Executive Summary

Sichuan Telecom, a branch of China Telecom Ltd., is a leading provider of Telecom services in the Sichuan province of China. The internet service provider division is a business priority due to high growth rate in 2006, with a focus on ADSL business and related value added services.

Sichuan Telecom has been struggling with operational management of ADSL modem inventory with constant overstock and out-of-stock problems in 2006. The manager of the procurement centre and her team carried out a supply chain analysis to understand the root cause of this problem and control the increasing complexity of supply chain logistics in a rapid growth market.

This paper provides an overview of these challenges with supporting detail; and examines the effect of changing the supplier aggregation, transhipment, and high service level on safety stocks and associated costs in the supply chain. The key recommendations provided are: streamline supplier management by aggregating suppliers, accommodate transhipment between and within districts, and implement a decentralised tree system to drive down costs by reducing over-stock situations. When implemented, these recommendations can cut overstock and out-of-stock issues and help maintain a high service level, while driving down overall holding costs.

Contents

1 Introduction

1.1 Company Overview

In 1998, the Postal Administration Bureau in China made a series of major reforms to the national telecommunication system. These changes included giving away its paging business to China Unicom, separating postal and telecommunication services, and separating mobile and satellite communications. The Postal Administration Bureau intended to cease being a governmental establishment, and evolve into a dynamic enterprise instead. These wholesale changes gave birth to the Sichuan Telecom Company, which was founded and began to operate in July 2000.

China Telecom Co. Ltd. acquired Sichuan Telecom Co. Ltd and formally registered it in 2002, listing it on the New York and Hong Kong stock exchanges. As a subsidiary of China Telecom, Sichuan Telecom provided telecommunication services for both fixed and mobile telephones, and data access to the Chinese province of Sichuan. By 2006, the company's market share had exploded to 17 million subscribers with 1.5 million broadband users, generating revenue of approximately RMB 12 billion for Sichuan Telecom.

The rapid development of the telecommunications market included five main competitors in the Sichuan province: Sichuan Telecom, China Mobile (CMCC), Unicom, China Netcom (CNC) and China Railcom (CRNET). Among these most of the market share (total number of users and business revenue) was held by Sichuan Telecom and Sichuan Mobile. However, Sichuan Mobile was not in direct competition with Sichuan Telecom since it focused its operations on mobile telecommunications only, which wasn't central to Sichuan Telecom's business strategy. The other three providers could not compete with the sheer size of Sichuan Telecom, which maintained superior scale and resources.

While mobile phone subscriptions grew rapidly, there was a diminishing demand for fixed telephone services because an increasing number of people were choosing to replace their fixed telephone with a mobile telephone. In fact, some areas of Sichuan even experienced negative growth in telephone services. Despite this downturn in fixed telephone subscriptions, revenue from Sichuan Telecom's Internet services and related value added services flourished with growths of 26.6% and 63.3% respectively. Broadband subscribers also increased at the high rate of 51.8% year on year.

Sichuan Telecom offered three kinds of broadband services: optical fibre, Local Area Network (LAN), and Asymmetric Digital Subscriber line (ADSL), with ADSL being the most popular. Due to the size of its ADSL customer base, each city and region dedicated most of its resources to the ADSL business. Optical fibres and LAN connections offered by Sichuan Telecom were preferred by the corporate consumers and did not play a crucial role in the growth of the Internet services of the company.

1.2 Supply Chain

Sichuan Telecom had an annual framework agreement with multiple suppliers (5 suppliers were chosen in 2006) concerning the model and prices of ADSL modems. Instead of specifying suppliers for each district, the supply volume was managed based on a set percentage of purchase for each supplier (Appendix 4). At the start of each year, Sichuan Telecom's marketing department allocated an annual sales target to each district based on their annual forecast and market conditions. Based on past performance, this annual target was broken down monthly and allocated among branches at lower level. These branches, based on the local business environment, set the sales target for the ground level sales staff (account manager, community manager etc.). The pricing scheme for modems was also developed independently by each district according to local market conditions which was implemented by local branches in each district, complemented by promotional activities to boost sales. Sichuan Telecom expected the local branches to maintain service levels at 99%.

Sichuan Telecom's insistence on a very high service level stemmed from its direct competition with Unicom, CNC, and CRNET in a rapidly developing market. Although Sichuan Telecom maintained majority market share in the region, the customers have had alternative service providers to choose from; so, Sichuan Telecom focused its business strategy around premium customer service. It could do this by using its market power to its advantage by providing better quality of services at a subsidised fee to its customers in comparison to competitor networks.

Another reason Sichuan Telecom demanded a 99% service level was due to the long-term relationships that were created with their customers. Typically, ADSL modems represented long-term functional products, which maintained customer subscriptions for a long time. However, if the company lost a customer, it was unlikely that he would reinstate a Sichuan Telecom ADSL modem.

An efficient and robust supply chain was needed to support these ambitious customer service targets. Installation of modem services was handled by community managers at the local level. After a contract was signed by a customer for service, the community manager completed the installation within 24 hours. These employees were mobile workers, carrying 2-3 modems with them for quick response. The number of community managers for each district can be found in Appendix 3.

When these district branches required replenishments, they placed an order with the procurement centre (subject to internal approval). The procurement centre then placed the order with each supplier in line with framework agreement. The order processing lead time was expected to be under two days. Once the order was placed, the supplier would deliver the modems in line with its expected lead time (Appendix 2) to the central warehouse in Wenjiang. Based on the procurement applications, the modems were delivered to district level warehouses.

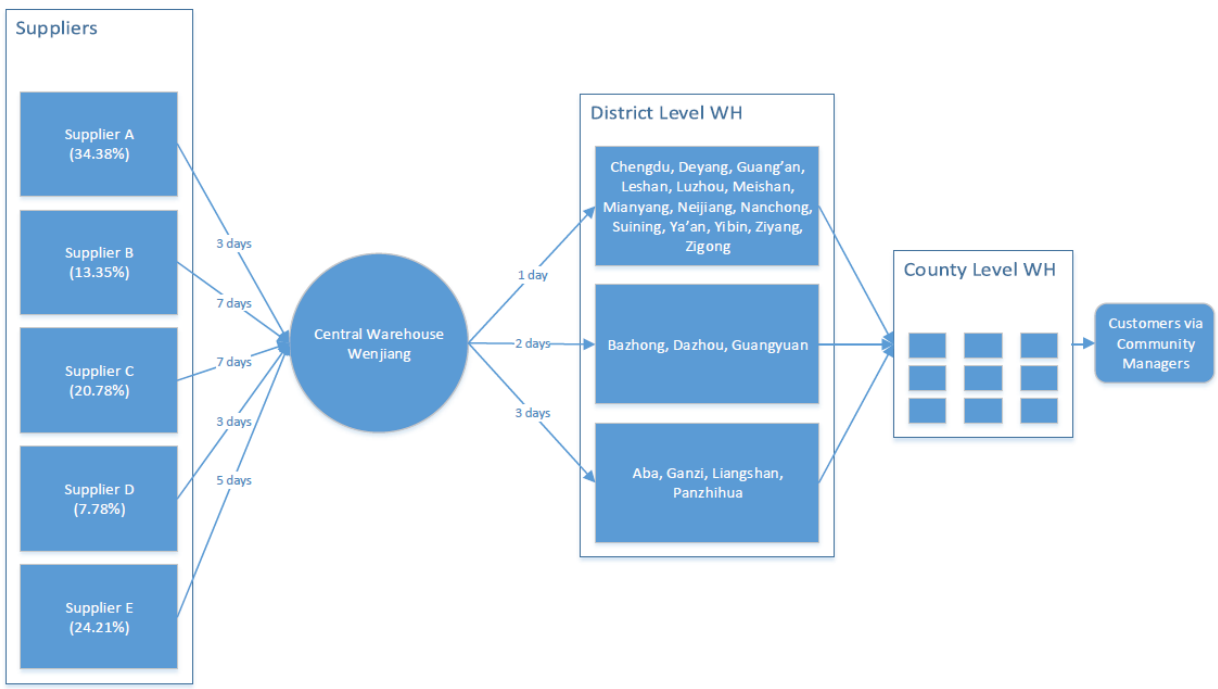


Figure 1: Multiple Supplier Supply Chain—System 1

The cost of distribution was fixed for each route (Appendix 1), using an average modem unit weight of 0.75 kg. Modems were delivered by the district level warehouses to local warehouses or were available for direct pickup by the customer.

1.3 Aggregated Supplier System

Sichuan Telecom's ADSL modem supply chain is a multi-echelon system that is structured as a tree system. This means that each stage may have multiple predecessors and successors but no undirected cycles; and the connections between stages represent physical shipments being made. For the design of a new inventory management system (System 2), the five suppliers have been aggregated into a single supplier with a 5-day deterministic lead time. This effectively changes the network topology from a tree system to a distribution system, where each stage has at most one predecessor and may have multiple successors. The final successors are retailers with different demand distributions. Each stage in the network is a potential location for holding safety stock inventory. Refer to Figure 2 for visual summary of this supply chain.

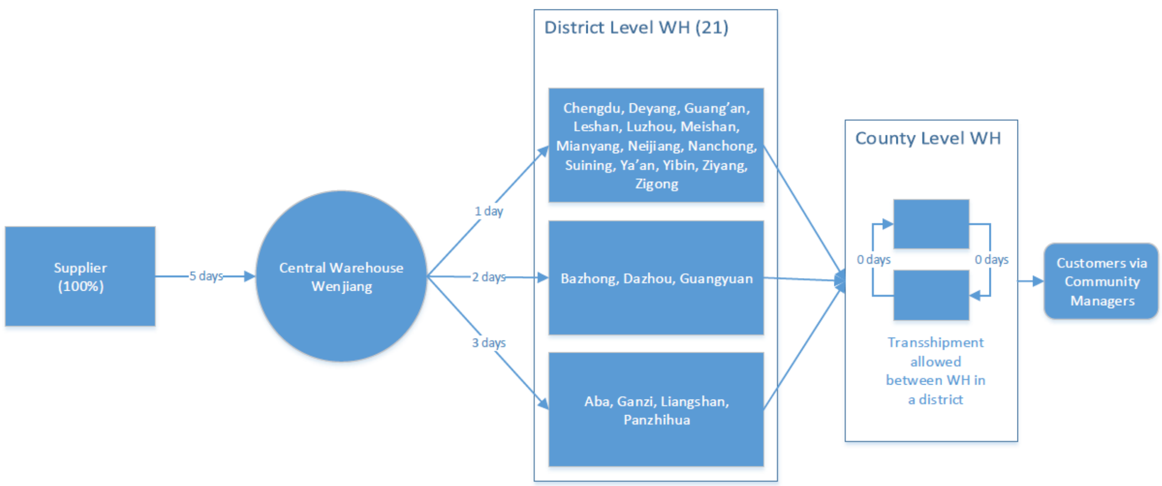


Figure 2: Aggregated Supplier Supply Chain—System 2

Since each stage must deal with backorders, inventory holding costs and lead times, the local optimization of each stage directly affects the rest of the supply chain performance. This can be seen as the costs imposed on stage j+1 by a shortage at stage j become the shortage costs as stage j. Therefore, to improve this system, a total supply chain perspective is essential. Otherwise, local sub-optimization occurs when each stage in a process operates independently to its own cost and profit measures. Some assumptions are made to determine the optimal echelon base stock level based on estimated costs. These include: periodic review, linear holding and backorder costs, and infinite capacity from the supplier. The holding costs were determined from the warehouse floor space and the standard warehouse rental costs per city (Appendix 5). The demand stored in a warehouse each month was used to determine the rental costs, which were then added to a 5% margin for the assumed local holding costs. Additionally, the holding cost for the Chengdu warehouse was assumed to be equal to the Wenjiang Central Warehouse's holding cost.

1.4 Review Period

The central warehouse replenished its stocks each week based on downstream demand. Sichuan Telecom had 200 warehouses across 21 district level sub-branch companies, with a total floor space of 82,000 square metres. Inventory inspection and reconciliation was carried out at the sub-branch companies every seven days. When a district warehouse required supplies, they were expected to fill out a procurement form to send to the central warehouse. The central warehouse then checked with the different suppliers and obtained supplies to fill the requested order within 2 days. The review period considered for System 2 is 7 days and is used in all parts of the analysis involving this system.

2. Analysis and Recommendations

2.1 Comparison of Supply Chain Structures

In System 1, where each supplier has a supply percentage quota it can satisfy, the lead time is not deterministic and transhipment is not possible within a district (between counties) or across districts. To develop an improved inventory management system for Sichuan Telecom's

ADSL modem supply chain, the following assumptions were made: all five suppliers can be aggregated into a single supplier with a deterministic lead time (to the central warehouse in Chengdu) of 5 days, the cost of capital is the same across the entire area served by Sichuan Telecom, and that transportation costs can be ignored.

In System 1, the lead time is not deterministic because there are multiple suppliers and each supplier has a quota cap. This causes an increase in uncertainty of lead time demand, causing the central warehouse to maintain a higher safety stock to hedge against unreliable suppliers. In System 2, the single supplier has promised to deliver goods at a deterministic value of 5 days.

Assuming this is a periodic review, a reduction in safety stock can be explained by the mean and variance of lead time demand which are given by the following equations:

Mean Lead Time Demand (LTD):

$$\mu_{LTD} = \mu_D(\mu_L + 1)$$

Variance of LTD:

$$\sigma_{LTD}^2 = \sigma_D^2(\mu_L + 1) + \sigma_L^2 \mu_D{}^2$$

Intuitively, aggregating suppliers and reducing lead time demand causes the variance of LTD and therefore safety stock levels to decrease.

Another implication of aggregation of suppliers is the effect on the service level. While there is a guarantee of high service level in System 1 from the sheer volume of safety stock at the central warehouse, there is a large cost disadvantage. Holding a large volume of safety stock in the central warehouse in System 1 results in more resources spent on holding costs. There is a possibility that service level decreases in System 2 because of a lower safety stock inventory. This risk is offset by the transhipment option provided for warehouses in the same district.

In System 2, if a local warehouse within one of the districts stocks out, demand can be met from another warehouse within the district (not between districts) at a negligible additional cost. But each district can receive only one shipment of modems from the central warehouse each period. This not only applies to supply from the central warehouse to the district warehouses but also to the supply from the main supplier to the central warehouse.

The possibility of transhipment decreases the safety stock needs at the district warehouses while maintaining a high service level in System 2. Now that reactive transshipment is possible within the district, the dependency on the district warehouses for supply is relaxed considerably. Therefore, the difference between target inventory levels and realized inventory levels both decrease because of transhipment.

In summary, the effect of each district receiving a single shipment in System 2 will be an increase in uncertainty and mean lead time demand. However, the low transportation costs relative to shortage costs, especially for transhipments within a district improves System 2's performance overall. This is because the district warehouses could overstock slightly to maintain a high service level, since it is more profitable to hold excess inventory than to stock out and lose out on customers.

2.2 Overstocking and Understocking

The issue of over/under stocking at district level warehouses can be understood by studying the inventory status and monthly demand in 2006. The amount ordered by each district can be computed using the following equation:

Amount ordered each month = (Inventory status of current month) –

(Inventory status of past month) + (Observed demand of the current month)

Almost all the districts were overstocked in the month of January and February which was a direct consequence of excess stock from 2005 and low demands in the month of January. This overstocking effect continues into February, driven by low sales and excess stocks. For instance, Deyang WH had 4646 units left over from 2005. It ordered an additional 3,523 units in January. However, the observed demand was just 2,841 units. This led to 5,328 units in the inventory at the start of February, which is clearly an issue of overstocking.

In the month of April, most of the district level warehouses ordered fewer modems as compared to their demand to clear up the overstock left from previous months. For example, Ganzi District WH ordered 565 units against a monthly demand of 2304 units. Most of the districts under ordered in April and May to reduce overstock at their warehouses. This cyclic trend continues throughout the year where districts over-order for few months and then react and under-order in the following months. Refer Figure 3 for a visual representation of this effect playing out in the Ganzi district warehouse. Appendix 7 shows the variance of demand and the variance of order quantities, and from here it is clear that there is a Bullwhip effect across almost all district warehouses.

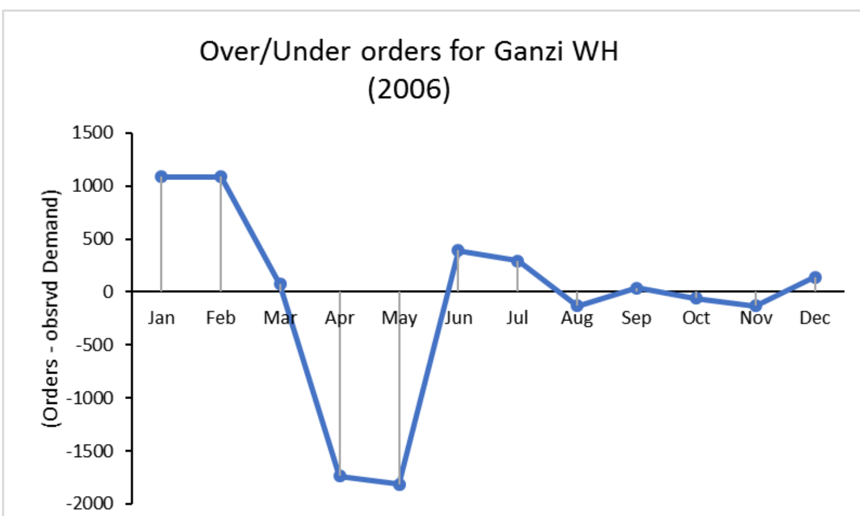


Figure 3 Over/Understocking at the Ganzi Warehouse (Refer to Appendix 5 for all district warehouses)

2.3 Computation of Base Stock Levels:

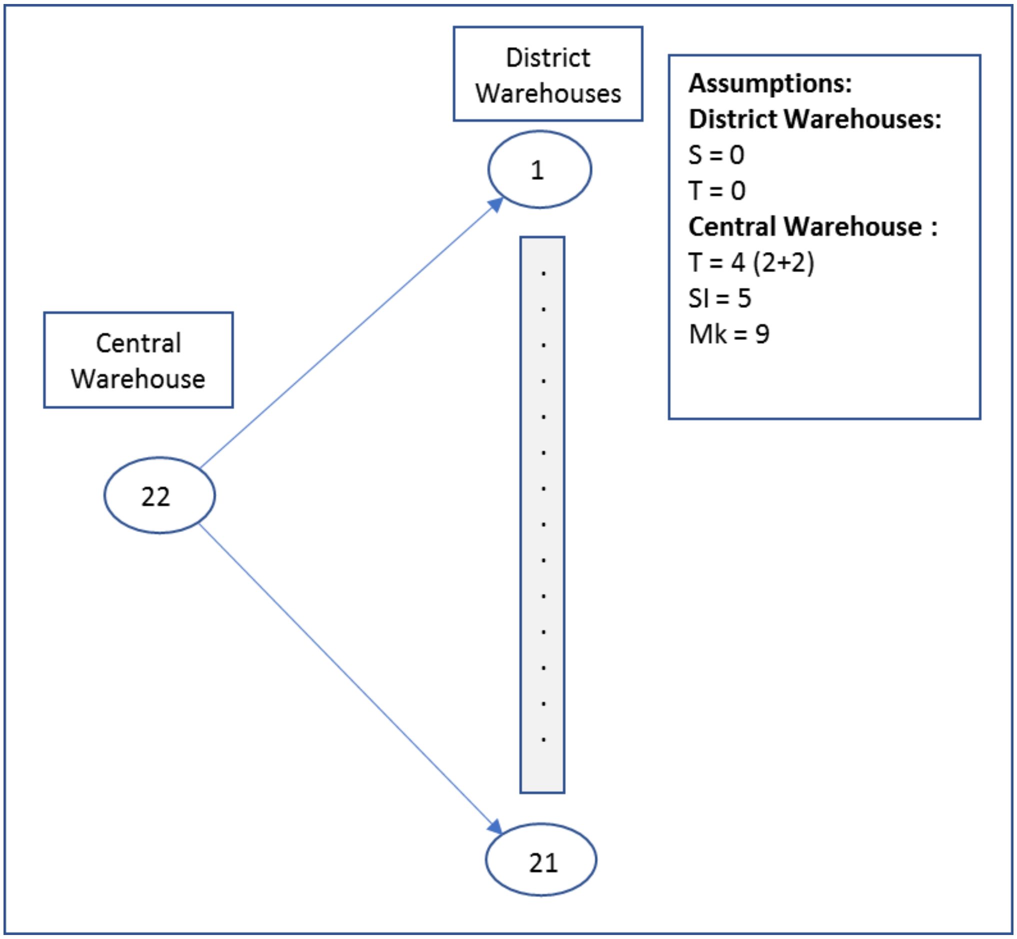


Figure 4 Components of the Tree Distributed System

The aggregated supply chain can be considered as a tree system. This system can be treated as a guaranteed service system at service level for 99%. The model and algorithm used was proposed by Graves and Willems (2000). The system is a two-stage tree system with 21 district WH in Stage II and one central warehouse in stage I.

For a tree-system the following assumptions are reasonable:

1. Stage II district warehouses face external demand. The demand is treated to be normally distributed and parameters are estimated based on 2006 monthly demand data (Appendix 8)
2. Holding costs for the central warehouse are the same as the Chengdu district warehouse
3. Since stage II district warehouses are 'demand' stages, the service time is taken to be zero
4. The transportation lead time to district warehouses is considered as the production lead times for district warehouses. It cannot be added to district warehouse service times as all downstream stages need to have same committed service time

2.3.1 Labelling the stages

The tree system can be solved using a dynamic programming (DP) algorithm. The DP algorithm requires us to re-label the stages so that each stage (other than stage N) needs exactly one adjacent stage with a higher index. Based on algorithm 5.1 (page 134, Snyder and Shen), all the stages are labelled from 1 through 22 (Refer to Appendix 9)

2.3.2 Cost Computation

Based on the stage and its successors, there are different functional equations for upstream and downstream stages that are used to computing the holding costs at each stage. (Refer 5.30 and 5.31 in Snyder and Shen page 136). Detailed computations can be found at Appendix 10. All costs were computed at a daily level. The optimal objective value is the minimum holding cost at the last stage. (9.6 Million RMB per year)

2.3.3 Suggested Inventory Levels

For the aggregated supplier system, optimal value is found at S = 0 and SI = 0. Using backtracking like Wagner – Whitin algorithm, optimal solution for the system can be found. Under the optimal condition, this system will work as a ‘decentralized’ system. Safety stock will be held at both all the district warehouses and the central warehouse. The corresponding base-stock levels and safety stock can be found in Appendix 10. Base-stock level at the central warehouse will be around 309K. District warehouses which are farther away from the central warehouses should have a higher base-stock and safety stock levels.

Because of the straightforward nature of the tree system, the holding costs and safety stock level drive the total system cost. Holding cost reduction and reducing the review period time are the direct ways of reducing the system cost while holding the high service level as expected by management.

2.4 Other Inventory systems

There are other inventory systems that can be considered apart from the aggregate supplier system considered here. Transhipment is not allowed between districts. A better system will allow proactive transhipment between districts with equal transport time. This will allow the system to maintain higher service level with lower safety stock, driving down the cost of the system. Cities with equal transport time from the central warehouse are often closer to each other. (For instance, distance between Bazhong and Dazhou is 146 km). Contingent on more information, this system can be implemented without major changes to infrastructure.

2.5 Recommendations

1. Sichuan Telecom can streamline their supply chain is by accommodating transhipment between districts (provided it is at a negligible cost). By doing this, each of the district warehouses will avoid overstocking and understocking. Even if one of the district warehouses run out of stock, reactive transhipment will allow them to keep enough stock to help them run at least till the end of the month.
2. Sichuan Telecom's marketing department performs demand forecasting, and it can be further be improved. The department can attempt improving the forecasting methods by applying any of the following four methods: exponential, Smoothing, Winters or Regression. By improving the forecast, although it may not result in 100% accuracy, it can still help the company reduce their issues with overstocking and understocking.
3. Aggregation of suppliers is another way by which Sichuan Telecom can attempt to reduce safety stock. As discussed in Section 2.1, signing a contract with a supplier who provides 100% of the demand will reduce both mean and variance of lead time demand, resulting in less safety stock. Another potential benefit discussed earlier in Section 2.1 is how service levels can be improved by aggregating suppliers.
4. Sichuan Telecom should consider implementing a decentralized system as shown in Section 2.4. Implementing a decentralized system will result in safety stock being held at both the district warehouses and the central warehouse. Sichuan Telecom will benefit from the reduced holding costs of a tree system, while continuing to provide best-in-class customer service.

3 Summary

Sichuan Telecom currently has the largest market share in the region due to large resources and relatively small competition. The company generates most of its revenue through its ADSL services. ADSL modems being functional products, do not vary too much across competition and hence uncertainty is caused purely due to varying demand.

The company has 21 warehouses across different districts in the Sichuan region. One of the major issues that the company is facing is the over and understocking of ADSL modems across these districts. This is primarily caused by the distortion in the demand signal leading to fluctuation in the monthly inventory status.

There are several ways in which the company can overcome the over/understocking problem. The company should consider spending more resources on the forecasting of their demand. If the demand forecast is made efficient, this would lead to the company understanding the level of inventory it should keep at the different district.

Another solution may involve accommodating transhipment between districts. This will lead to a lean system with reduced safety stock; and when combined with a good forecasting process over/under-stocking can be avoided. An additional advantage of transhipment will also help in attaining a high service level with lower holding costs as described previously.

Finally, Sichuan Telecom can also implement a decentralized system which will result in the safety stock being held at both the central warehouse and each of the 21 district warehouses. This will further help in reducing system cost as they are driven by holding costs and safety stock, which can be adjusted while maintaining a high service level.

4 Appendix

Appendix 1

COST OF DISTRIBUTION FROM WEIJIANG CENTRAL WAREHOUSE

Route	Carload Freight			Less than carload freight
	3 tons	5 tons	Over 8 tons	
Chendu-Nei'ian	250	200	150	1
Chendu-Zi on	350	250	220	1.1
Chendu-Yibin	370	310	250	1.1
Chendu-Luzhou	370	310	250	1.1
Chendu-Guan 'an	400	330	280	1.4
Chendu-Nanchon	350	250	220	1.1
Chendu-Dazhou	600	520	440	1.5
Chendu-Suining	310	250	200	1
Chendu-Bazhon	600	420	380	1.7
Chendu-Guan uan	350	280	250	1.3
Chendu-Mianyang	250	160	150	1
Chendu-Deyang	200	140	120	1
Chendu-Aba	850	470	420	1.8
Chendu-Ya'an	300	250	190	1.2
Chendu-Lian shan	760	580	420	4.5
Chendu-Panzhihua	910	650	480	2.5
Chendu-Meishan	200	145	120	1
Chendu-Leshan	320	220	190	1
Chendu-Ganzi	680	530	430	2.3

Appendix 2

THE LEAD TIME OF WENJIANG CENTRAL WAREHOUSE TO EACH DISTRICT

District	Number of days
Chengdu, Deyang, Guang'an, Leshan, Luzhou, Meishan ,Mianyang, Neijiang, Nanchong, Suining, Ya'an, Yibin, Ziyang, Zigong	1
Bazhong, Dazhou, Guangyuan	2
Aba, Ganzi, Liangshan, Panzhihua	3

Appendix 3

NUMBER OF COMMUNITY MANAGERS IN EACH DISTRICT

District	Number	District	Number	District	Number
Aba	40	Leshan	230	Guang'an	190
Bazhon	98	Lian shan	77	Guangyuan	107
Chengdu	956	Luzhou	200	Nanchong	40
Dazhou	169	Meishan	81	Panzhihua	89
Deyang	108	Miangyang	223	Sui'ning	41
Ganzi	18	Neijian	270	Ya'an	74
Zigong	136	Ziyang	60	Yibin	317

Appendix 4

THE SUPPLY PERCENTAGE OF MAJOR SUPPLIERS

Supplier	Percentage of Supply
A	34.38
B	13.35
C	20.78
D	7.28
E	24.21

Appendix 5

COMPUTATION OF HOLDING COSTS FOR DISTRICT WAREHOUSES

District WH	Floor Space	Rent	Yearly HC	Rent Component	Local Holding Cost
Aba	1027	5	61,620	4.44	11.94
Bazhong	1640	10	1,96,800	4.46	11.96
Chengdu	9600	15	17,28,000	4.10	11.60
Dazhou	4772	10	5,72,640	7.43	14.93
Deyang	10792	10	12,95,040	19.06	26.56
Ganzi	1907	5	1,14,420	9.79	17.29
Guang'an	1174	10	1,40,880	2.60	10.10
Guangyuan	2040	10	2,44,800	5.21	12.71
Leshan	1717	10	2,06,040	2.41	9.91
Liangshan	1296	5	77,760	1.68	9.18
Luzhou	4154	10	4,98,480	6.19	13.69
Meishan	2672	10	3,20,640	5.68	13.18
Mianyang	3840	10	4,60,800	4.78	12.28
Nanchong	6742	10	8,09,040	14.40	21.90
Neijiang	7802	10	9,36,240	9.07	16.57
Panzhihua	3534	10	4,24,080	16.69	24.19
Suining	1999	10	2,39,880	4.26	11.76
Ya'an	3770	10	4,52,400	14.29	21.79
Yibin	5932	10	7,11,840	8.24	15.74
Zigong	2600	10	3,12,000	7.62	15.12
Ziyang	3272	10	3,92,640	6.32	13.82

METHODOLOGY:

Monthly Holding Costs = Floor space x Rent

Rent Component = Monthly Holding Costs/(Average Inventory Level)

Daily Local Holding Costs = (Opportunity Costs*/365) + (Rent Component/30)

*Opportunity Costs are assumed to be 5% of a single Modem ($150)

Appendix 6

OVER AND UNDER STOCKING COMPARED TO DEMAND

	Over/Under Ordered compared to demand											
District WH	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Aba	964	849	421	-1474	-497	-200	-138	-289	639	-510	109	-459
Bazhong	484	1235	358	-1875	-824	12	452	106	177	-206	-185	1501
Chengdu	3569	7935	2880	-13032	1277	102	-3115	1188	-651	2883	-8340	6803
Dazhou	466	3094	2241	-6279	-5129	597	-466	573	1625	-2281	354	3050
Deyang	682	282	1210	-2605	-2814	-52	-235	473	-11	-430	672	-1117
Ganzi	1087	1088	75	-1739	-1814	390	295	-130	40	-60	-130	140
Guang'an	2236	2822	-2700	-1149	-1509	375	-160	804	173	-921	573	358
Guangyuan	2870	1718	-695	-4244	-3526	-339	388	-154	713	-326	-50	-833
Leshan	2723	6146	2167	-6413	-2963	-249	126	42	-101	-413	-491	-190
Liangshan	461	2098	-277	-3665	-178	114	-61	74	174	-743	-197	986
Luzhou	1102	756	-64	-2461	-1220	-312	505	-374	2146	-1302	-787	1026
Meishan	170	1765	1594	-1955	2471	-2140	-1168	-234	711	-642	-58	-165
Mianyang	2644	15288	2930	-17932	-1522	-287	-4029	782	-100	74	230	-2187
Neijiang	-1006	2931	2711	-4949	-1721	-1359	1064	-328	-324	452	-682	43
Nanchong	709	16993	1470	-20068	-6480	-780	-313	492	4599	-934	-660	-865
Panzhihua	255	142	-800	-791	1006	-274	274	303	370	-579	65	-278
Suining	1280	3807	571	-6416	-3761	239	-85	-109	182	-247	218	20
Ya'an	1446	837	-510	-1728	-632	-67	-14	25	74	-527	407	95
Yibin	301	2470	775	-4219	-1597	-276	929	-1074	2152	253	0	325
Ziyang	1849	1740	2173	-4029	-5051	-589	461	-56	269	-943	-144	0
Zigong	3628	8114	488	-9742	-3712	-763	-82	196	1096	-429	163	-1799

Appendix 7

AMOUNT ORDERED EACH MONTH

	Amount ordered each Month														
District WH	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Var(Orders)	Var(Demand)	BWE
Aba	1,025	1,025	1,965	240	800	818	1,612	1,318	3,067	180	672	566	6,51,041	4,92,768	1.32
Bazhong	5,140	10,630	6,650	118	50	2,802	4,335	3,720	3,030	2,120	2,855	3,901	81,62,601	51,41,700	1.59
Chengdu	19,929	38,896	63,816	49,464	2,000	44,676	44,744	52,490	50,664	48,200	13	7,604	4780,96,939	5220,29,419	0.92
Dazhou	5,063	9,094	12,380	4,515	550	7,051	6,746	8,180	7,350	4,530	5,600	3,830	88,75,747	66,24,802	1.34
Deyang	3,523	3,903	10,586	7,073	0	4,694	6,651	5,975	5,680	3,922	6,519	5,488	64,07,548	50,14,555	1.28
Ganzi	1,861	1,862	1,058	565	0	630	350	940	900	140	820	1,800	4,15,076	4,57,305	0.91
Guang'an	4,087	8,218	8,930	7,176	240	3,560	5,770	4,952	2,699	2,870	3,390	3,270	63,78,305	85,91,048	0.74
Guangyuan	5,806	10,883	8,255	67	1,345	4,124	4,628	2,660	1,720	1,101	1,135	798	111,84,377	76,25,198	1.47
Leshan	9,401	18,602	14,072	3,293	0	6,451	10,441	8,499	7,948	5,725	1,351	2	318,77,921	150,35,112	2.12
Liangshan	2,790	6,675	4,325	1,172	0	4,639	5,660	4,379	4,772	3,366	2,559	4,739	35,39,869	21,69,152	1.63
Luzhou	7,833	13,033	10,549	5,351	0	6,746	7,890	6,680	8,282	3,949	3,730	5,513	113,25,003	82,25,819	1.38
Meishan	170	12,165	11,994	1,599	7,473	2,137	4,180	5,108	5,670	2,667	3,439	213	164,13,096	101,46,728	1.62
Mianyang	2,844	41,846	18,763	-1,002	18,424	281	1,701	8,440	291	325	305	0	1652,25,758	876,43,920	1.89
Neijiang	2,368	12,997	12,129	-988	0	3,359	4,970	5,300	3,300	5,110	1,429	3,048	182,49,885	67,68,734	2.70
Nanchong	3,101	23,312	37,465	-738	552	6,587	9,699	8,363	7,307	387	1,339	0	1300,12,152	1006,33,470	1.29
Panzhihua	1,730	3,334	1,586	-28	2,012	2,499	4,079	3,226	3,203	2,350	620	492	16,23,444	12,78,487	1.27
Suining	6,006	12,402	8,043	-2,438	0	4,500	5,540	4,192	5,189	2,560	3,234	2,728	141,32,518	32,67,832	4.32
Ya'an	3,641	5,421	4,110	1,089	410	2,379	3,081	2,460	2,360	1,910	2,250	1,960	17,96,842	11,06,502	1.62
Yibin	9,872	20,212	15,775	4,912	0	7,601	11,553	8,346	5,620	1,701	191	630	411,36,945	339,55,333	1.21
Ziyang	4,859	5,001	7,223	2,392	0	2,697	4,491	4,168	4,456	1,255	92	1	55,38,565	35,87,391	1.54
Zigong	5,178	14,106	11,323	-606	0	3,647	6,046	5,330	5,552	3,645	3,645	1,416	181,06,451	66,91,426	2.71

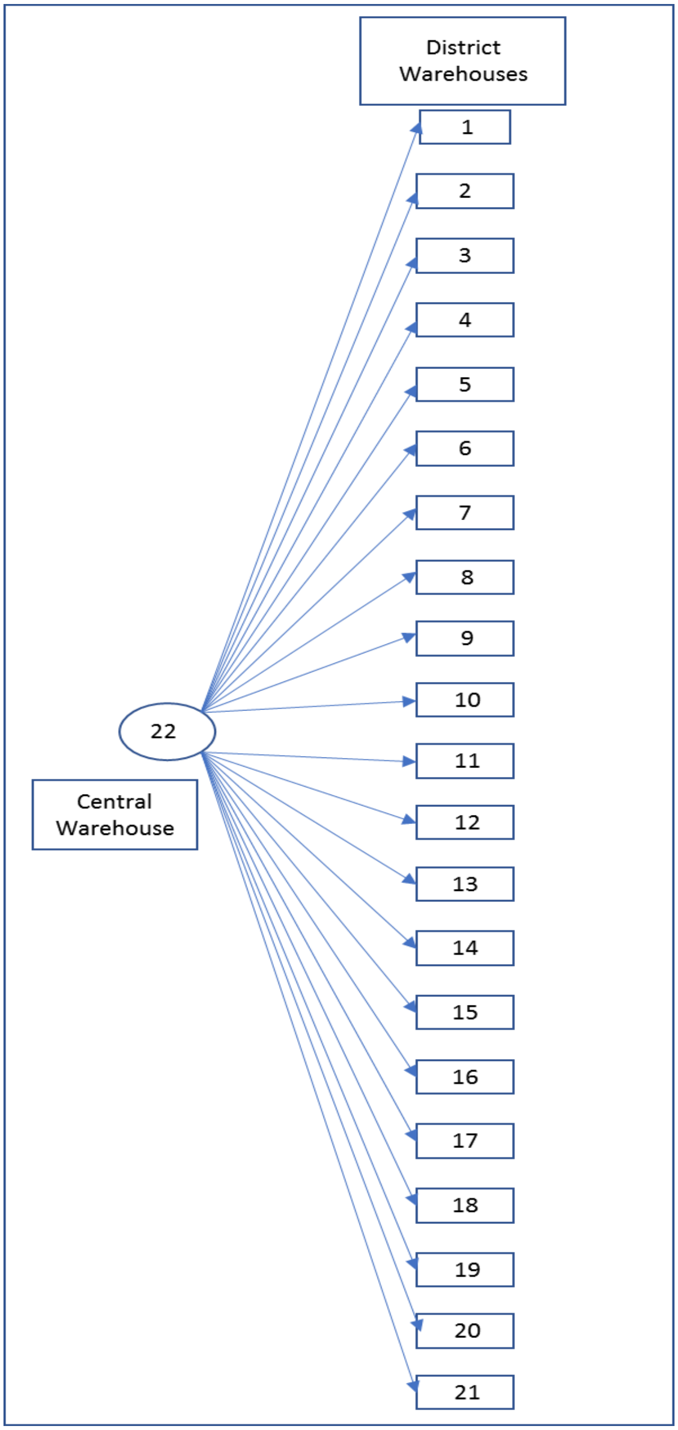
Appendix 8

MEAN AND STANDARD DEVIATION OF MONTHLY DEMAND

	Monthly Demand													
District WH	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean	Std.Deviation
Aba	61	176	1,544	1,714	1,297	1,018	1,750	1,607	2,428	690	563	1,025	1,156	702.0
Bazhong	4,656	9,395	6,292	1,993	874	2,790	3,883	3,614	2,853	2,326	3,040	2,400	3,676	2267.5
Chengdu	16,360	30,961	60,936	62,496	723	44,574	47,859	51,302	51,315	45,317	8,353	801	35,083	22848.0
Dazhou	4,597	6,000	10,139	10,794	5,679	6,454	7,212	7,607	5,725	6,811	5,246	780	6,420	2573.9
Deyang	2,841	3,621	9,376	9,678	2,814	4,746	6,886	5,502	5,691	4,352	5,847	6,605	5,663	2239.3
Ganzi	774	774	983	2,304	1,814	240	55	1,070	860	200	950	1,660	974	676.2
Guang'an	1,851	5,396	11,630	8,325	1,749	3,185	5,930	4,148	2,526	3,791	2,817	2,912	4,522	2931.0
Guangyuan	2,936	9,165	8,950	4,311	4,871	4,463	4,240	2,814	1,007	1,427	1,185	1,631	3,917	2761.4
Leshan	6,678	12,456	11,905	9,706	2,963	6,700	10,315	8,457	8,049	6,138	1,842	192	7,117	3877.5
Liangshan	2,329	4,577	4,602	4,837	178	4,525	5,721	4,305	4,598	4,109	2,756	3,753	3,858	1472.8
Luzhou	6,731	12,277	10,613	7,812	1,220	7,058	7,385	7,054	6,136	5,251	4,517	4,487	6,712	2868.1
Meishan	-	10,400	10,400	3,554	5,002	4,277	5,348	5,342	4,959	3,309	3,497	378	4,706	3185.4
Mianyang	200	26,558	15,833	16,930	19,946	568	5,730	7,658	391	251	75	2,187	8,027	9361.8
Neijiang	3,374	10,066	9,418	3,961	1,721	4,718	3,906	5,628	3,624	4,658	2,111	3,005	4,683	2601.7
Nanchong	2,392	6,319	35,995	19,330	7,032	7,367	10,012	7,871	2,708	1,321	1,999	865	8,601	10031.6
Panzhihua	1,475	3,192	2,386	763	1,006	2,773	3,805	2,923	2,833	2,929	555	770	2,118	1130.7
Suining	4,726	8,595	7,472	3,978	3,761	4,261	5,625	4,301	5,007	2,807	3,016	2,708	4,688	1807.7
Ya'an	2,195	4,584	4,620	2,817	1,042	2,446	3,095	2,435	2,286	2,437	1,843	1,865	2,639	1051.9
Yibin	9,571	17,742	15,000	9,131	1,597	7,877	10,624	9,420	3,468	1,448	191	305	7,198	5827.1
Ziyang	3,010	3,261	5,050	6,421	5,051	3,286	4,030	4,224	4,187	2,198	236	1	3,413	1894.0
Zigong	1,550	5,992	10,835	9,136	3,712	4,410	6,128	5,134	4,456	4,074	3,482	3,215	5,177	2586.8

Appendix 9

LABELLING DISTRICT WAREHOUSES FOR SIMPSON'S METHOD AND THEIR RESPECTIVE LOCAL HOLDING COSTS



District WH	Local Holding Cost
Aba	0.35
Bazhong	0.59
Chengdu	0.79
Dazhou	0.61
Deyang	1.50
Ganzi	0.50
Guang'an	0.48
Guangyuan	0.44
Leshan	0.42
Liangshan	0.34
Luzhou	0.74
Meishan	0.79
Mianyang	0.42
Nanchong	1.07
Neijiang	0.56
Panzhihua	1.25
Suining	0.45
Ya'an	0.95
Yibin	0.87
Zigong	0.52
Ziyang	0.49

Appendix 10

ASSUMPTIONS FOR THE MODEL

Raw Data	
SI	5
S (1..19,21)	0
T20	2
Mk - Tk	7
z	2.33

SUMMARY VALUES FOR THE SYSTEM

Central Warehouse	
Sigma	5280
Daily Holding Cost	0.56
C	6832
Holding Cost	$36,620.97
Safety Stock	65,849

Index	Warehouse	Sigma	Daily Holding Cost	Lead time	Holding Cost	Safety Stock	Basestock Level
1	Aba	128	$ 0.13	3	$ 72	573	611
2	Bazhong	414	$ 0.36	2	$ 550	1511	1633
3	Dazhou	470	$ 0.38	2	$ 654	1715	1929
4	Deyang	409	$ 1.27	1	$ 1,344	1055	1244
5	Ganzi	123	$ 0.27	3	$ 152	552	584
6	Guang'an	535	$ 0.25	1	$ 346	1381	1531
7	Guangyuan	504	$ 0.21	2	$ 393	1839	1970
8	Leshan	708	$ 0.19	1	$ 347	1826	2064
9	Liangshan	269	$ 0.11	3	$ 130	1202	1330
10	Luzhou	524	$ 0.51	1	$ 693	1351	1575
11	Meishan	582	$ 0.56	1	$ 840	1500	1657
12	Mianyang	1709	$ 0.19	1	$ 823	4410	4677
13	Neijiang	475	$ 0.33	1	$ 409	1225	1382
14	Nanchong	1832	$ 0.85	1	$ 3,995	4725	5012
15	Panzhihua	206	$ 1.02	3	$ 944	923	993
16	Suining	330	$ 0.22	1	$ 185	852	1008
17	Ya'an	192	$ 0.72	1	$ 359	495	583
18	Yibin	1064	$ 0.64	1	$ 1,768	2745	2985
19	Ziyang	346	$ 0.26	1	$ 231	892	1006
20	Chengdu	4171	$ 0.56	1	$ 5,985	10762	11932
21	Zigong	472	$ 0.29	1	$ 350	1218	1391

COMPUTATION VALUES

For all k=1 to 21, p(k) = 22

Upstream Calculations

			Sample District WH Index						
C	**S**	**SI (0 to Mk)**	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Theta i(S = 0 ,SI =0)	0	0	65	496	590	1,212	137	312	354
Theta i(S = 0 ,SI =1)	0	1	75	607	722	1,714	158	442	434
Theta i(S = 0 ,SI =2)	0	2	84	701	834	2,099	177	541	501
Theta i(S = 0 ,SI =3)	0	3	92	784	932	2,423	193	624	560
Theta i(S = 0 ,SI =4)	0	4	99	859	1,021	2,709	209	698	614
Theta i(S = 0 ,SI =5)	0	5	106	927	1,103	2,968	223	765	663
Theta i(S = 0 ,SI =6)	0	6	112	991	1,179	3,206	237	826	709
Theta i(S = 0 ,SI =7)	0	7	118	1,052	1,251	3,427	250	883	752

For k=22 p(k) = 21

Downstream Calculations

Value	**S (0 to Mk)**	**5**
Theta o(S =0)	0	36,620.97
Theta o(S =1)	1	44,974.72
Theta o(S =2)	2	51,644.36
Theta o(S =3)	3	57,407.70
Theta o(S =4)	4	62,574.13
Theta o(S =5)	5	67,306.07
Theta o(S =6)	6	71,702.02
Theta o(S =7)	7	75,827.38