation to develop a lean logistics design methodology [48].
- On their paper, Schnetzler developed a method of supply chain design decomposition (SCDD) that distinguishes objectives and means of SCM [49].
- On their paper Celik et al, propose a hybrid approach on ensuring the competitiveness requirements for major Turkish container ports by utilizing fuzzy axiomatic design (FAD) and fuzzy technique for order performance by similarity to ideal solution (TOPSIS) methodologies to manage strategic decision-making with incomplete information [50]

- On their paper Kulak and Kahraman developed a Fuzzy multi-attribute selection among transportation companies using axiomatic design and analytic hierarchy process[51].

3. MATERIAL LOGISTICS NETWORK

Because of changing format of war, defense departments started to develop new logistics concepts. In 2004 Dod issued logistic transformation strategy. The guidance directed to reconcile 3 logistics concepts [52]:

- Force centric logistic enterprise
- Sense and respond logistics
- Focused logistics

Force centric logistics enterprise is a concept for enhancing support to war fighter and it encompasses 6 initiatives:

- Depot maintenance partnership
- Condition-bases maintenance
- Total life cycle systems management
- End-to-end distribution (The End-to-End Distribution initiative is directed toward streamlining war fighter support by providing materiel, including retrograde and associated information, from the source of supply or point of origin to the point of use or disposal, as defined by the CINC, Military Service, or characteristics of the commodity, on a worldwide basis. The intent of the initiative is to influence acquisition, sourcing, positioning, and transportation to facilitate the flow of materiel to the end user, ensuring that deployment and sustainment are synchronized)
- Executive agents
- Enterprise integration

Sense and respond logistics is a future concept envisioning a networked logistics system that would provide joint strategic and tactical operations with predictive, precise and agile support [53]. It calls for a transformation from a sole focus on prediction and inward optimization to an outward focus on sensing what is needed and responding quickly in a unpredictable environment [54]. Sense and Respond Logistics is a transformational network-centric concept that enables Joint effects-based operations and provides precise, agile support. Sense and Respond Logistics relies upon highly adaptive, self-synchronizing, and dynamic physical and functional processes. It predicts, anticipates, and coordinates actions that provide competitive advantage spanning the full range of military operations across the strategic, operational, and tactical levels of war. Sense and Respond Logistics promotes doctrinal and organizational transformation, and supports scalable coherence of command and control, operations, logistics, intelligence, surveillance, and reconnaissance. Some of the key ideas of Sense and Respond, which can be found in science and business literature and practice, reflect the application of network-centric theory and principles:

- Demand is ultimately unpredictable, so success depends on speed of pattern recognition and speed of response.
- The best supply chain is no longer highly optimized; it is highly flexible, and is considerably more networked and less linear.
- Organization of business units and subunits into modular dynamically reorganizable capabilities that negotiate with one another over commitments, and that have adaptable control via brokers, negotiators, and arbitrators, replaces fixed organizational structures.
- Networks self-synchronize via a common environment and set of shared objectives; typically commander's intent and mission/task/effect achievement measures, focusing on operational effectiveness.
- Adaptable enterprises depend on sophisticated information technology support to enable data sharing, knowing earlier, commitment tracking, predictions, adaptation, cognitive decision support, and role reconfiguration.

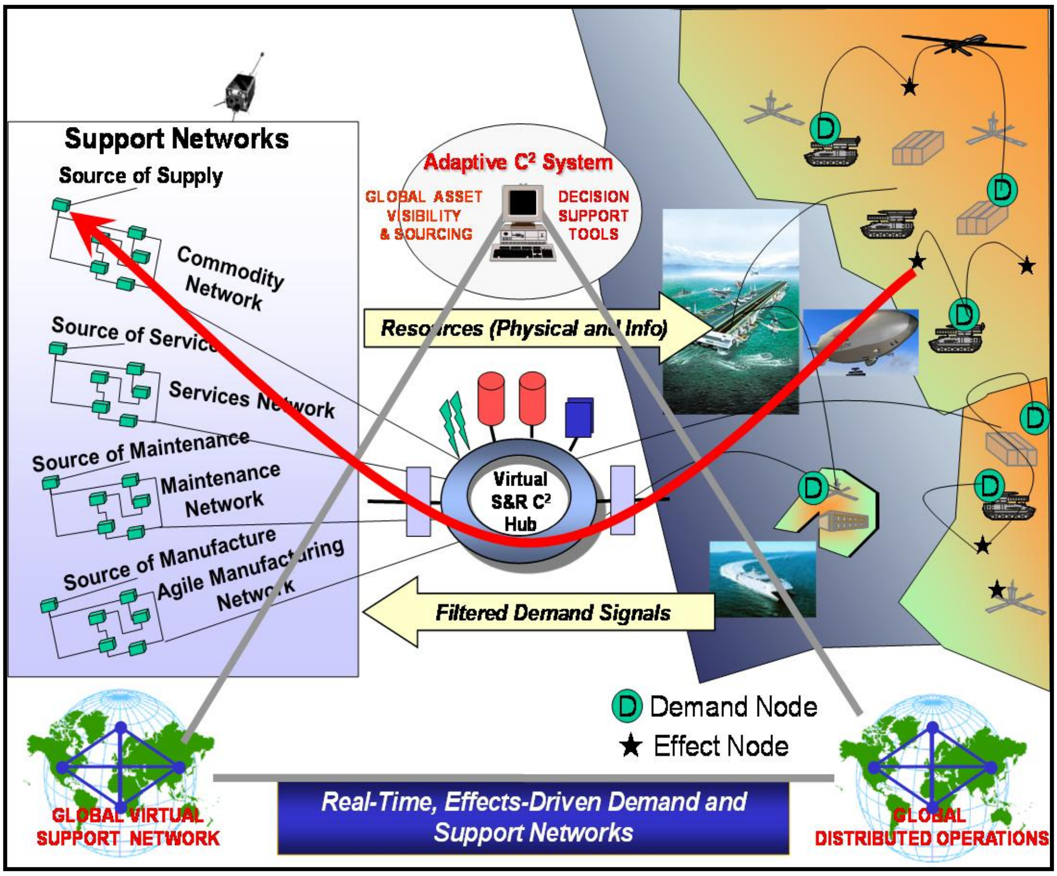


Figure 3.1. End-to-End Sense and Respond, from Point-of-Effect Source of Support

Figure 3.1 depicts the concept of an S&RL capability that operates end-to-end, from *point-of-effect* through *source-of-support.* The point-of-effect (denoted by stars in the Joint Operations Area [JOA]) is where the demand process starts (it does not start at the platform). The point-of-effect is where the pure demand process starts and where the ultimate customer is the enemy/enemy's behavior that we are trying to change by creating an effect (which may not be kinetic or may not even be military, and may be implemented through another national asset). If the enemy is the ultimate customer in this model (or the customer's customer in SCOR terminology), the customer to the support network is the operational commander and the commander's intent. Effects are generated by capability packages, which, in turn, are composed of entities that create resource demands. The points-of-effect, the capability packages, and the resource consumption/demand nodes together represent the demand network.

The area between the points-of-effect and the resource demand signals (in Figure 2.2, the area between the stars and the D-nodes) is the *Logistics No-Man's Land* and is the least understood, but highest potential payoff area for understanding and linking effects-based operations and logistics. Part of the challenge of building the S&RL system is traversing this area and linking effects and resource demands directly. The support network comprises all nodes involved in responding to needs. It includes not only traditional supply chain nodes, but also any node or potential node capable of satisfying that need. In this definition of the support network, even demand nodes under certain conditions become potential sources of support, as do commandeered assets, coalition assets, etc. There are different kinds of support networks that must be accommodated. These include commodities, services, maintenance, and manufacturing. Implied but not shown in Figure 3.1, the support network includes distribution services, including transportation services.

The S&R C2 hub is the virtual cross-roads (the technical and system architectures would ensure that this hub is not a single-point-of-failure vulnerability in the *infostructure* supporting S&RL) where standards-based transactional information would flow through in real-time to send filtered demand signals back to the support networks and send status and constraint information from the support network to the demand network. Lessons learned and experience feedback loops would assist in adaptation of logistics support strategies over time to meet evolving commander's intent. The S&R C2 hub is a part of an enterprise-wide Joint Dynamic Adaptive Command and Control System (DAC2) that embodies NCW principles, synchronizes Ops, ISR, and Log, and supports planning and execution of Joint Adaptive Expeditionary Warfare. Real-time information flows will link global support networks with total asset and process visibility and global anticipatory demand networks to support effects-based operations and provide a constantly adapting enterprise capability.

Focused logistics have 7 future logistics capabilities by DoD: All capabilities are intended to support an overall joint logistics capability which DoD defines as 'the capability to build effective, responsive, and efficient capacity into the deployment and sustainment pipeline; exercise control over the pipeline from end to end; and provide certainty to the supported joint force commander that forces, equipment, sustainment and support will arrive where needed on time' [55]:

- Joint theater logistics : Important areas for joint theater logistics [55]:
    - Receiving and processing a large influx of supplies at the beginning of a military operation. In order to achieve, command and control should be plained.
    - Management of supplies moving across the distribution system, to achieve it should be developed an information technology system and container management procedures.
    - Theater wide coordination of surface transportation assets. To do so, information technology should be used, skilled personnel number should increase and the command structure should be made clear.
    - Consolidation of supply storage and shipping activities
- Joint deployment\ rapid distribution
- Agile sustainment
- operational engineering
- Force health protection
- Multinational logistics
- Logistics information fusion

3.1. Acquisition

The department responsible from acquisition has three aims [7]:

- Creating an efficient logistical systems that provided sufficient quantities of supplies in a timely manner
- Assisting movement of supplies to the field forces
- Maintaining strict accountability for money and supplies

In order to have products in desired quantity and quality in minimum cost at the right time, acquisition strategies should be developed:

$F_{1:}$ Acquisition design

D_1: Strategy development

By acquisition, it is desired to have needed- featured new product in minimum cost at the right time. Strategies are decreasing cost elements, knowledge of contemporary products and right time to order. Axiomatic design equation is given by Equation 3.1.

$F_{1:}$ Acquisition design	D_1: Strategy development
F_{11}: decrease total cost F_{12}: have products in desired features F_{13}: have product in right time	D_{11}: reduced total cost elements D_{12}: contemporary knowledge of products D_{13}: ordering time

$$\begin{bmatrix} F11 \\ F12 \\ F13 \end{bmatrix} = \begin{bmatrix} X & 0 & 0 \\ 0 & X & 0 \\ 0 & 0 & X \end{bmatrix} \begin{bmatrix} D11 \\ D12 \\ D13 \end{bmatrix} \quad \textbf{(3.1)}$$

Cost includes fixed costs, variable costs and shipping& storage costs. Decrease in variable cost can be achieved by decreasing essential needs, decreasing buying, and buying products with a reasonable price. Decrease in buying depends on knowledge about the quantity of the inventory and usage inventory in all quality aspects.

Strategies to decrease cost are consolidation, outsourcing and demand decrease.

1. Consolidation: Logistics economies are achieved through the consolidation of customers' shipments or suppliers (in a single pick up) [53]. DoD currently uses multiple storage and shipping sites within a theater to supply items to its customers. In some cases these sites may carry the same supply items and ship to same customers. Operating multiple sites requires additional facilities, personnel, contract services and inventories and also result in extra movement of stock, inefficient use of surface and air distribution assets, increased opportunities for information processing errors, and the loss of asset visibility. Consolidating storage and shipping arrangements can help address these supply chain problems while at the same time reducing DoDs logistics footprint. So what should do for consolidation? [55]: First initiative is to develop a small-scale, rapidly deployable distribution center that has the capability to provide consolidated shipping, receiving, cross-docking, storage, communication and order processing. The initiative is aimed at improving the flow of logistics information along the supply chain and also providing

efficient physical management of material in the theater. Volume consolidation can be made in order to decrease the number of suppliers [58]. A second consolidation initiative is Joint Regional Inventory and Material Management, which is aimed at streamlining the storage and distribution of common items for multiple military service locations in a region from a DLA hub. The objectives of Joint Regional Inventory and Material Management include eliminating duplicate materiel handling and inventory layers. Third initiative is in order to improve the overall efficiency and interoperability of material consolidation and shipping activities. [55].

2. Outsourcing: DOD uses a combination of in-house military and civilian employees and contractors to provide the support operations that are required to keep military airplanes, ships, and ground vehicles operational for peacetime training and operations and ready to support contingency operations whenever or wherever they occur [59, 60, 61, 62].

Private sector applications recommended by GAO are given by Table 3.1 [5, 63, 64]:

Table 3.1: Private sector applications recommended by GAO.

Concept	Description
Prime Vendor	A prime vendor buys inventory from a variety of suppliers, stores the inventory in its own warehouse, and delivers inventory to the customer within hours of receiving the order [64].
Integrated Supplier	An integrated supplier assumes almost total inventory management responsibilities for a customer. This is the most aggressive form of a supplier partnership where a supplier representative works in the customer’s facility, ordering supplies as they are needed, and replenishing storage locations. Inventory is stored by the supplier in the supplier’s warehouse until ordered and then delivered on a just-in-time basis. An integrated supplier can also perform quality inspections, maintain data on usage, test the quality of parts, prepare parts kits, establish electronic data

	interchange links and barcoding, and provide vendor selection management.
Local Distribution Centers/ Supplier Parks	One or more suppliers locate a distribution center within close proximity to their customers. From this location, the supplier delivers items to the customer within 24 hours or less of receiving an order. The supplier is linked electronically with the customer. In some cases the supplier can perform the receiving function for the customer in the local distribution center before inventory leaves the facility.

DOD has successfully used prime vendor arrangements for some consumable items such as foods and medical supplies [59]. The prime vendor program uses a contractual arrangement with one or more commercial vendors to supply a wide range of commercial off-the-shelf material directly to military customers on a just-in-time basis [65, 66]. Under the prime vendor concept, DOD relies on a distributor of a commercial product line, who provides that product line and incidental services to customers in an assigned region or area of responsibility. Products or services are to be delivered within a specified period of time after order placement. Logistics support arrangements include [67]:

- contractor logistics support, where the contractor provided most or all elements of logistics support, including depot maintenance;
- total system performance responsibility, under which the contractor assumed responsibility for the weapon system's life-cycle management;
- total system sustainment responsibility or total system support responsibility, which gave the contractor responsibility for all contracted sustainment actions including parts management and depot level repair.

The Walter Reed Army Medical Center started stocking their pharmacies through the Prime Vendor Program 3 years ago. Since then they have reduced warehouse space from seven to half of one, eliminated 32 staff positions saved $400000 [68]. Under the medical prime vendor program, % 98 of orders are delivered within 24 hours, compared to previous time of 30 days-while at the same time prices are generally

35% less than before; and inventory reductions of more than 29% [68]. Under the Industrial Prime Vendor initiative, the vendor is contractually required to meet %100 of customer needs and deliver items.

The benefits of prime vendor contracts include [69]:

- improved access to a wide range of high-quality commercial products,
- rapid and predictable delivery from a single vendor at the time and in the manner most conducive to the customer's needs, and reduced overhead charges
- significant reductions in the manpower needed to manage these items at DLA,
- elimination of any DLA inventory investment, reduction of the infrastructure and related costs associated with warehousing that inventory,
- reduced transportation costs via multiple-item prime vendor deliveries to the customer rather than transportation from vendors to the military depots for subsequent transportation to the ultimate customer.
- provide for surge and broader mobilization capabilities,
- worldwide customer support.

DOD spends $10billion annually on multiyear procurement (MYP) contracts for weapon systems. MYPS may save money through more efficient relations with suppliers and producers but may also suffer losses if canceled and can limit future budget flexibility [70]. MYP are expected to achieve lover unit costs through the following sources:

- Purchase of parts and materials in economic order quantities
- Improved production processes and efficiencies
- Better utilized industrial facilities
- Limited engineering changes due to the design stability during MY period
- Cost avoidance by reducing the burden of placing and administrating annual contracts

Equation 3.2 is given for axiomatic design of F11: decreasing total cost.

F_{111}: variable product costs F_{112}: decrease fixed costs F_{113}: decrease shipping& storage costs	D_{111}: reduced demand D_{112}: consolidation D_{113}: outsourcing

$$\begin{bmatrix} F111 \\ F112 \\ F113 \end{bmatrix} = \begin{bmatrix} X & 0 & 0 \\ X & X & 0 \\ X & X & X \end{bmatrix} \begin{bmatrix} D111 \\ D112 \\ D113 \end{bmatrix} \quad \textbf{(3.2)}$$

Decrease in variable costs depends on decrease in the quantity of demand. Decreasing logistics demand is a major element of cutting costs and improving flexibility. Reducing demand requires concerted emphasis on [71, 72]:

- Reducing legacy systems' maintenance requirements
- Reducing the consumption of consumables
- Designing new systems to be more reliable and require fewer people to operate and maintain
- Redesigning of combat and support organizations and their equipment to reduce their size, weight and consumption rates
- Adopting management techniques that reduce system/ equipment maintenance demands and supply consumption.

Another factor decreases variable cost is unit price. Procurement should be made by best value concept. Best value procurements are those that in the federal government's view provide the greatest overall benefits, not just the price [73]. In order to improve management of spare part prices these steps can be taken [74]:

- Detailed analysis of price increases
- Management reviews to address the risk of overpricing
- Information technology initiatives at helping DLA buyers determine price reasonableness and better alerting customer to possible price increases. Shopping should be mad via e-commerce channels. DLA's electronic mall enables customers to shop via the internet and because electronic catalogs, compare prices, and order items from pre-established contracts via computers [75].

Equation 3.3 is given for axiomatic design of F_{111}: decrease in. variable product cost. Equation 3.4 is given for F_{1133}: decrease new acquisition which is another functional requirement to decrease in variable product cost. Equation 3.5.

F_{1131}: buy product with a reasonable price F_{1132}: decrease in shipping in theatre F_{1133}: decrease new acquisition F_{11331}: exact usage of inventory in depots by quantity and quality F_{113311}:exact usage in quantity $F_{113312:}$ exact usage in quality F_{11332}: decrease in logistics demand seems necessary	$D_{1131:}$ price analysis D_{1132}: order in economic quantity D_{1133}: demand analysis D_{11331}: inventory management D_{113311}:inventory visibility D_{113312}:maintenance procedure $D_{11332:}$ minimized demand by redesigning Forces

$$\begin{bmatrix} F1131 \\ F1132 \\ F1133 \end{bmatrix} = \begin{bmatrix} X & 0 & 0 \\ 0 & X & 0 \\ 0 & 0 & X \end{bmatrix} \begin{bmatrix} D1131 \\ D1132 \\ D1133 \end{bmatrix} \quad \textbf{(3.3)}$$

$$\begin{bmatrix} F11331 \\ F11332 \end{bmatrix} = \begin{bmatrix} X & O \\ O & X \end{bmatrix} \begin{bmatrix} D11331 \\ D11332 \end{bmatrix} \quad \textbf{(3.4)}$$

$$\begin{bmatrix} F113311 \\ F113312 \end{bmatrix} = \begin{bmatrix} X & O \\ O & X \end{bmatrix} \begin{bmatrix} D113311 \\ D113312 \end{bmatrix} \quad \textbf{(3.5)}$$

For security, in procurement not only cost is important but also desired-features of the product is important. Desired features means quantity and the quality of the product are in enough level. Axiomatic design equation for desired product features is given by Equation 3.6.

F_{121}: buy desired-quality product F_{122}: buy desired-quantity product	D_{121}: quality standard development update D_{122}: filing product data

$$\begin{bmatrix} F121 \\ F122 \end{bmatrix} = \begin{bmatrix} X & 0 \\ 0 & X \end{bmatrix} \begin{bmatrix} D121 \\ D122 \end{bmatrix} \quad \textbf{(3.6)}$$

Demand quantity depends on safety stock in peace time and probability of war. Demand quantity for probability of war depends on what enemy has in quantity and quality, and in required time to rebound from the war to fight again. Product quality is not robustness but also dependent on enemy's product quality. In order to order product having desired features, it is required to have up-to-date product information. The currency of product information includes product data folder currency and quality standard currency. During filing product data, inventory visibility and forecasting is important. Simulation techniques should be used in forecasting.

DOD forecasts operational requirements for spare and repair parts differently than it does for items that result from rapidly emerging needs. DOD forecasting methods for spare and repair parts vary by service. The Army normally uses a computer model to forecast its spare and repair parts requirements based on the average monthly demand over the previous 24 months. The model uses DOD planning guidance and Army information on anticipated force structure including a list of the end items and associated spare parts. For each end item or part, the model uses data on expected usage and spare-parts consumption rates based on breakage, geography, environment, and rates of equipment loss due to battle damage. [56]. The Marine Corps also uses models and involves operational and logistics planners at several levels of command to validate their forecasted requirements. Operational requirements to support rapidly emerging needs, such as Interceptor body armor and up-armored High-Mobility Multi-Purpose Wheeled Vehicle (HMMWV), are developed outside of normal supply forecasting procedures. They are identified through operational needs statements from the theater that are validated and resourced by the Army. Units in theater submit operational needs statements for the items, which are combined by their higher headquarters into theater requirements. The Coalition Forces Land Component Command communicates these requirements to the Department of the Army, where they are validated and resourced by offices of the Assistant Secretary of the Army (Financial Management and Comptroller), the Deputy Chief of Staff for Operations, the Deputy Chief of Staff for Program and Analysis, and the Deputy Chief of Staff for Logistics and eventually transmitted to the program manager [56]. To improve the forecast , data about operations plan should be obtained accuretly [56].

To determine the number and the type of munitions(muhimmat) needed, the services annually evaluate their munition requirements using a multiphase analytical precess. The phases of the process[76]:

- Identify targets by phases of the war
- Develop combat requirements using battle simulation models and scenerios
- Training of the forces by munitions
- Providing Post-major theater of war combat capability
- Peacetime requirements
- Munitions effectiveness data

The accuracy of the process is critical as its outcomes defines the number and types of munitions necessary to defeat potential threats; affects munitions planning, programming and budgeting decisions; and influences industrial production base decisions [76]. But the munition requirement determination process should be improved like [76]:

- Coordinating the threat assessment
- Updating projections about the amount of time it would take a potential enemy to repair and return damaged targets to the battlefield and damage assessments for input into the services' battle simulation models
- Modifying the target allocation process
- Making a more comprehensive risk assessment

Equation 3.7 is given for axiomatic design of F_{122}: buy desired-quantity product. Equation 3.8 is given for sub-functional requirements of F_{1221}: know required inventory for probability of war.

F_{1221}: know required inventory for probability of war F_{12211}: inventory belonging to enemy F_{12212}: time to rebound from the war F_{1222}: know required inventory for peacetime (safety stocks, training stocks)	D_{1221}: forecasting D_{12211}: spying D_{12212}: simulation D_{1222}: inventory visibility

$$\begin{bmatrix} F1221 \\ F1222 \end{bmatrix} = \begin{bmatrix} X & 0 \\ X & X \end{bmatrix} \begin{bmatrix} D1221 \\ D1222 \end{bmatrix} \quad \textbf{(3.7)}$$

$$\begin{bmatrix} F12211 \\ F12212 \end{bmatrix} = \begin{bmatrix} X & 0 \\ X & X \end{bmatrix} \begin{bmatrix} D12211 \\ D12212 \end{bmatrix} \quad \textbf{(3.8)}$$

Another concern in acquisition is right-time delivery. For cost side, products should be delivered quickly. Management of inventory acquisition lead times is important in maintaining cost-effective inventories, budgeting, and having material available when needed, as lead times are DOD's best estimate of when an item will be received. Acquisition lead time, also known as procurement lead time, measures the length of time between the initiation of a procurement action and the receipt of items into the supply system.

Acquisition lead time consists of two parts [77]:

- Administrative lead time is the time interval from the initiation of a procurement action to the contract award
- production lead times is the interval from the contract award to delivery of the items.

Reducing acquisition lead times decreases inventory levels and associated inventory holding costs.

In order to get orders on time, they should be given in time. By contract management and information technologies and outsourcing, lead time can be decreased. To give order on time, an automation system that alerts customer can be used to ensure asset visibility for re-order point. Depending on the item, the reorder point may include requirements for one or more of the following [78]:

- war reserves that are authorized to be purchased,
- customer-requisitioned material that has not been shipped,

- a safety level to be on hand in case of minor interruptions in the resupply process or unpredictable fluctuations in demand,
- stock to satisfy demands during the period between when a need to buy an item is identified and when it is received,
- minimum quantities for designated items (insurance items), and
- stock to satisfy demands during the repair period for repairable items

Generally, inventory managers order an amount of inventory called an economic order quantity, which is the quantity of inventory that will result in the lowest total costs for ordering and holding inventory.

Axiomatic design equation for F_{13} is given by Equation 3.9. Equation 3.10 is given for sub-functional requirements of F_{132} lead time.

F_{131}: time of giving order F_{132}: lead time F_{1321}: production lead time F_{1322}: administrative lead time	D_{131}: re-order point design D_{132}: lead time strategies D_{1321}: outsourcing D_{1322}: contract management tools

$$\begin{bmatrix} F131 \\ F132 \end{bmatrix} = \begin{bmatrix} X & 0 \\ 0 & X \end{bmatrix} \begin{bmatrix} D131 \\ D132 \end{bmatrix} \tag{3.9}$$

$$\begin{bmatrix} F1321 \\ F1322 \end{bmatrix} = \begin{bmatrix} X & 0 \\ X & X \end{bmatrix} \begin{bmatrix} D1321 \\ D1322 \end{bmatrix} \tag{3.10}$$

Figure 3.2 is the design mapping for axiomatic design of acquisition design.

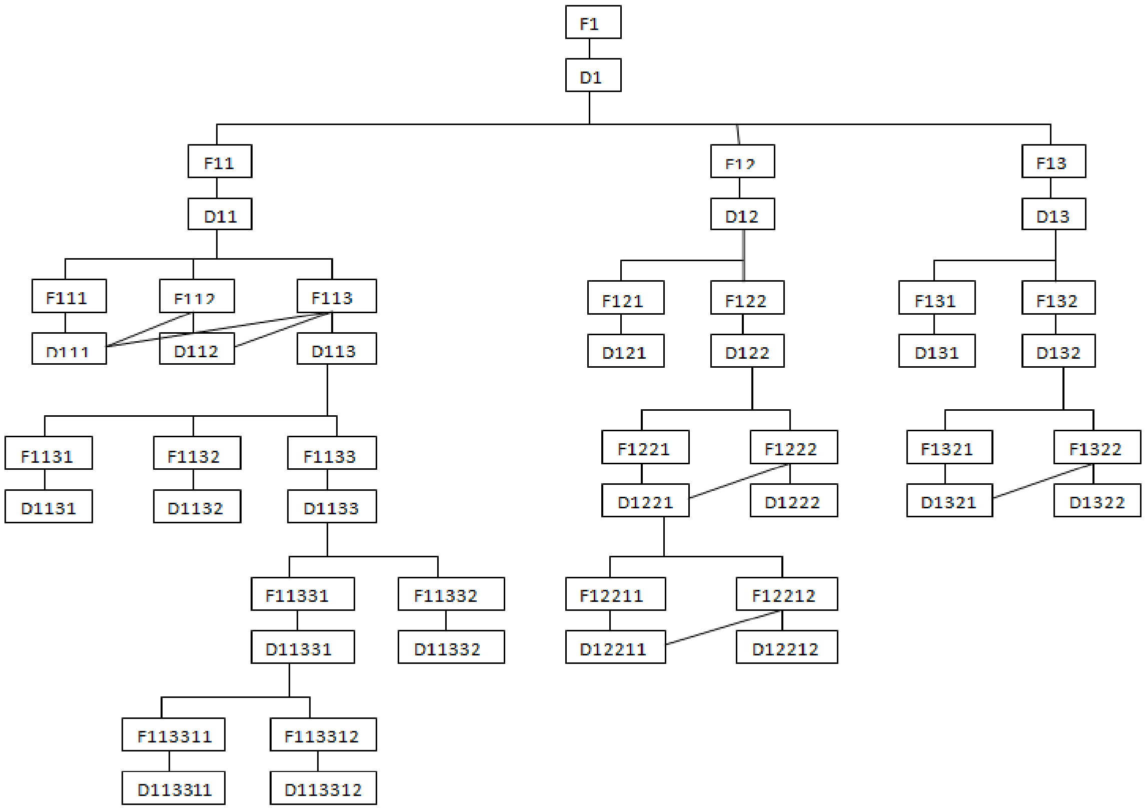


Figure 3.2 Design mapping for acquisition

3.2. Storage

The war reserves are indented to fill the gap until the national supply system can increase production [56]. They consist of major items including trucks and secondary items such as spare parts, food, clothing, medical supplies, and fuel. When the total of on-hand and due-in inventory falls to or below a certain level-called reorder point-inventory managers place orders for additional inventory [78]. At first DLA was buying consumable items in large quantities, states them in distribution depots until they are requested by military services, and then shipped them to a service facility where they are used [79]. But now it is different. Now it is outsourced for just-in-time or prepositioned.

Managing inventory is one of the key features of logistics. Inventory management includes minimization of costs and maximization of usage of inventory. Profit maximization and risk minimization strategies should be developed to better management. Equation 3.11 is given to show the axiomatic relation.

$F_{2:}$ Satisfy customers	D_2: Inventory strategy
F_{21}: decrease costs F_{22}: increase inventory usage	D_{21}: increased profit D_{22}: reduced inventory risks

$$\begin{bmatrix} F21 \\ F22 \end{bmatrix} = \begin{bmatrix} X & 0 \\ X & X \end{bmatrix} \begin{bmatrix} D21 \\ D22 \end{bmatrix} \qquad \textbf{(3.11)}$$

In order to minimize costs, fixed costs including fixed assets and administration& selling costs should be decreased; inventory levels and movement of inventory in depots should be minimized by eliminating nonvalue added functions as much as possible, inventory accuract and developing inventory allocation strategy.

Equation 3.12 is given for axiomatic design of F_{21}:decrease cost.

F_{211}: decrease fixed costs F_{212}: decrease inventory level F_{213}: decrease movement of equipment in Depot	D_{211}: elimination as much as possible D_{212}: inventory accuracy D_{213}: inventory allocation strategy

$$\begin{bmatrix} F211 \\ F212 \\ F213 \end{bmatrix} = \begin{bmatrix} X & 0 & 0 \\ 0 & X & 0 \\ 0 & 0 & X \end{bmatrix} \begin{bmatrix} D211 \\ D212 \\ D213 \end{bmatrix} \quad \textbf{(3.12)}$$

Decrease in fixed costs can be achieved by eliminating as much as possible via outsourcing and selecting assets based on long term strategy which is given by Equation 3.13.

F_{211}: decrease fixed costs F_{2111}: decrease administration and selling costs F_{2112}: decrease fixed assets	D_{211}: elimination as much as possible D_{2111}: outsourcing D_{2112}: asset selection (tangible or intangible) based on long term strategy

$$\begin{bmatrix} F2111 \\ F2112 \end{bmatrix} = \begin{bmatrix} X & 0 \\ X & X \end{bmatrix} \begin{bmatrix} D2111 \\ D2112 \end{bmatrix} \quad \textbf{(3.13)}$$

The objective in inventory strategy is to achieve desired customer service with min inventory level [58]. GAO identified dods supply chain management as a high risk area because of high inventory levels [56]. Inventory level minimization means minimization in depot inventory, minimization of non-stable inventory (under maintenance [80] and in-transit), clarification of pre-positioned equipment quantity and minimization of in-theater inventory.

For strategic mobility framework, some equipment should be prepositioned. Instead of long movement of needed equipment, by prepositioning it allows combat-ready forces [81, 82, 83]. Each military services prepositions combat and support equipment and supplies in order to speed response times of US forces to operating locations and reduce the strain on scarce airlift or slower sealift assets [54]. Army, navy and air force prepositioned equipment list is given by Table 3.2 [81, 83, 84]:

Table 3.2: Prepositioned equipment list of Army, Navy and Air Force.

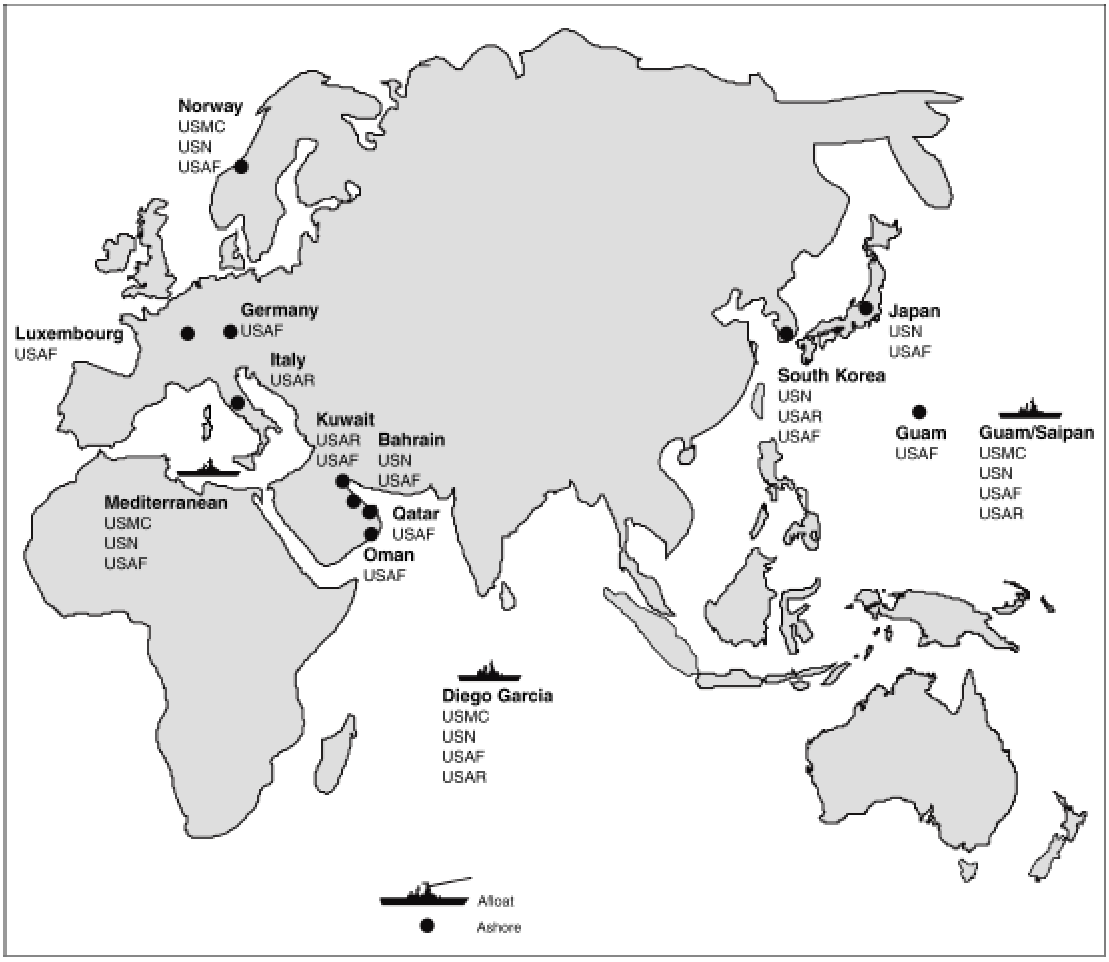
Service	Types of stocks	Description
Army	Combat brigade sets	➢ are designed to support 3000-5000 force ➢ Include support equipment such as trucks and high mobility multipurpose wheeled vehicles ➢ Include spare parts and other sustainment stocks to support the early stage of a conflict ➢ Include heavy weaponry such as tanks and brodley fighting vehicles
	Sustainment stocks	➢ Items to sustain the battle unit until resupply can be ramped up to wartime levels and arrive in theater ➢ War reserve secondary items include clothing, textiles, construction and barrier material, medical supplies, repair parts and major assemblies (reparables and consumables)
	Operational project stocks	➢ Authorized material above unit authorizations designed to support Army operations ➢ Equipment and supplies for special operation forces, bare base sets, petroleum and water distribution, mortuary operation and prisoner-of-war operations (Bare base set: tents for troops, latrines, kitchens,

		airlift hangers, maintenance shops, generators, and environmental controls. The sets support early arriving combat forces and are especially critical in austere environment [83])
Navy/Marine Corps	Maritime prepositioning force	➢ Consists of 16 prepositioninig ships organized into three squadrons (Planners have created mobile forward supply depots. Material has been placed on squadrons of large ships, which are rotated near potential hotspots. The ships are designed to rapidly unload equipment and supplies and then exit the combat area. To maintain the resupply effort, the concept of logistics over horizon is developed which allows ships to offload miles from shore on floating causeways. In regions without seaport, the resupply is conducted via air [85].) ➢ Each squadron supports about 15000 marines for up to 30 days ➢ Includes combat systems, communications systems, construction equipment, munitions, medical supplies, and sustainment stocks
	Prepositioning program-Norway	➢ Several land sites located in central Norway ➢ Designed to support 13000 marines for up to 30 days ➢ Includes vehicles, weapons, munitions, rations, and other equipment that will be

		used to support any geographic combatant command
	Navy prepositioned assets	➢ Assets are stored aboard maritime prepositioning ships and at land sites ➢ Equipment to offload prepositioned ships, including material handling equipment, ramps and barges, landing and amphibious craft, and bulk fuel ➢ Construction equipment such as cranes, forklifts, trucks, and tractor trailers ➢ Includes six 500-bed fleet hospitals
Air Force	Bare base sets	➢ Base operating support equipment used to house forces, and equipmement and supplies needed to support airfield operations
	Vehicles	➢ Includes trucks, buses, and High mobility multipurpose wheeled vehicles
	Other support equipment and supplies	➢ Includes material handling equipment, rotations, fuel, fuel support equipment, aircraft accessories, and medical supplies at land sites and munitions aboard four prepositioning ships

The other concern about prepositioning is to decide what to store, how many and where. It should be compared the risk of insufficient inventory to gained profitability. Experiences in Iraq showed that prepositioned secondary item stocks did not adequately support the troops in combat operations. Lessons learned also show considerable mismatches between what was available and what units actually needed. In retro respect Army did a poor job in forecasting [81]. Where to position equipment is another concern. They should be positioned to the area which conflicts can arise. As seen below, Army prepositioned military equipment on ships afloat near Guam and Diego Garcia and overseas on land Europe, Northeast Asia, Southwest Asia [81] which can be positioned against Middle East, Russia and China.

Figure 1: Locations of Army (USAR), Marine Corps (USMC), Navy (USN), and Air Force (USAF) Prepositioned Stocks



Source: GAO analysis.

Note: DOD also prepositions smaller stocks of equipment and supplies at other locations not identified on this map.

Figure 3.3 Location of Army, Navy and Air Force prepositioned stock

Army has developed a pool of equipment in theater to expedite the replacement of equipment damaged during operations referred as TSS theater sustainment stocks which includes tanks , or support vehicles. On the other hand TPE (theater provided equipment) is developed in order to ensure that deployed units receive required amount of equipment critical for their missions, like MMWV or communication device. TPE is known as stay-behind-equipment. The disadvantage of TPE is that they are only fixed at unit level. Keeping large amount of stocks in theater for long periods of time without the opportunity of depot level maintenance has created a number of consequences: like training of unit level personnel, high fixing costs [24]. To minimize inventory level, inventory accuracy should be provided via minimizing lead time, outsourcing, developing forecasting strategies and maintenance procedures. The relationship is given by Equation 3.14.

F_{2121}: clarify pre-positioned equipment feature F_{2122}:reduce in-theater inventory F_{2123}: reduce in-depot inventory F_{2124}: reduce non-stable inventory	D_{2121}: forecasting strategies D_{2122}: decreased lead time D_{2123}: outsource (integrated supplier, vendor) D_{2124}: maintenance procedure

$$\begin{bmatrix} F2121 \\ F2122 \\ F2123 \\ F2124 \end{bmatrix} = \begin{bmatrix} X000 \\ XX00 \\ XXX0 \\ XXXX \end{bmatrix} \begin{bmatrix} D2121 \\ D2122 \\ D2123 \\ D2124 \end{bmatrix} \quad \textbf{(3.14)}$$

Another cost factor in inventory management beside inventory level and fixed cost is inventory movement in depots. Movement on depot for distribution and for finding location should be minimized. Inventory allocation strategies should be developed based on turn out rate of equipment, volume, weight, and critical features like flammability. Tagging technologies can be used. Before Iraqu War, DOD integrated supply chain by using softwares, barcodes and RFID [5]. Instead of passive RFID systems active ones are preffered [55, 86]. Before the war, return and reuse of active RFID tags was 10% but during war decreased to %3. And only % 16 was used more than twice. Active RFID tags have transmitters that transmit information through radis signals. They hold large amount of data so they are capable of storing detailed manifest and transportation data [86]. The next generation Mobile Tracking System is a satellite tracking system for trucks that in its most advanced configuration is also able to read and relay information from radio frequency identification tags attached to containers and pallets traveling in a supply convoy. This technology could provide near real-time visibility and location data on supplies moving through the theater by surface transportation. However, the technology is expensive and few trucks are equipped with this latest configuration.

In order to decrease movement of equipment, sub-functional requirements, their design parameters and relation is given by Equation 3.15.

F_{2131}: decrease transportation in depot F_{2132}: decrease movement to find	D_{2131}: inventory allocation procedures D_{2132}: tagging strategy for visibility

$$\begin{bmatrix} F2131 \\ F2132 \end{bmatrix} = \begin{bmatrix} X & 0 \\ X & X \end{bmatrix} \begin{bmatrix} D2131 \\ D2132 \end{bmatrix} \quad \textbf{(3.15)}$$

Another way to increase profit via customer satisfaction is maximization of inventory usage. In order to use inventory in high percents, security should be provided, inventory should be stored in sufficient quantity and quality depots in order to be in good-condition, and equipment reset strategies should be developed to have currently-usable inventory. DOD has a $60 billion inventory of which General Accounting Office found 50 % to be obsolete [5].

The armys lack of adequate storage facilities for prepositioned equipment has led to equipment being stored outdoor, leaving it relatively unprotected from moisture, sand, and other elements and thus contributing to a number of maintenance problems including corrosion. For example if tanks are stored outside, preventive maintenance inspections should be performed every 30 days. If they are stored in controlled humidity warehouses, inspections are only performed every 6 months [81]. So maintenance strategy and procedures should be developed. Requirements are defined invalid and poorly resulting unreliable reporting of readiness of prepositioned equipment sets. On the other hand, by asset visibility it should be ensured what is stored and what is currently usable. Recapitalization of equipment via army reset program can help inventory currency.
In order to increase inventory usage, functional reqirements and their design parameters relation is given by Equation 3.16.

F_{221}: secure inventory F_{222}: update currently-usable inventory F_{223}:keep inventory in-good condition	D_{221}: protection measures D_{222}: equipment reset procedures D_{223}: depot features

$$\begin{bmatrix} F221 \\ F222 \\ F223 \end{bmatrix} = \begin{bmatrix} X & 0 & 0 \\ 0 & X & 0 \\ 0 & 0 & X \end{bmatrix} \begin{bmatrix} D221 \\ D222 \\ D223 \end{bmatrix} \quad \textbf{(3.16)}$$

DOD invests billions of dollars on sophisticated weapon systems and technologies. These may be at risk of exploitation when exported, stolen or lost during combat or routine missions. In order to decrease risk anti-tamper policy is developed for critical technologies. Anti-tamper techniques include software and hardware protective devices, when technologies are determined to be critical and vulnerable. To protect its critical assets, DOD established several protection measures [87]:

i) Information assurance to protect information and information systems
ii) Software protection to prevent the unauthorized distribution and exploitation of critical software
iii) Anti-tamper tech. to help delay exploitation of technologies through means such as reverse engineering when US weapons are exported or lost in battle field

In order to secure inventory, functional requirements and their design parameters relation is given by Equation 3.17.

F_{2211}: security of tangible inventory (weapon) F_{2212}: security of software	D_{2211}: anti-damper laws D_{2212}: software security tools

$$\begin{bmatrix} F2211 \\ F2212 \end{bmatrix} = \begin{bmatrix} X & 0 \\ 0 & X \end{bmatrix} \begin{bmatrix} D2211 \\ D2212 \end{bmatrix} \quad \textbf{(3.17)}$$

Design map for axiomatic design of ‘Storage management’ is given by Figure 3.4.

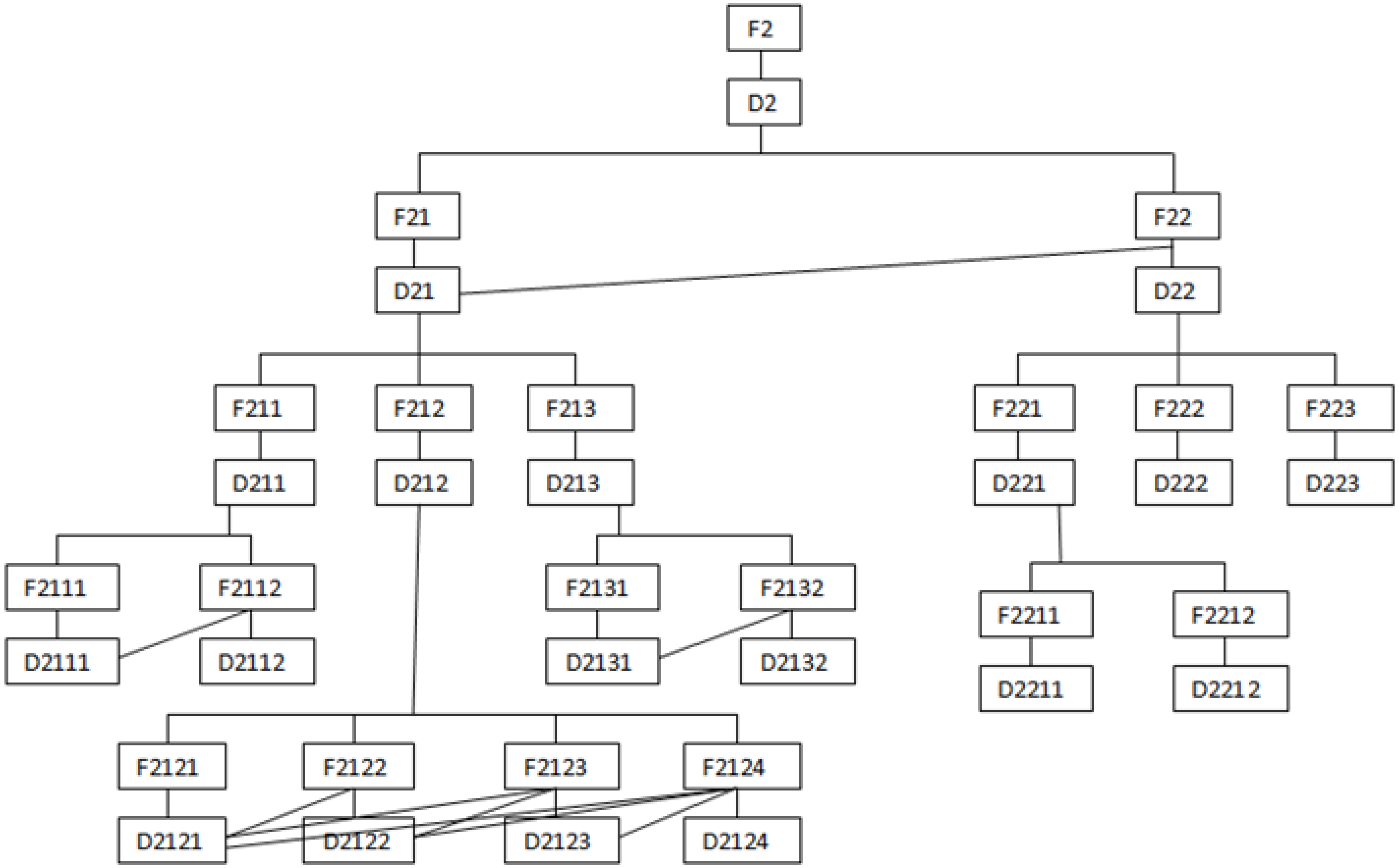


Figure 3.4 Design mapping for storage management

3.3. Distribution

According to DoD distribution is the operational process of synchronizing all elements of the logistics system to deliver right items to right place [56]. In wars, order-to-receipt time is one of the success criteria. In 2003 Iraq war, US troops upset the Saddam government in just half time of settling in 1991 Desert Storm [5].

The military distribution system has two distinct segments: strategic-national and theater. The strategic-national segment consists of moving supplies from points outside a theater of military operations into the theater. The military services and the Defense Logistics Agency manage supplies and provide for asset visibility. U.S. Transportation Command provides transportation support, primarily strategic airlift and sealift, as well as intransit asset visibility. The theater segment consists of distribution that occurs within a theater of military operations. Theater distribution is the responsibility of the geographic combatant command, such as U.S. Central Command. The combatant commander will generally designate one military service to act as the theater lead service to oversee logistics support to all of the service components and to the theater [52]. During Operation Iraqi, the Army and Marine Corps experienced problems with delivery of supplies to warfighter. To solve the problem they identified 'joint theater logistics' [55]. Joint theater logistics is aimed at improving the ability of a joint force commander to a direct various logistics functions which is shown by Figure 3. 5 [55, 88].

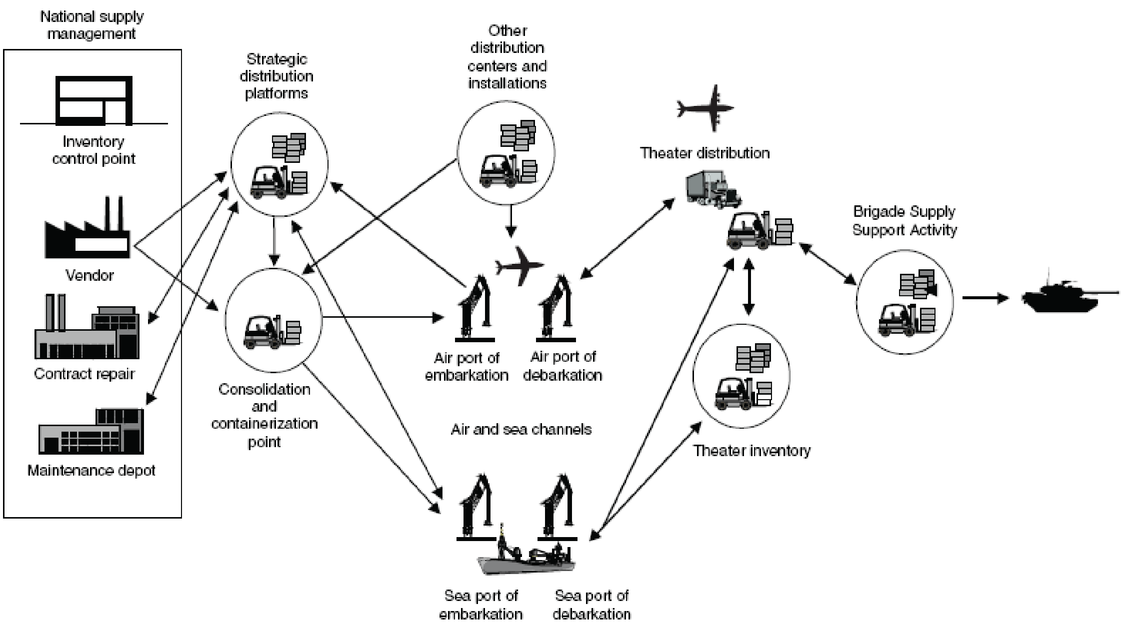


Figure 3.5. Joint Distribution System

In order to have a customer- satisfied distribution system transportation performance should be increased whereas risk of failure should be decreased. A company's distribution network design is the number and type of customer interfaces. That is, designing order entry points (where and how orders are placed) and fulfillment nodes (where and how customers obtain finished goods). Th aximatic relation is given by Equation 3.18.

F_3: customer- satisfied distribution system	D_3: distribution network design
F_{31}: increase transportation performance F_{32}: reduce risk of failure	D_{31}: transportation optimization D_{32}: increased consistency

$$\begin{bmatrix} F31 \\ F32 \end{bmatrix} = \begin{bmatrix} X & O \\ X & X \end{bmatrix} \begin{bmatrix} D31 \\ D32 \end{bmatrix} \tag{3.18}$$

Performance indicators for transportation are throughput maximization, time definite delivery, cost minimization and flexibility. Throughput maximization is reduction the number of times that supplies must be opened and sorted, for example because of pure packaging [55]. Fundamental economic principles impacting transportation economy are economy of scale and economy of distance. Transportation costs are driven by distance, volume, density, stowability -how product case dimensions fit into transportation equipment-, handling, and liability -product characteristic to damage- [58].

By flexibility, it is aimed to define a transportation mode having high maneuverability, large freight volume, can be used in all weather and climatic condition.

Transportation optimization methods are consolidation, outsourcing, route optimization and selecting right transportation mode based on product features, quantity and critique. Equipment and supplies are delivered in three ways: by air, by sea or by prepositioning [81]. Because of it is anywhere that conflict starts, and because of high cost and time consuming, land is not preferred. While airlift is fast it is expensive to use and impractical for moving all of the material needed for a large scale deployment. Although ships can carry loads, they are slower than airlift. For speed up and minimization of risk, ships are designed smaller [23]. Transportation vehicle should have capability of high speed, long distance, high maneuverability, and large freight volume [22].

By consolidating of procurement and consolidating of shipping can minimize cost and increase efficiency of distribution. Especially for their intermediaries, third party logistics is preferred. Another outsourcing method that can be used for having procurement as quickly as possible is supplier integration. An integrated supplier assumes almost total inventory management responsibilities for a customer. This is the most aggressive form of a supplier partnership where a supplier representative works in the customer's facility, ordering supplies as they are needed, and replenishing storage locations. Inventory is stored by the supplier in the supplier's warehouse until ordered and then delivered on a just-in-time basis. An integrated supplier can also perform quality inspections, maintain data on usage, test the quality of parts, prepare parts kits, establish electronic data interchange links and barcoding, and provide vendor selection management which is shown in Figure 3. 6 [79].

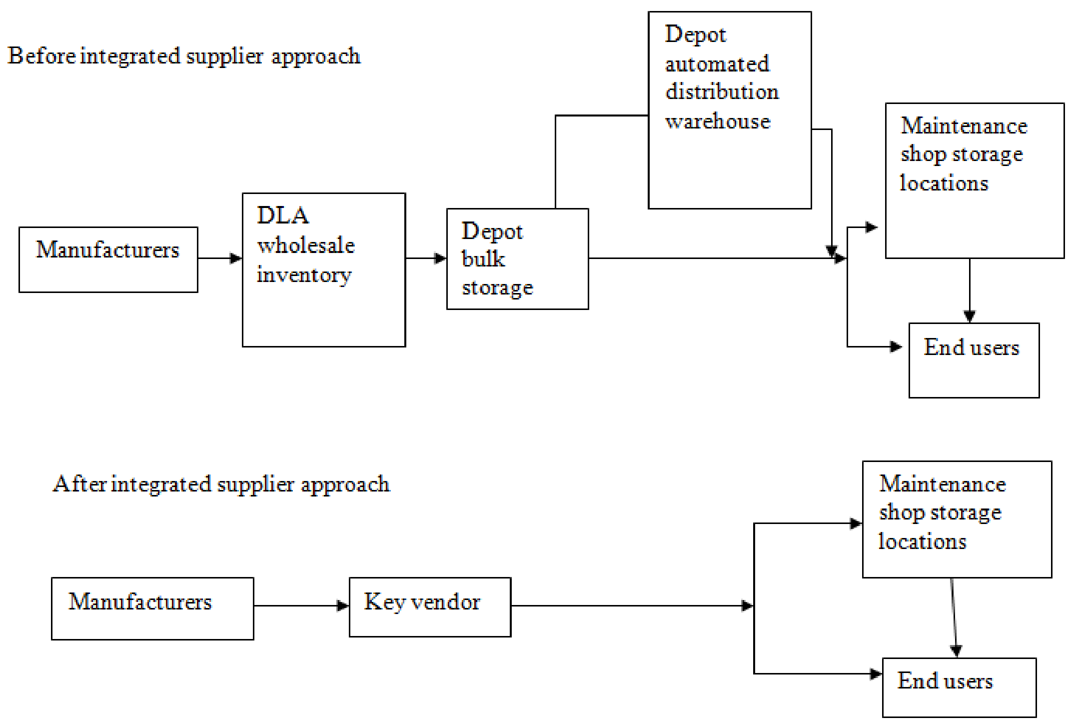


Figure 3.6 Integrated supplier

In order to increase transportation performance, sub-functional requirements and their design parameters relation is given by Equation 3.19. Equation 3.20 is given for axiomatic relation of functional requirement of increasing efficiency of distribution.

F_{311}: increase efficiency of distribution	D_{311}: routing management
F_{3111}: flexibility	D_{3111}:transportation mode selection
F_{3112}: achieve time definite delivery	D_{3112}: route optimization
F_{312}: increase throughput	D_{312}:consolidation
F_{313}:decrease cost	D_{313}:outsoursing

$$\begin{bmatrix} F311 \\ F312 \\ F313 \end{bmatrix} = \begin{bmatrix} X & 0 & 0 \\ X & X & 0 \\ X & X & X \end{bmatrix} \begin{bmatrix} D311 \\ D312 \\ D313 \end{bmatrix} \tag{3.19}$$

$$\begin{bmatrix} F3111 \\ F3112 \end{bmatrix} = \begin{bmatrix} X & O \\ X & X \end{bmatrix} \begin{bmatrix} D3111 \\ D3112 \end{bmatrix} \tag{3.20}$$

In order to minimize risk of failure, continuous flow of resources should be maintained, shipping priorities should be managed and accuracy of inventory should be provided. In order to maintain continuous, seamless, two-way flow of resources, the distribution channel principles should be integrated. Each layer of marketing intermediaries that performs some work in bringing the product to its final buyer is a "channel level". Cross-docking, transshipment and direct shipment are some of the strategies to increase distribution efficiencies. Cross-docking involves central warehousing, which do not stock inventory but serve as transshipment locations for outside vendors connecting to the organization. Direct shipment from manufacturer to customer reduces the need for intermediate transit or warehouse points [5]. Advantages of direct shipment are reduction in lead times and reduction in the expenses because of not operating a distribution center [90]. Disadvantages are risk-pooling effects and costs increase because it must send smaller trucks to more locations. Another concern in flow of resources is having a safety stock in theater. The safety stock should be minimized in order to reduce reliance on large, costly stockpiles.

Another important point in risk minimization and increase consistency is to decide shipping priorities: which one, in which order, what quantity, in which conditions, what frequency, etc [90]. To solve the problem shipping procedures should be developed based on defined criteria.

In order to have inventory accuracy, the quantity and the quality of the inventory –in transit or in warehouses- should be known, and logistician should be connected. To connect logisticians Army stated that it would acquire systems [52]:

- The very small aperture terminal: a compact satellite to replace line-of-sight communications to send and monitor requisitions for supplies from the battlefield
- Mobile tracking systems: a satellite based way text messaging system installed in trucks to provide position locations and allow truck drivers to communicate with a dispatcher

. Systems developed for distribution visibility are:

- Battle Command Sustainment Support System processes a large amount of logistics data and can facilitate decision making by providing a means for commanders to determine the sustainability of current and planned operations. The system provides a capability for tracking supply convoys moving through an area of operation. However, it lacks the integration to produce and send a cargo manifest that can be linked to an in-transit visibility device for tracking.
- TransLog Web was designed to serve as the single point of entry for transportation movement requests. This Web-based program could serve as a transportation planning and movement tracking tool to assist movement managers in coordinating supplies and transportation assets. However, the system (1) is not used by all movement control teams, (2) does not provide visibility of the cargo's description beyond the supply class, and (3) does not feed information to the Global Transportation Network.
- Transportation Coordinator's Automated Information for Movements System II is expected to enhance and improve the efficiency and effectiveness of support planning needed to deploy and redeploy forces and equipment; improve the visibility of assets; and enhance cargo and passenger receiving,

controlling, and shipping. However, the system is not scheduled to be fully operational until around 2010, and while the Army justified the system based on its joint service application, two services (the Air Force and the Marine Corps) have stated that they do not intend to use it.

In order to reduce risk of failure, axiomatic design functional requirements and design parameters relation are given by Equation 3.21.

F_{321}:accuracy of inventory F_{322}: managing shipping priorities F_{323}: maintain continuous flow of resources	D_{321}: inventory visibility D_{322}: criteria development D_{323}: distribution channel strategy

$$\begin{bmatrix} F321 \\ F322 \\ F323 \end{bmatrix} = \begin{bmatrix} X & 0 & 0 \\ X & X & 0 \\ X & X & X \end{bmatrix} \begin{bmatrix} D321 \\ D322 \\ D323 \end{bmatrix} \quad \textbf{(3.21)}$$

Design map for axiomatic design of 'Distribution Management' is given by Figure 3.7.

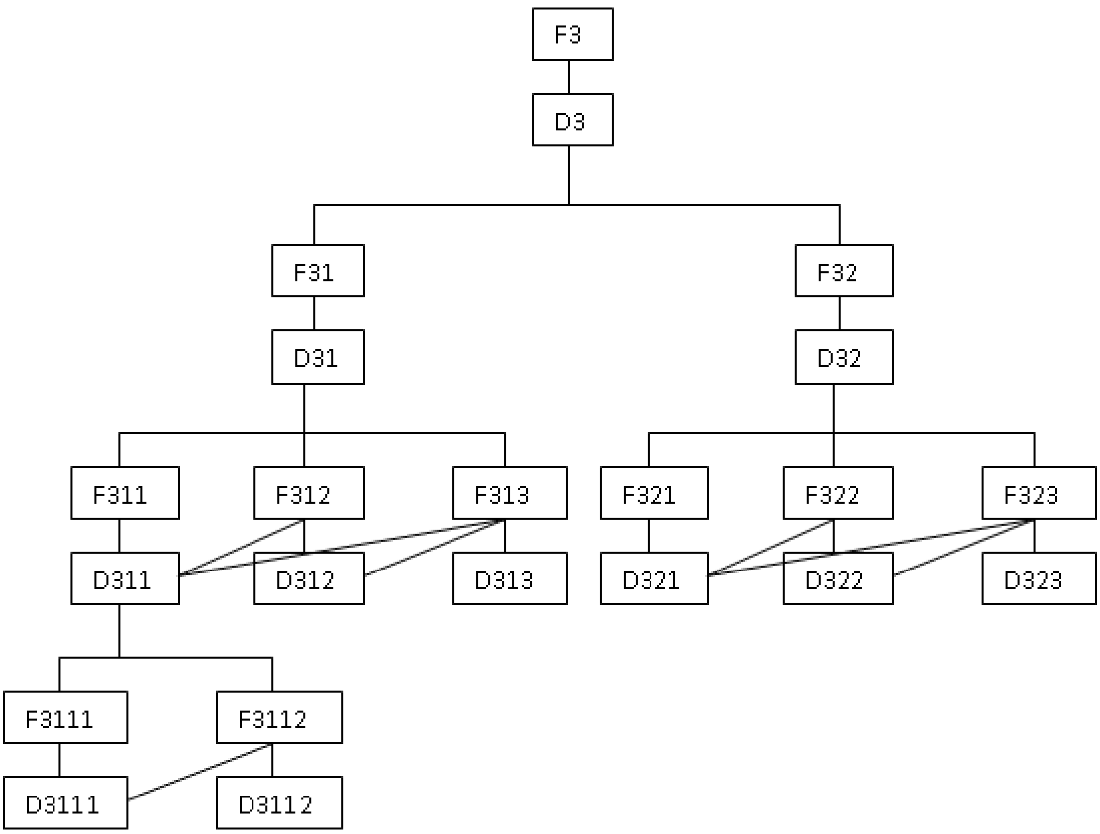


Figure 3.7 Design mapping for distribution management

3.4. Maintenance

Harsh combat and environmental conditions in theater over sustain periods exacerbates the wear and tear on equipment [91]. Maintenance is an important aspect of military logistics and includes those activities needed to keep weapons, vehicles, and other materiel in an operable condition; to restore them to a serviceable condition when necessary; or to improve their usefulness through modifications. Such maintenance activities include inspection, testing, and classification as to serviceability, adjustment, servicing, recovery, evacuation, repair, overhaul, and modification. Modern military equipment is complex and expensive and must be designed with reliability, durability, and ease of maintenance in mind. Thus, maintenance requirements, the potential usage of repair parts, and the tools and equipment needed to effect repairs are determined during the equipment development process, and operational capabilities must sometimes be sacrificed for greater reliability or ease of maintenance. Life cycle maintenance costs are also an important consideration inasmuch as the lifetime maintenance costs usually exceed an item's initial acquisition costs.

The Army calls maintenance as reset as the repair, recapitalization and replacement of equipment to equip units preparing for deployment and improve next-to-deploy unit’s equipment on hand levels. Repair can be made at the field level or national (depot) level. Field level maintenance is done by soldiers augmented by contractors, as required and is usually performed at installations where the equipment is stationed. National level maintenance work performed on equipment that exceeds field level reset capabilities. Depot maintenance as defined as the material maintenance and repair requiring the overhaul, upgrading, or rebuilding of parts, assemblies, or subassemblies, and the testing and reclamation of equipment as necessary, regardless of the source of funds or the location at which the maintenance or repair is performed [92]. National level maintenance may be done at Army depots by contractors, by installation activities or as a combination of the two [91]. Recapitalization includes rebuilding of equipment which could include: extending service life, reducing operating and support costs, enhancing capability and improving system reliability. The objective of recapitalization process include extending equipment service life, reducing operating and support costs, enhancing capability, improving system reliability and maintainability [93]. Replacement includes buying new equipment to replace confirmed battle losses, washouts, obsolete equipment and critical equipment deployed and left in theater but needed by reserve components for homeland defense and security missions [91, 93].

In order to have a customer satisfied maintenance function, total cost, risk and required time should be decreased. By taking some precautions, customers can be satisfied. The relation is given by Equation 3.22.

F_4: satisfy customer	D_4: strategy development
F_{41}: reduce total cost F_{42}: decrease risk F_{43}: decrease time per work	D_{41}: decreased repairing D_{42}: accuracy D_{43}: speed up strategies

$$\begin{bmatrix} F41 \\ F42 \\ F43 \end{bmatrix} = \begin{bmatrix} X & 0 & 0 \\ 0 & X & 0 \\ 0 & 0 & X \end{bmatrix} \begin{bmatrix} D41 \\ D42 \\ D43 \end{bmatrix} \quad \textbf{(3.22)}$$

Cost for repairing are shipping, material and personnel costs. Shipment cost is the cost of delivering the product to the repair facility including the packaging and shipping cost of both sending the product for repair and returning it alter it is repaired. Personnel cost is the direct and indirect cost of human resources applied to a repair job. Material cost is the direct and indirect cost of parts and machinery applied to a repair job [94]. Personnel costs include training and labor costs. In order to minimize costs there are some strategies like consolidation and outsourcing. Directly a firm just responsible for repair and maintenance can be outsourced. At the same time especially for weapon systems the firm sold products can be responsible. Another method to decrease cost is to take precautions for breakdown like predictive and preventive maintenance or resetting the equipment. The relation is given by Equation 3.23.

F_{411}: decrease personnel costs F_{412}: material costs F_{413}: decrease shipping& storage cos	D_{411}: outsourcing D_{412}: taking precautions for breakdown frequency D_{413}: consolidation

$$\begin{bmatrix} F411 \\ F412 \\ F413 \end{bmatrix} = \begin{bmatrix} X & 0 & 0 \\ X & X & 0 \\ X & X & X \end{bmatrix} \begin{bmatrix} D411 \\ D412 \\ D413 \end{bmatrix} \quad \textbf{(3.23)}$$

For military risk is human life. So everything should be made to decrease risk. Equipment should be repaired correctively and should not affect army readiness too much. If it takes too much time army should use another equipment instead of it [89]. So life of the equipment and all of its affect should be forecasted. To be repaired correctively equipment should be sent to a maintenance center that satisfies criteria for that problem. In order to decrease risk, functional requirements and their relation to design parameters is given by Equation 3.24.

F_{42}: decrease risk	D_{42}: accuracy
F_{421}: repaire correct way F_{422}: decrease affect to army readiness	D_{421}: maintenance center capability criteria D_{422}: time and life forecasting for if new procurement is needed

$$\begin{bmatrix} F421 \\ F422 \end{bmatrix} = \begin{bmatrix} X & 0 \\ 0 & X \end{bmatrix} \begin{bmatrix} D421 \\ D422 \end{bmatrix} \quad \textbf{(3.24)}$$

Another important point is minimization of time for maintenance and shipping. By choosing faster transportation methods – decreasing distance or speed up- shipping time can be reduced. If unit level is enough there is no need to send equipment to another center. Maintenance time includes preparation time and core-repair time. To decrease time, maintenance procedure should be developed and maintenance center should be designed in that way. Procedures should be developed based on the environment where the equipment is used. For example for vehicles used in Iraq and Afghanistan 3D (delayed desert damage) and STIR (special technical inspection and repair) methods are developed [24]. Another important point is repair items in the sequence of their critical level [95]. One approach to accelerate the repair process and promote flexibility in the repair shop is the “cellular” concept. Under this concept, an airline moved all of the resources that are needed to repair broken parts, such as tooling and support equipment, personnel, and inventory, into one location or repair center "cell." This approach simplifies the repair of parts by eliminating the time-consuming exercise of routing parts to workshops in different locations. It also ensures that mechanics have the technical support to ensure that operations run smoothly. In addition, because inventory is placed near workshops, mechanics have quick access to the parts they need to complete repairs more quickly. British Airways adopted the cellular approach after determining that parts could be repaired as much as ten times faster using this concept [96].

In order to decrease time, maintenance time and shipping time should be decreased. The axiomatic relation is given by Equation 3.25 and Equation 3.26.

F_{43}: decrease time	D_{43}: speed up strategies
F_{431}: decrease maintenance time F_{4311}: decrease core-repair time F_{4312}: decrease preparation time F_{432}: decrease shipping time	D_{431}: reduce time for non-value added tasks D_{4311}: maintenance procedure D_{4312}: maintenance center design D_{432}: faster transportation

$$\begin{bmatrix} F431 \\ F432 \end{bmatrix} = \begin{bmatrix} X & 0 \\ 0 & X \end{bmatrix} \begin{bmatrix} D431 \\ D432 \end{bmatrix} \tag{3.25}$$

$$\begin{bmatrix} F4311 \\ F4312 \end{bmatrix} = \begin{bmatrix} X & 0 \\ X & X \end{bmatrix} \begin{bmatrix} D4311 \\ D4312 \end{bmatrix} \tag{3.26}$$

Design map for axiomatic design of 'Maintenance Management' is shown by Figure 3.8.

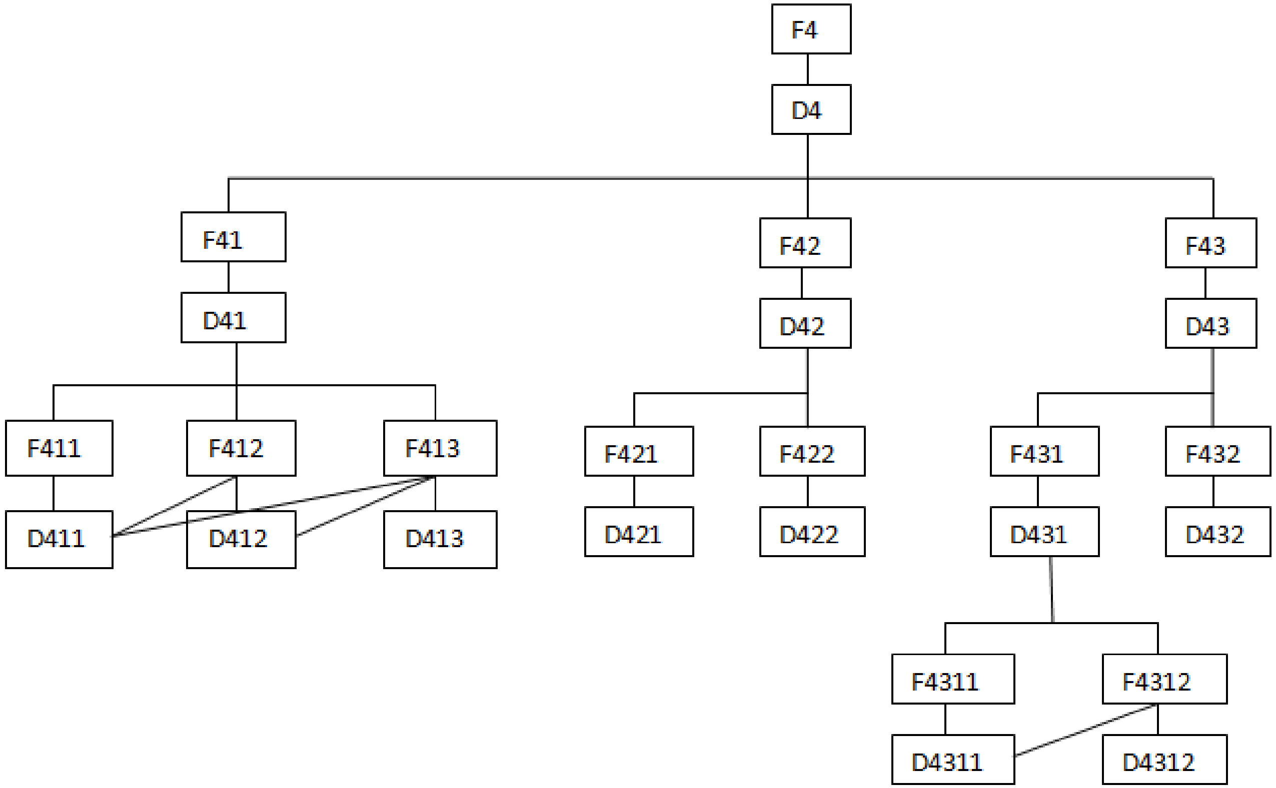


Figure 3.8. Design mapping for maintenance management

4. CONCLUSION

As long as there is a conflict of any kind, and weapons are being used by the parties, the military is the only organization that can secure interests. In war, the victory does not always go to those having the largest army or the most sophisticated equipment. It goes to who has more efficient strategic plan. Strategy considers all the components of national power: economic, political, socio-psychological and military. At the beginning of WWII, both French and British had tanks superior to those used by the Panzer Divisions. However the Germans knew how to employ their weapons. As another example Iraqi war can be given. Although USA forces were more sophisticated, it is hard to tell about a victory. So everything depends on strategic plan: when, where and with what forces a battle is to be delivered; in other words on logistics how and where to locate.

In this study, it is aimed to develop military logistics network via axiomatic design principles. In the first part of the study, military logistics definitions are given and it is told how military logistics reached its current form. In the second part, axiomatic design principles and a brief literature review in supply chain is told. On the third part, in order to be as an example, US military logistics transformation is given. Especially new terms and methods are told.

During logistics network design, it is divided to 4 steps: acquisition, storage, distribution and maintenance.

As seen during study, in acquisition it is important to buy products in required amount and desired features to minimum cost at the right time. Cost includes variable product costs, shipping cost and fixed costs. In order to decrease cost, consolidation, outsourcing or any step that will decrease demand can be used. Price analysis should be made and inventory visibility should be maintained. In acquisition, besides cost, it is important to buy products in desired features- desired quantity and quality. Demand quantity depends on safety stock in peace time and probability of war. Quality not only depends on what is available in the market but also depends on enemy's' quality standards. Forecasting, spying and updating product information are necessities. In order to buy products at the right time order-management procedures should be developed and lead time should be decreased.

Second design step is storage. For strategic mobility framework, some equipment should be prepositioned. Instead of long movement of needed equipment, by prepositioning it allows combat-ready forces. Managing inventory is one of the key features of logistics. Inventory management includes minimization of costs and maximization of usage of inventory. Profit maximization and risk minimization strategies should be developed to better management. In order to minimize costs, fixed costs including fixed assets and administration& selling costs should be decreased; inventory levels and movement of inventory in depots should be minimized by eliminating non-value added functions as much as possible, inventory accuracy and developing inventory allocation strategy. Inventory level minimization means minimization in depot inventory, minimization of non-stable inventory (under maintenance and in-transit), clarification of pre-positioned equipment quantity and minimization of in-theater inventory. Another concern in storage design is to keep assets in safe and good conditions.

Third design step is distribution design. The military distribution system has two distinct segments: strategic-national and theater. The strategic-national segment consists of moving supplies from points outside a theater of military operations into the theater. The theater segment consists of distribution that occurs within a theater of military operations. In distribution it is aimed to increase efficiency and decrease risk of failure. Performance indicators for transportation are throughput maximization, time definite delivery, cost minimization and flexibility. Fundamental economic principles impacting transportation economy are economy of scale and economy of distance. Transportation costs are driven by distance, volume, density, stowability -how product case dimensions fit into transportation equipment-, handling, and liability. By flexibility, it is aimed to define a transportation mode having high maneuverability, large freight volume, can be used in all weather and climatic condition. In order to increase efficiency transportation methods should be optimized. Transportation optimization methods are consolidation, outsourcing, route optimization and selecting right transportation mode based on product features, quantity and critique. Another important point in distribution is to decide shipping priorities: which one, in which order, what quantity, in which conditions, what frequency. To solve the problem shipping procedures should be developed based on defined criteria.

The last design step is maintenance design. Maintenance is an important aspect of military logistics and includes those activities needed to keep weapons, vehicles, and other materiel in an operable condition; to restore them to a serviceable condition when necessary; or to improve their usefulness through modifications. The Army calls maintenance as reset as the repair, recapitalization and replacement of equipment to equip units preparing for deployment and improve next-to-deploy unit's equipment on hand levels. In order to have a customer satisfied maintenance function, total cost, risk and required time should be decreased. Cost for repairing are shipping, material and personnel costs. Outsourcing, consolidation and decrease breakdown-frequency can reduce costs. Speed and the accuracy of repair are other issues. Figure 4.1 shows the whole design process on the next page.

The weak parts of the study are its assumptions. It is assumed that:

- All geographical conditions are known.
- There is no source restriction.
- War is conventional.
- Material logistics is designed.
- Outbound logistics is studied.

For further studies, logistics can be designed to a special geography. Money, men and time restrictions should be added. Nowadays wars are generally unconventional. So designing a peer-to-peer war is just the first step. Military logistics does not only include material logistics but also human logistics and facility logistics. These items should be integrated to the system. Military logistics includes 2 parts: outbound and in-theater. In-theater logistics network is absolutely a different design and should be studied separately.

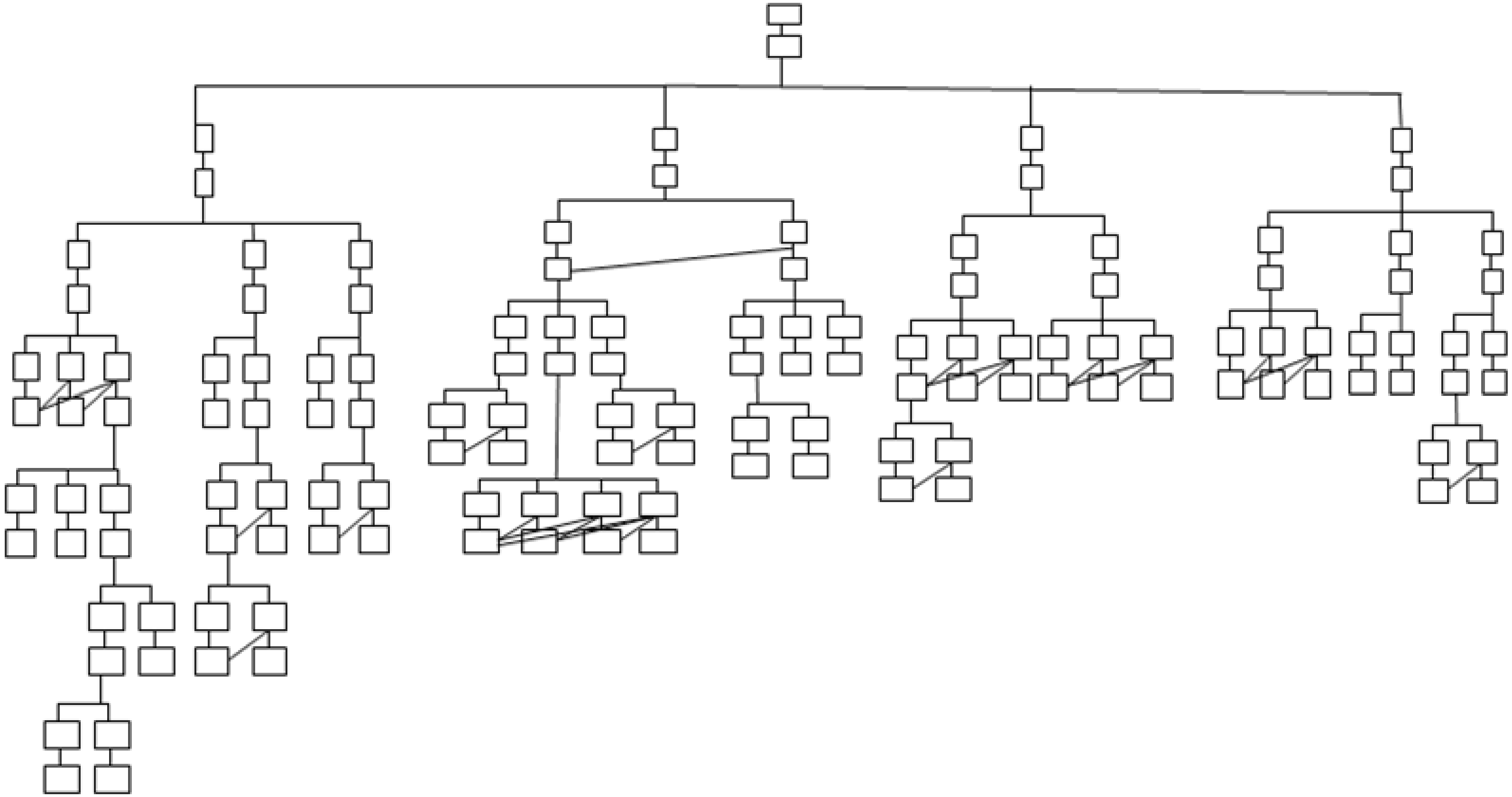


Figure 4.1. Design mapping for logistics network

REFERENCES

[1] **Pitney, J**., 2000. *The Art of political warfare*, University of Oklahama Press, Oklahama, USA.

[2] **Megargee, G**., 2000. *Inside Hitler’s High Command*, University Press of Kansas, Kansas, USA.

[3] **Gansler, J. & Luby, R**., 2004. *Transforming government supply chain management*, Rowman &Littlefield Publishers, USA.

[4] **Leonard, R**., 1967. *A short guide to Clausewitz on war*, G.P. Putnam’s Sons, Newyork, USA.

[5] **GAO,** June 2000. *Defense logistics: Actions needed to enhance success of reengineering initiatives*, Washington, USA.

[6] **Windass, S., Walker P., & Winsdor, P.,** 1985. *Avoiding nuclear war common security as a strategy for defense of the west*, Brasseys Defense Publishers, USA.

[7] **Metz, S. & Millen, R.,** 2003. *Future war/ future battlespace the strategic role of American landpower*, Strategic Studies Institute, Pennsilvania, USA.

[8] **Mockaitis, T.,** 2007. *The Iraq war: Learning from the past, adapting to the present, and planning for the future*, Strategic Studies institute, Pennsilvania, USA.

[9] **Martin, L.,** 1984. *Before the Day After: Can NATO Defend Europe?,* Newnes Books, Feltham, England.

[10] **Thompson, J.,** 1998. *Lifeblood of War: Logistics in Armed Conflict*, Brassey's, London, England.

[11] **Wavell, Field Marshal**, 1946. *Speaking Generally*, Macmillan, London, England.

[12] **Machiavelli, N.**, 2003. *Art of War*, The University of Chicago Press, Chicago, USA.

[13] **Cinar, B**., 2003. Savas tarihinde saldiri-savunma iliskisi, *Stradigma*, **Vol 9**., pg. 24-32.

[14] **Stockholm International Peace Research Inst**, 1978. *Tactical nuclear weapons: European perspectives*, Taylor & Francis, Newyork, USA.

[15] **Dunn, K**., 1990. *In defense of Nato the Alliances enduring value,* Westview Press, USA.

[16] **Kibaroglu, M**., 2008. *Nukleer silahlar ve Turkiye*, TUSIAD, Turkey, www. Tusiad.org.

[17] **Secretary of Air Force,** 2002. *Air Force Doctrine Document: Electronic warfare*, Washington DC, USA.

[18] **Huston, J.,** 1984, *one for all: nato strategy and logistics through the formative period 1949-69*, University of Delaware Press, Newark, USA.

[19] **Quinlan, M.,** 2001. *European Defense Cooperation: asset or threat to Nato*, Woodow Wilson center press, Washington, USA.

[20] **Smith, R.,** 1997. Logistical support to the US Army during the War with Mexico 1845-1847, *Master Theisis*, Kansas City, Missouri University, USA.

[21] **Young, S.,** 2004. *Defense Logistics Agency's Business Systems Modernization: Delivering 21st Century Logistics*, Rowman & Littlefield Publishers, Newyork, USA.

[22] **Machiavelli, N.,** 2003. *Art of War*, The University of Chicago Press, Chicago, USA.

[23] **Kiley, D.,** (2003). Persian Gulf Star Humvee back in spotlight, USA Today, USA. http://www.usatoday.com/money/world/iraq/2003-03-23 humvee_x.htm, 29.08.2008

[24] **Dunn, K.,** 1990. *In defense of NATO: the Alliances Enduring Value*, Westview Press, Colorado, USA.

[25] **Huston, J.,** 1984. *One for all: NATO strategy and logistics through the formative period (1949-69)*, University of Delaware Press, Newark, DE, USA.

[26] **Sun Tzu,** 1971. *Art of War*, Oxford University Press, England.

[27] **Leonard, A.,** 1967. *A short guide to Clausewitz on war*, G.P. Putnams sons, Newyork, USA.

[28] **Jouston, M.,** 1984. *NATO strategy and Logistics*, University of Delaware Press, Newark, DE, USA.

[29] **Pillsburg, M.,** 1998. *Chinese views of future warfare*, National University Press, Washington DC, USA.

[30] **Pitney, J.,** 2000. *The Art of Political Warfare*, University of Oklahoma Press, Oklahoma, USA.

[31] **Megargee, P.,** 2000. *Inside Hitlers High Command*, University Press Kansas, Kansas, USA.

[32] **Kiley, D.,** (2004). Military uses private sector supply tactics, USA Today, USA.*http://www.ccdott.org/transfer/projresults/2005/task%205.05/task%205.05_7g.pdf* , 14.11.2009.

[33] **Alexander, J.,** 2003. *Winning the war: advanced weapons, strategies and concepts for post 9-11*, Thomas dunne Books, Newyork, USA.

[34] **Gansler, J., &Luby, R.,** 2004. *Transforming government supply chain management*, Rowman &Littlefield Publishers, Newyork, USA.

[35] **Mackaitis, T.,** 2007. *The Iraq war: learning from past, adapting to present,and planning for the future',* Strategic studies Institute.

[36] **Cardinali, R.,** 2001. Does the future of military logistics lie in outsourcing and privatization?, *ABI/INFORM Global*, **Vol. 50** Issue 3, pg. 105.

[37] **Smith, R.,** 1997. Logistical support to the US Army during the war with mexico 1845-1847, *Master Theisis*, University of Kansas city, Kansas City MO, USA.

[38] **Arikan, M. O.,** 2004. Transformation of the Israel DefenseForces: An Application of the US Military Transformation?, *Master Theisis*, Naval Postgraduate School, Monterey, California, USA.

[39] A**lcide,D.,** 2006. Transformation of organizational Legacy Logistics Systems and Facilitating an Integrated Lean Enterprise: A Case Study within the United States Army, *Phd Theisis*, Capella University, Minneapolis, USA.

[40] **Maddox,D.,** 2005. Organizing Defense Logistics: What Strategic Structures Should Exist for the Defense Supply Chain?, *Master Theisis*, Faculty of the US Army Command and General Staff College Kansas, USA.

[41] **Windass, S., Walker P., & Winsdor, P.,** 1985. *Avoiding nuclear war common security as a strategy for defense of the west*, Brasseys Defense Publishers, London, England.

[42] **Pillsburg, M.,** 1998. *Chinese views of future warfare*, National Defense University Press, Washington, DC, USA.

[43] **Suh, N. P.,** 1990. Design of thinking design machine, *Annals of the CIRP*, **volume 39** issue 1, pg145–149.

[44] **Martin, B. & Kar, K.,** 2001. *Developing E-Commerce Strategies Based on Axiomatic Design*, Marmara University, Faculty of Engineering Istanbul, Turkey.

[45] **Suh, N. P.**, 2001. *Axiomatic design: Advance and applications*, Oxford University Press, England.

[46] **Kulak, O., cebi, S.& Kahraman, C.,** 2010. Applications of axiomatic design principles: aliterature review, *Expert Systems with Applications*, In press.

[47] **Ozel, B. &Ozyoruk, B.,** 2007. Bulanik Aksiyomatik Tasarim ile tedarikci secimi, *Gazi Uni. Mim. Muh. Fak. Dergisi*, **Vol 22**, No 3, 415-423.

[48] **Favaro,** 2008, '*Application of axiomatic design to develop a lean logistics design method',*The 41st CIRP conference on manufacturing systems.

[49] **Matthias J Schnetzler, Andreas Sennheiser, Paul Schönsleben,** 2007. A decomposition-based approach for the development of a supply chain strategy, *International Journal of Production Economics*, **Vol. 105,** Iss. 1; pg. 21

[50] **Celik, M., Cebi, S., Kahraman, C., & Er, D.,** 2009. Application of axiomatic design and TOPSIS methodologies under fuzzy environment for proposing competitive strategies on Turkish container ports in maritime transportation network, *Expert Systems with Applications*, **Volume 36**, Issue 3, Part 1, , Pages 4541-4557.

[51] **Kulak, O.,& Kahraman, C.,** 2005. Fuzzy multi-attribute selection among transportation companies using axiomatic design and analytic hierarchy process, *Information Sciences,* **Volume 170**, Issues 2-4, 25, Pages 191-210.

[52] **GAO,** May 2008. *Defense logistics: Navy needs to develop and implement a plan to ensure that voyage repairs are available to ships operating near Guam when needed*, Washington, USA.

[53] **Solis, W,,** January 2007. *Defense logistics: Preliminary observations on the Army's implementation of its equipment reset strategies*, GAO, Washington, USA.

[54] **GAO,** February 2007. *Defense logistics: Improved oversight and increased coordination needed to ensure viability of the Army's prepositioning strategy,* Washington, USA.

[55] **GAO,** June 2007. *Defense Logistics: Efforts to Improve Distribution and supply support for Joint Military Operations Could Benefit from a Coordinated Approach,* Washington, USA.

[56] **GAO,** March 2006. *Defense logistics: More efficient use of active RFID tags could potentially avoid millions in unnecessary purchases,* Washington, USA.

[57] **GAO,** September 2007. *Defense logistics: Army& Marine Corps connot be assured that equipment reset strategies will sustain equipment availability while meeting ongoing operational requirements,* Washington, USA.

[58] **Solis, W.,** March 2006. *Defense logistics: Preliminary observations on equipment reset challenges and issues for the Army and Marine Corps,* GAO, Washington, USA.

[59] **GAO,** September 2006. *Defense logistics: Changes to stryker vehicle maintenance support should identify strategies and addressing implementation challenges*, Washington, USA.

[60] **GAO,** March 2005. *Defense logistics: High-level DoD coordination is needed to futher improve the management of the Army's LOGCAP contract*, Washington, USA.

[61] **GAO,** June 2006. *Defense logistics: Lack of synchronized approach between the Marine Corps and Army affected the timely production and installation of Marine Corps truck armor*, Washington, USA.

[62] **GAO,** April 2005. *Defense logistics: Actions needed to improve the availability of critical items during current and future operations,* Washington, USA.

[63] **GAO,** August 2005. *Defense logistics: DoD has begun to improve supply distribution operations, but further actions are needed to sustain these efforts,* Washington, USA.

[64] **GAO,** September 2005. *Defense logistics: Better management and oversight of prepositioning programs needed to reduce risks and improve future programs*, Washington, USA.

[65] **GAO,** September 2002. *Defense logistics: Improving customer feedback program could enhance DLA's delivery of services*, Washington, USA.

[66] **GAO,** February 2002. *Defense logistics: opportunities to improve the Army's and the Navy's decision-making process of weapon systems support*, Washington, USA.

[67] **GAO,** April 2001. *Defense logistics: unfinished actions limit reliability of the munition requirements determination process,* Washington, USA.

[68] **GAO,** June 2000. *Defense logistics: integrated plans and improved implementation needed to enhance engineering efforts,* Washington, USA.

[69] **Trump, P.,** 1996. *Strategic planning in the defense logistic agency*, Langley Air Force Base, VA, USA.

[70] **GAO,** October 2001. *Defense logistics: Actions needed to overcome capability gaps in the public depot system*, Washington, USA.

[71] **GAO,** October 2001. *Defense logistics: Strategic planning weakness leave economy, efficiency and effectiveness of the future support systems at risk*, Washington, USA.

[72] **GAO,** April 2000. *Defense logistics: Air force report on contractor support is narrowly focused*, Washington, USA.

[73] **GAO,** June 2000. *Defense logistics: Actions needed to enhance success of reengineering initiatives*, Washington, USA.

[74] **GAO,** November 1999. *Defense logistics: Army should assess costs and benefits of the workload performance system expansion*, Washington, USA.

[75] **GAO,** April 1998. *Defense logistics agency: process for selecting defense distribution center site contained weakness*, Washington, USA.

[76] **GAO,** February 1997. *Defense logistics: Much of the inventory exceeds current needs*, Washington, USA.

[77] **GAO,** October 2005. *Information Security: the defense logistics agency needs to fully implement its security program*, Washington, USA.

[78] **GAO,** April 2002. *Defense acquisitions: status of defense logistics agency's efforts to address spare part price increases*, Washington, USA.

[79] **GAO,** January 2000. *Defense inventory: Opportunities exist to expand the use of defense logistics agency best practises*, Washington, USA.

[80] **GAO,** March 2007. *Defense inventory: opportunities exist to improve DoD's acquisition lead times for spare parts*, Washington, USA.

[81] **GAO,** February 2007. *Defense management: DLA has made progress in improving prime vendor program, but has not yet completed all corrective actions*, Washington, USA.

[82] **GAO**, June 2006. *Defense management: Attention is needed to improve oversight of DLA prime vendor program*, Washington, USA.

[83] **GAO**, February 2003. *Contract management: DLA properly implemented best value contracting for clothing and textiles and views the supplier base uncertain*, Washington, USA.

[84] **GAO,** July 1997. *Inventory management: greater use of best practices could reduce DoD's logistics costs*, Washington, USA.

[85] **Office of the Under Secretery of Defense for Acquisition, Technology &Logistics,** January 2001. *Defense science board task force on logistics transformation –phase II*, Washington, USA.

[86] **GAO,** January 1998. *Defense inventory management expanding use of the best practices for hardware items can reduce logistics costs,* Washington, USA.

[87] **GAO**, December 1998. *The defense science board 1998 summer study task force DoD logistics transformation Volume I,* Washington, USA.

[88] **Glisson, H.,** 1999, *'Revolution in military logistics- improving support to warfighter'*, Army Logistican, Vol. 31 Issue 1.

[89] **Roberts, M.,** 2005. PWC logistics wins military contracts, *Gulf Shipper*, **Vol 12**, pg 9.

[90] **Shister, N.,** 2004. What the military is teaching us about supply chains, *World Trade*, **Vol 17** Issue 12, pg 8.

[91] **Denicoff, M.,** 1967. Military essentiality of naval aviation repair parts', *Management Science*, **Vol. 13** issue 8.

[92] **Stokes, C.,** 2006. *Adaptive performance implications for military logistics*, IEEE.

[93] **Arnold, M., & Lisall, E.,** 1997. *Outsourcing: implications for supply chain*, Advanced Purchasing Studies Center, pennsilvania, USA.

[94] **Bowersox, D., Closs, D. &Cooper, B**., 2002. *Supply Chain logistics management*, McGraw Hill, USA.

[95] **Simchi-Levi, D., &Kominsky**, P., 2003. *Designing & managing the supply chain concepts, strategies and case studies*, McGraw-Hill, Second Edition, USA.

[96] **Shapiro, R. & Heskett**, J., 1985. *Logistics strategies,* West publishing Company, Chicago, USA .

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