

## **CHAPTER IV**

### **RESULTS**

In this chapter, it consists of two sections that are the healthcare supply chain performance evaluation framework development in section 4.1 and the application of ANP framework to a case study of pharmaceutical supply chain in section 4.2.

#### **4.1 The Healthcare Supply Chain Performance Evaluation Framework Development**

The first step in developing the Analytical Network Process (ANP) is to identify criteria as main criteria and sub-criteria. The main criteria and sub-criteria adopting in this study are based on reviewing relevant literatures and gathering the opinions by healthcare supply chain experts through the modified Delphi processes (Table 4.1). By applying the modified Delphi method, the experts have a more thorough thinking. The studies of literature reviews discovered that the collaboration criterion is the newest important criterion for supply chain performance. Furthermore, Simatupang and Sridharan (2004a), Sanders and Premus (2005), Vereecke and Muylle (2006) and Sanders (2008) claim that the successful supply chain collaboration enables firms to achieve better performance improvement. The collaboration consists of three main criteria that are information sharing utilizes better visibility of process status and performance metric for decision maker, incentive alignment motivates chain members to make joint decisions that it aims to the common goals and decision synchronization drives the improvement process through using key operational metrics (Simatupang and Sridharan, 2004a).

Table 4.1 Synopsis of feasible and useful measures for healthcare supply chain performance measurement

Criteria	Sub-criteria
1. Quality (Q)	Backorders (bo), Delivery accuracy (da), Fill rate (fr), Delivery reliability (dr) Distribution planning (dp) Delivery invoice method (dim) Accuracy of forecasting techniques (aft) Customer satisfaction (cs)
2. Cost (C)	Overhead cost (oc), Warehouse cost (wc) Distribution cost (dc), Return on investment (roi) Transport productivity (tp) Economic order quantity (eoq) Inventory investment (in)
3. Time (T)	Customer response time (crt) Delivery lead time (dlt) On-time delivery (otd)
4. Flexibility (F)	Volume flexibility (vf), Order flexibility (of) Transport flexibility (tf), Resource flexibility (rf) Responsiveness to urgent deliveries (rud) Flexibility of service system (fs)
5. Innovativeness (I)	New technology (nt) New product launched (npl)
6. Collaboration (CO)	Information sharing (is) Decision synchronization (ds) Incentive alignment (ia) Buyer-supplier relations (bsr) Supplier ability to respond to quality problem (sqp)

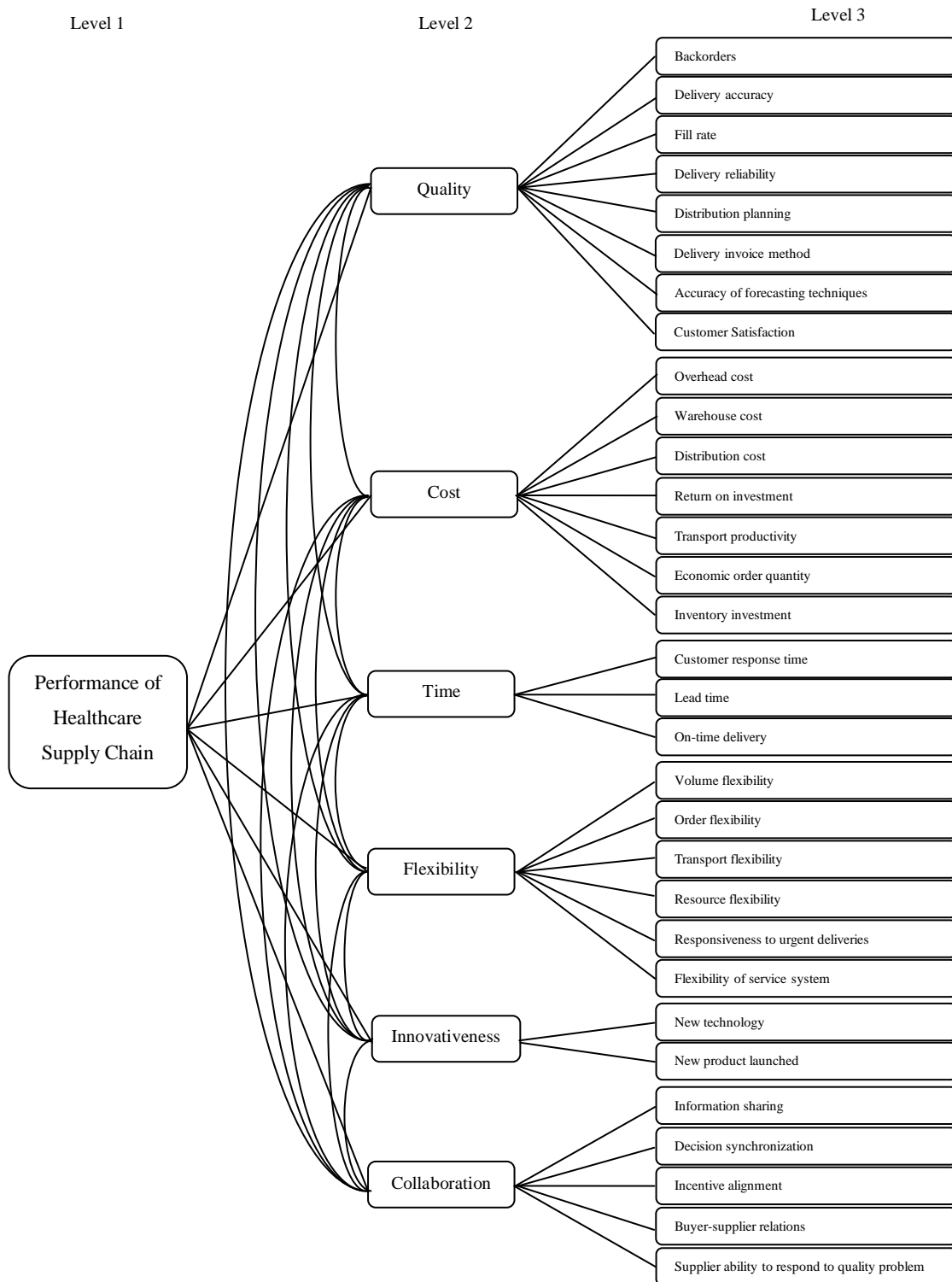


Figure 4.1 The ANP-based framework for evaluating Healthcare supply chain performance

The ANP based framework for the healthcare supply chain performance measurement is built with questionnaire for pairwise comparison according Saaty’s 1-9 scale (Saaty, 2003). The relationships between goal (first level) and criteria (second level), and criteria (second level) and sub-criteria (third level) are identified as a strict hierarchical structure. The inner relationships in the second level are shown in Figure 4.1 as a network structure. Table 4.2 presents an example of pairwise comparison of main criteria respect to goal rating scale by three experts (expert A, B and C)’ rating while Table 4.3 shows a synthesized pairwise comparison matrix for comparing the main criteria in level 2 in terms of their contribution to achieve the primary objective and the synthesized pairwise comparison matrix is presented through the geometric mean method from aggregating of expert’s opinions in Table 4.2 and using an Equation 2.1.

Table 4.2 Pairwise comparison of main criteria respect to goal

	Importance scales																	Expert’s rating			
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	A	B	C	
Q	9	8	A7	6	B5C	4	3	2	1	2	3	4	5	6	7	8	9	C	1/7	1/5	1/5
	9	8	7	6	5	4	3	2	B1C	2	A3	4	5	6	7	8	9	T	1/3	1	1
	9	8	7	6	5	4	A3B	2	1	2	3	4	5	6	7	8	9	F	3	3	5
	9	8	7	6	A5B	4	3C	2	1	2	3	4	5	6	7	8	9	I	3	3	5
	9	8	7	6	5	4	3C	2	A1B	2	3	4	5	6	7	8	9	CO	1	1	3
C	9	8	7	6	5	4	3	2	1	2	A3	4	B5C	6	7	8	9	T	1/3	1/5	1/5
	9	8	7	6	5	4	3	2	1	2	3	4	A5C	6	B7	8	9	F	1/5	1/5	1/7
	9	8	7	6	5	4	A3B	2	1	2	3	4	5	6	7	8	9	I	3	3	1
	9	8	7	6	5	4	3	2	1	2	B3C	4	A5	6	7	8	9	CO	1/5	1/3	1/5
T	9	8	7	6	5	4	A3B	2	1	2	3	4	5	6	7	8	9	F	1	3	3
	9	8	B7C	6	A5	4	3	2	1	2	3	4	5	6	7	8	9	I	5	7	7
	9	8	7	6	5	4	A3B	2	1	2	3	4	5	6	7	8	9	CO	3	3	1
F	9	8	A7	6	B5C	4	3	2	1	2	3	4	5	6	7	8	9	I	7	5	5
	9	8	7	6	5	4	C3	2	A1B	2	3	4	5	6	7	8	9	CO	1	1	3
I	9	8	7	6	5	4	3	2	1	2	A3C	4	B5	6	7	8	9	CO	1/3	1/5	1/3

Quality (Q); Cost (C); Time (T); Flexibility (F); Innovativeness (I); Collaboration (CO)

Table 4.3 A synthesized pairwise comparison matrix with respect to goal by the geometric mean method

	Q	C	T	F	I	CO
Q	1	5.593	0.693	3.557	4.217	1.442
C	0.179	1	0.237	0.179	2.080	0.281
T	1.442	4.217	1	2.080	6.257	2.080
F	0.281	5.593	0.481	1	5.593	1.442
I	0.237	0.481	0.160	0.179	1	0.281
CO	0.693	3.557	0.481	0.693	3.557	1

#### 4.1.1 A synthesized pairwise comparison matrix based on the Geometric mean method

The eigenvector (W) can calculate by using the Equation 2.4 as Table 4.4 and Table 4.5, and W' can calculate by using the Equation 2.5 as Table 4.6. Where CI is the consistency index, CR is the consistency ratio,  $k_{max}$  is the largest eigenvalue of the pairwise comparison matrix, n is the matrix order, and RI is the random index. CI and CR are calculated as Table 4.7. From Table 2.7, it shows a set of recommended the Random Index (RI) values proposed by Saaty (2005). When CR values are  $> 0.1$  for a matrix larger than  $4 \times 4$ , it indicates an inconsistent judgment. Decision makers should revise the original values in the pairwise comparison matrix. Table 4.7 presents the results for the proposed example. The eigenvector shows the priority of the six main criteria that were assessed by the experts (Table 4.7). The results of the synthesized main criteria's pairwise comparison matrix based on the Geometric mean method with C.R. value are shown in Table 4.8 to Table 4.14.

Table 4.4 Sum of columns

	Q	C	T	F	I	CO
Q	1	5.593	0.693	3.557	4.217	1.442
C	0.179	1	0.237	0.179	2.080	0.281
T	1.442	4.217	1	2.080	6.257	2.080
F	0.281	5.593	0.481	1	5.593	1.442
I	0.237	0.481	0.160	0.179	1	0.281
CO	0.693	3.557	0.481	0.693	3.557	1
SUM	3.833	20.442	3.052	7.688	22.705	6.527

Table 4.5 Eigenvector (W)

	Q	C	T	F	I	CO	Eigenvector
Q	0.261	0.274	0.227	0.463	0.186	0.221	0.272
C	0.047	0.049	0.078	0.023	0.092	0.043	0.055
T	0.376	0.206	0.328	0.271	0.276	0.319	0.296
F	0.073	0.274	0.158	0.130	0.246	0.221	0.184
I	0.062	0.024	0.052	0.023	0.044	0.043	0.041
CO	0.181	0.174	0.158	0.090	0.157	0.153	0.152

Table 4.6 W' value

	Q	xW	C	xW	T	xW	F	xW	I	xW	CO	xW	W'
Q	1	0.272	5.593	0.055	0.693	0.296	3.557	0.184	4.217	0.041	1.442	0.152	1.833
C	0.179	0.272	1	0.055	0.237	0.296	0.179	0.184	2.080	0.041	0.281	0.152	0.336
T	1.442	0.272	4.217	0.055	1	0.296	2.080	0.184	6.257	0.041	2.080	0.152	1.878
F	0.281	0.272	5.593	0.055	0.481	0.296	1	0.184	5.593	0.041	1.442	0.152	1.162
I	0.237	0.272	0.481	0.055	0.160	0.296	0.179	0.184	1	0.041	0.281	0.152	0.255
CO	0.693	0.272	3.557	0.055	0.481	0.296	0.693	0.184	3.557	0.041	1	0.152	0.954

Table 4.7 CR value

	W	W'	
Q	0.272	1.833	$\lambda_{max} = 6.323,$ $CI = \frac{6.323-6}{6-1}, CR = \frac{0.052}{1.25}$ $= 0.052$ $= 0.052 \text{ or } 5.2\%$
C	0.055	0.336	
T	0.296	1.878	
F	0.184	1.162	
I	0.041	0.255	
CO	0.152	0.954	

Table 4.8 A synthesized pairwise comparison matrix with respect to goal

(C.R. = 0.002 or 0.2%)

	Q	C	T	F	I	CO	Eigenvector
Q	1	5.593	0.693	3.557	4.217	1.442	0.272
C	0.179	1	0.237	0.179	2.080	0.281	0.055
T	1.442	4.217	1	2.080	6.257	2.080	0.296
F	0.281	5.593	0.481	1	5.593	1.442	0.184
I	0.237	0.481	0.160	0.179	1	0.281	0.041
CO	0.693	3.557	0.481	0.693	3.557	1	0.152

Table 4.9 A synthesized pairwise comparison matrix with respect to quality

(C.R. = 0.020 or 2%)

	C	T	F	I	CO	Eigenvector
C	1	0.481	0.481	3.000	1.000	0.154
T	2.080	1	1.000	4.217	5.000	0.350
F	2.080	1.000	1	5.000	3.000	0.322
I	0.333	0.237	0.200	1	0.481	0.062
CO	1.000	0.200	0.333	2.080	1	0.113

Table 4.10 A synthesized pairwise comparison matrix with respect to cost

(C.R. = 0.032 or 3.2%)

	Q	T	F	I	CO	Eigenvector
Q	1	0.693	5.000	5.593	4.217	0.368
T	1.442	1	4.217	5.593	2.080	0.361
F	0.200	0.237	1	1.442	1.442	0.098
I	0.179	0.179	0.693	1	0.481	0.061
CO	0.237	0.481	0.693	2.080	1	0.113

Table 4.11 A synthesized pairwise comparison matrix with respect to time

(C.R. = 0.041 or 4.1%)

	Q	C	F	I	CO	Eigenvector
Q	1	4.217	2.080	4.217	0.200	0.227
C	0.237	1	0.481	1.000	0.179	0.068
F	0.481	2.080	1	2.080	0.281	0.131
I	0.237	1.000	0.481	1	0.179	0.068
CO	5.000	5.593	3.557	5.593	1	0.507

Table 4.12 A synthesized pairwise comparison matrix with respect to flexibility

(C.R. = 0.028 or 2.8%)

	Q	C	T	I	CO	Eigenvector
Q	1	3.557	1.442	3.557	0.281	0.221
C	0.281	1	0.481	1.442	0.281	0.091
T	0.693	2.080	1	2.080	0.281	0.149
I	0.281	0.693	0.481	1	0.179	0.069
CO	3.557	3.557	3.557	5.593	1	0.471

Table 4.13 A synthesized pairwise comparison matrix with respect to innovativeness  
(C.R. = 0.074 or 7.4%)

	Q	C	T	F	CO	Eigenvector
Q	1	1.442	0.322	2.289	1.817	0.203
C	0.693	1	0.281	0.322	0.322	0.082
T	3.107	3.557	1	1.710	3.915	0.396
F	0.437	3.107	0.585	1	1.442	0.181
CO	0.550	3.107	0.255	0.693	1	0.137

Table 4.14 A synthesized pairwise comparison matrix with respect to collaboration  
(C.R. = 0.096 or 9.6%)

	Q	C	T	F	I	Eigenvector
Q	1	0.693	1.442	0.281	4.217	0.163
C	1.442	1	4.217	2.080	4.217	0.345
T	0.693	0.237	1	0.237	5.000	0.117
F	3.557	0.333	4.217	1	6.257	0.329
I	0.237	0.237	0.200	0.160	1	0.047

The results of the synthesized sub-criteria's pairwise comparison matrix based on the geometric mean with C.R. value are shown in Table 4.15 to Table 4.20.

Table 4.15 A synthesized pairwise comparison matrix with respect to quality  
(C.R. = 0.041 or 4.1%)

	BO	DA	FR	DR	DP	DIM	AFT	CS	Eigenvector
BO	1	2.080	1.442	3.557	3.557	2.466	5.593	2.466	0.250
DA	0.481	1	1.710	3.557	2.466	4.217	3.557	1.442	0.194
FR	0.693	0.585	1	5.593	4.217	2.466	3.557	1.442	0.189
DR	0.281	0.281	0.179	1	2.080	1.442	3.557	0.481	0.080
DP	0.281	0.405	0.237	0.481	1	0.481	1.442	0.481	0.053
DIM	0.405	0.237	0.405	0.693	2.080	1	1.442	0.481	0.071
AFT	0.179	0.281	0.281	0.281	0.693	0.693	1	0.405	0.043
CS	0.405	0.693	0.693	2.080	2.080	2.080	2.466	1	0.120

Table 4.16 A synthesized pairwise comparison matrix with respect to cost  
(C.R. = 0.088 or 8.8%)

	OC	WC	DC	ROI	TP	EOQ	IN	Eigenvector
OC	1	0.405	0.405	0.179	0.281	0.212	0.237	0.038
WC	2.466	1	4.718	0.281	4.718	2.466	1.442	0.194
DC	2.466	0.212	1	0.281	2.466	0.281	0.281	0.072
ROI	5.593	3.557	3.557	1	4.718	4.217	2.466	0.346
TP	3.557	0.212	0.405	0.212	1	0.281	0.481	0.062
EOQ	4.718	0.405	3.557	0.237	3.557	1	1.442	0.150
IN	4.217	0.693	3.557	0.405	2.080	0.693	1	0.138

Table 4.17 A synthesized pairwise comparison matrix with respect to time

(C.R. = 0.022 or 2.2%)

	CRT	DLT	OTD	Eigenvector
CRT	1	1.000	0.179	0.145
DLT	1.000	1	0.281	0.168
OTD	5.593	3.557	1	0.687

Table 4.18 A synthesized pairwise comparison matrix with respect to flexibility

(C.R. = 0.045 or 4.5%)

	VF	OF	TF	RF	RUD	FS	Eigenvector
VF	1	1.442	1.442	2.080	0.237	0.281	0.113
OF	0.693	1	1.442	1.442	0.237	0.481	0.100
TF	0.693	0.693	1	0.481	0.281	0.481	0.079
RF	0.481	0.693	2.080	1	0.281	0.237	0.089
RUD	4.217	4.217	3.557	3.557	1	2.080	0.375
FS	3.557	2.080	2.080	4.217	0.481	1	0.243

Table 4.19 A synthesized pairwise comparison matrix with respect to Innovativeness

(C.R. = 0)

	NT	NPL	Eigenvector
NT	1	3.557	0.781
NPL	0.281	1	0.219

Table 4.20 A synthesized pairwise comparison matrix with respect to collaboration

(C.R. = 0.044 or 4.4%)

	IS	DS	IA	BSR	SQP	Eigenvector
IS	1	1.442	1.442	2.080	0.237	0.165
DS	0.693	1	2.080	1.442	0.237	0.143
IA	0.693	0.481	1	0.481	0.281	0.090
BSR	0.481	0.693	2.080	1	0.281	0.123
SQP	4.217	4.217	3.557	3.557	1	0.478

Since CR is  $< 0.1$  or 10%, it shown that the comparison matrix in the example is consistent. As the comparison matrices for sub criteria are in accordance with their respective upper level dimensions (cost, quality, flexibility, time, innovativeness, and collaboration), their eigenvectors and consistent ratios are obtained (Table 4.21).

Table 4.21 The relative important weight of the sub-criteria

Sub-criteria of Q	BO	DA	FR	DR	DP	DIM	AFT	CS
Weights	0.250	0.194	0.189	0.080	0.053	0.071	0.043	0.120
CR = 0.041								
Sub-criteria of C	OC	WC	DC	ROI	TP	EOQ	IN	
Weights	0.038	0.194	0.072	0.346	0.062	0.150	0.138	
CR = 0.088								
Sub-criteria of T	CRT	DLT	OTD					
Weights	0.145	0.168	0.687					
CR = 0.022								
Sub-criteria of F	VF	OF	TF	RF	RUD	FS		
Weights	0.113	0.100	0.079	0.089	0.376	0.243		
CR = 0.045								
Sub-criteria of I	NT	NPL						
Weights	0.781	0.219						
CR = 0								
Sub-criteria of CO	IS	DS	IA	BSR	SQP			
Weights	0.165	0.143	0.090	0.124	0.478			
CR = 0.044								

In the ANP, Saaty introduces the super matrix concept that is similar to Markov chains; it is used to handle the interdependence characteristics among criteria and sub-criteria. From pairwise comparison, the relative importance weight of each criterion is made into the unweighted supermatrix (Table 4.22). For all experts, a synthesized pairwise comparison matrix will be presented by the geometric mean method from aggregating of expert's opinions in AHP/ANP (Aczel and Saaty, 1983; Saaty, 2005; Xu, 2000).

Table 4.22 Unweighted Supermatrix

	Q	C	T	F	I	CO	Goal
Q	0.000	0.370	0.216	0.217	0.205	0.152	0.285
C	0.152	0.000	0.064	0.088	0.081	0.390	0.052
T	0.355	0.363	0.000	0.147	0.402	0.107	0.294
F	0.320	0.097	0.124	0.000	0.177	0.307	0.179
I	0.062	0.060	0.064	0.067	0.000	0.044	0.040
CO	0.112	0.109	0.532	0.480	0.135	0.000	0.149

Table 4.23 The limit matrix

	Q	C	T	F	I	CO	Goal
Q	0.184	0.184	0.184	0.184	0.184	0.184	0.184
C	0.152	0.152	0.152	0.152	0.152	0.152	0.152
T	0.194	0.194	0.194	0.194	0.194	0.194	0.194
F	0.180	0.180	0.180	0.180	0.180	0.180	0.180
I	0.055	0.055	0.055	0.055	0.055	0.055	0.055
CO	0.234	0.234	0.234	0.234	0.234	0.234	0.234
Goal	0	0	0	0	0	0	0

To determine the final local priorities to the global priorities, the limit supermatrix is obtained by raising the weighted supermatrix to powers by multiplying it by itself. When the column of numbers is the same for each column, the limit matrix is reached, and the matrix multiplication process is discontinued. Table 4.23 shows the limit supermatrix for the criteria. This matrix indicates the most important criterion for healthcare supply chain performance measurement that is “collaboration” criterion with the percentage weight score of 23.4% and there are no more different for the second most important criterion that are “Time” criterion with 19.4%, “Quality” criterion with 18.4% and “Flexibility” criterion with 18%. For the third, it is “Cost” criterion with 17.7% and finally, “Innovativeness” criterion with 5.5%.

## 4.2 Application of ANP Framework to a case study of Pharmaceutical Supply Chain

Pharmaceutical industry in Thailand is as the stage 3 of finished goods manufacturing (stage 1 is the research and development; stage 2 is the raw material manufacturing) (Office of the National Economic and Social Development Boards, 2005). In drug manufacturing processes, Thailand have imported raw materials approximately 95 percent in mixing with drug’s formulation to be in form of tablet, capsules, syrup, or cream. In Thailand, Generic drug is manufactured as a mass production and Thai industry has high potential in competing with other countries among Asian markets because Thai industry’s technology and cost are better than other countries.

Nowadays, a Pharmaceutical sector or pharmaceutical supply chain plays a critical role in the medical and health care system. It is very complex and highly responsible to ensure that the right drug, reaches the right people at the right time and in the right condition to fight against disease and sufferings. This is a highly sensitive supply chain where anything less than 100 percent of customer service level is unacceptable as it impacts the health and safety directly. The way that many pharmaceutical industries adopt is to carry a huge inventory in the supply chain to ensure close to 100 percent fill rate as. However, it is so hard to ensure 100 percent product availability at an optimal cost unless supply chain processes are streamlined towards customer needs and demands as Figure 4.2. Partly due to the distorted health services price schedule and mark-up pricing pattern, which provide incentives for physicians over-providing drugs to patients, pharmaceuticals represent a significant cost driver in the health care systems and account for a last share of health expenditures (Yu et al., 2010). The time to market, research & development productivity (innovations), product life cycle shrinkage, government regulations, shortening exclusive patent life, production flexibility, and increasing cost, those are the key challenges that pharmaceutical sector are facing today. A manufacturer who can cut down development time by 19% can save up to \$100 million (Viswanathan, 2004). For a cast study through interviewing the supply chain members, a typical pharmaceutical supply chain consists of the following key players: Domestic drug manufacturing firms/Imported drugs, distributor, group purchasing organization, hospital/clinic/pharmacy and patients according Figure 4.3. In the supply chain analysis, the pharmaceutical industry is applied by the Leagility conception. The concept of Leagility is the method that integrated the Lean manufacturing and Agile manufacturing method together and aimed to study the supply chain state. The conceptual Leagility is the decoupling point (DP) or strategic stock that is often held as a buffer between fluctuating customer orders or product variety and normal production output. This DP is divided for Lean that eliminate all non-value adding processes and Agile management that production process must be able to respond quickly to changes in supply chain (Naylor et al., 1999). The decoupling point of a pharmaceutical supply chain is shown in Figure 4.2. For pharmaceutical industry, the product variety of drugs is not much and its production is followed by plans and

formulation mixings, while demand variation is not constant as quantitative demand. In the left side of the Decoupling Point (DP), when the finished products are produced and stocked following production planning, forecasting, and scheduling, then the Lean manufacturing method should be applied for this part as strategic stock. For Agile manufacturing method, it should be applied to the rapid response of the customer ordering such as rapidly reconfigure of products, repackaging upon customer requirements, redistribution planning to distribute products to customers as soon as possible, etc.

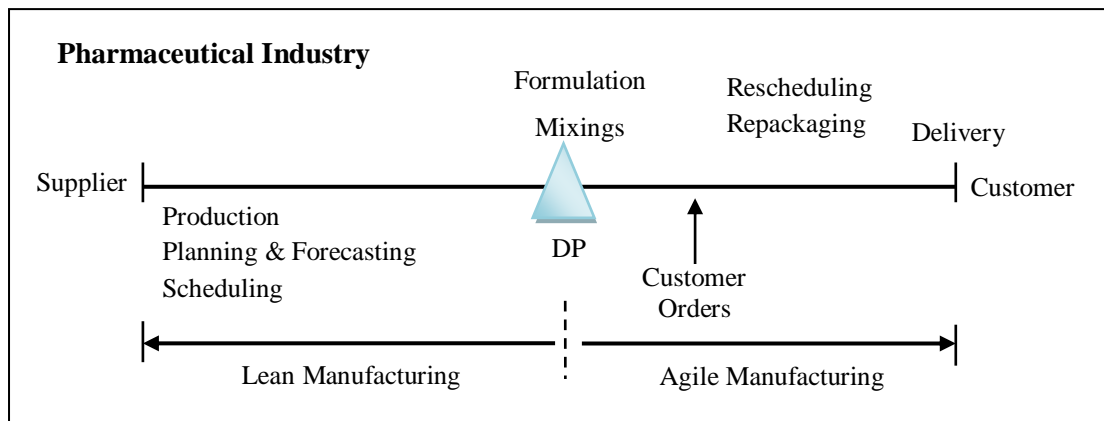


Figure 4.2 Leagility with pharmaceutical industry

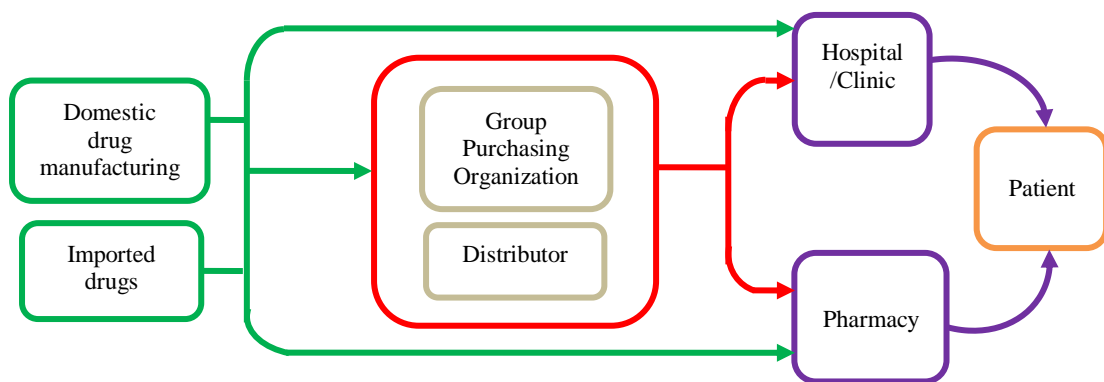


Figure 4.3 Pharmaceutical supply chain structure

The data was explored by the 5 supply chain members who are in the same of the pharmaceutical supply chain, each with experience at least 5 years in their current job. A questionnaire with questions is determined by applying a five-point

Likert scale. The scale has integer values between 1 and 5, where 1 indicates “low preference”, 3 indicates “moderate performance”, and 5 indicates “high performance”. Even numbered values fall between performance levels.

Table 4.24 presents the mean pharmaceutical supply chain performance. The weights of each sub criterion (DCW) are obtained by using the AHP approach (Table 4.21), and the weights of each main criterion (CW) are obtained by using the ANP approach (Table 4.23). All calculation steps are shown following Figure 4.4 to 4.12.

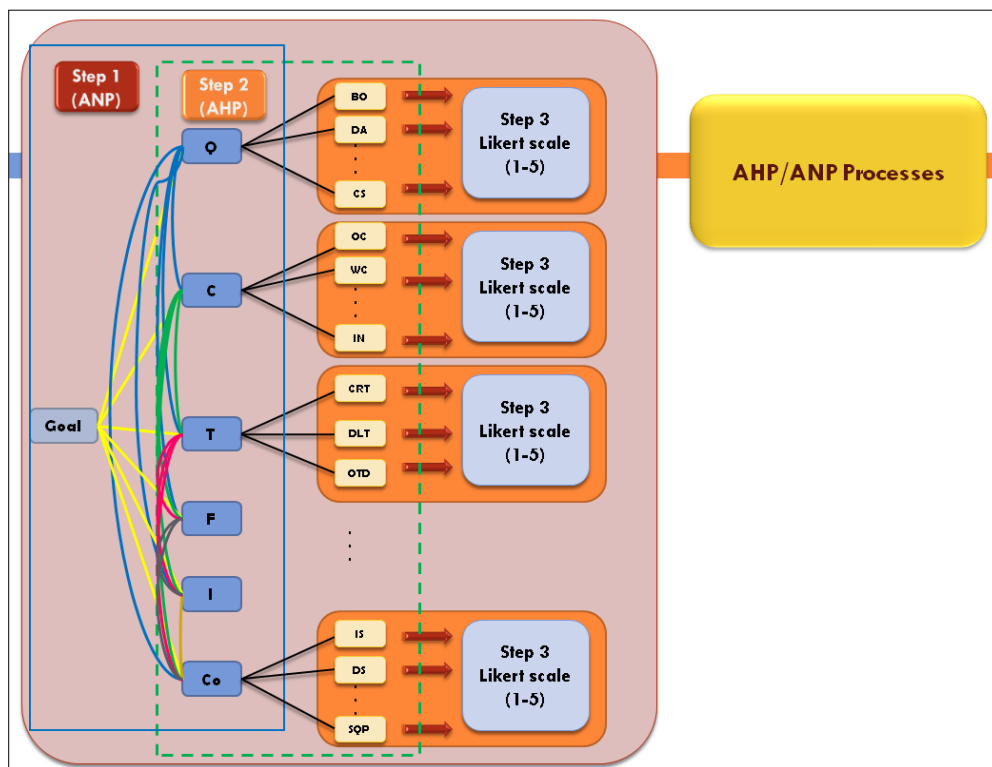


Figure 4.4 AHP/ANP processes

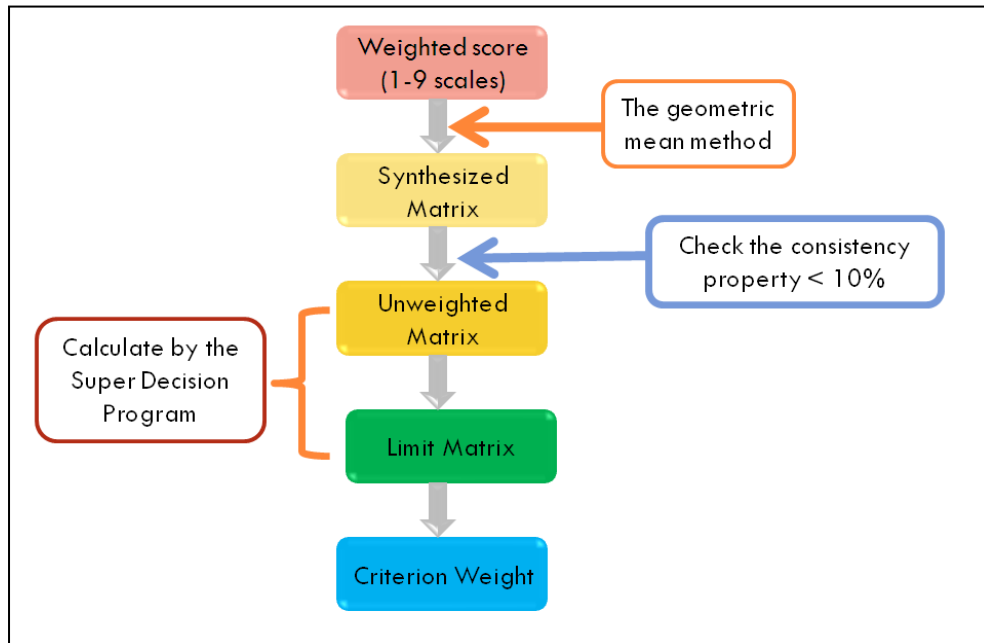


Figure 4.5 Calculation steps

**Weighted score  
1-9 scales**

	Importance scales																		Expert's rating				
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	A	B	C			
Q	9	8	A	6	B	C	4	3	2	1	2	3	4	5	6	7	8	9	C	1/7	1/5	1/5	
	9	8	7	6	5	4	3	2	B	C	A	4	5	6	7	8	9	T	1/3	1	1		
	9	8	7	6	C	A	B	4	3	2	1	2	3	4	5	6	7	8	9	F	3	3	5
	9	8	7	6	A	B	C	4	3	2	1	2	3	4	5	6	7	8	9	I	3	3	5
	9	8	7	6	5	4	C	A	B	2	3	4	5	6	7	8	9	CO	1	1	3		
C	9	8	7	6	5	4	3	2	1	2	A	B	C	6	7	8	9	T	1/3	1/5	1/5		
	9	8	7	6	5	4	3	2	1	2	3	4	A	C	6	B	8	9	F	1/5	1/5	1/7	
	9	8	7	6	5	4	A	B	C	2	3	4	5	6	7	8	9	I	3	3	1		
	9	8	7	6	5	4	3	2	1	2	B	C	A	6	7	8	9	CO	1/5	1/3	1/5		
T	9	8	7	6	5	4	A	B	C	2	3	4	5	6	7	8	9	F	1	3	3		
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	I	5	7	7		
	9	8	B	C	A	4	3	2	1	2	3	4	5	6	7	8	9	CO	3	3	1		
F	9	8	A	6	B	C	4	3	2	1	2	3	4	5	6	7	8	9	I	7	5	5	
	9	8	7	6	5	4	C	A	B	2	3	4	5	6	7	8	9	CO	1	1	3		
I	9	8	7	6	5	4	3	2	1	2	A	C	B	6	7	8	9	CO	1/3	1/5	1/3		

Quality (Q); Cost (C); Time (T); Flexibility (F); Innovativeness (I); Collaboration (C)

Figure 4.6 Criteria weighted step

In Figure 4.6, three experts (A, B, and C) have weighted score as 1-9 Saaty's scale respecting to goal. Then, all weighted scores will be placed into the

geometric mean calculating process and the outcome is to be the synthesized matrix as Figure 4.7. The synthesized matrix is needed the consistency checking and the consistency value must be less than 10 percent as Figure 4.8.

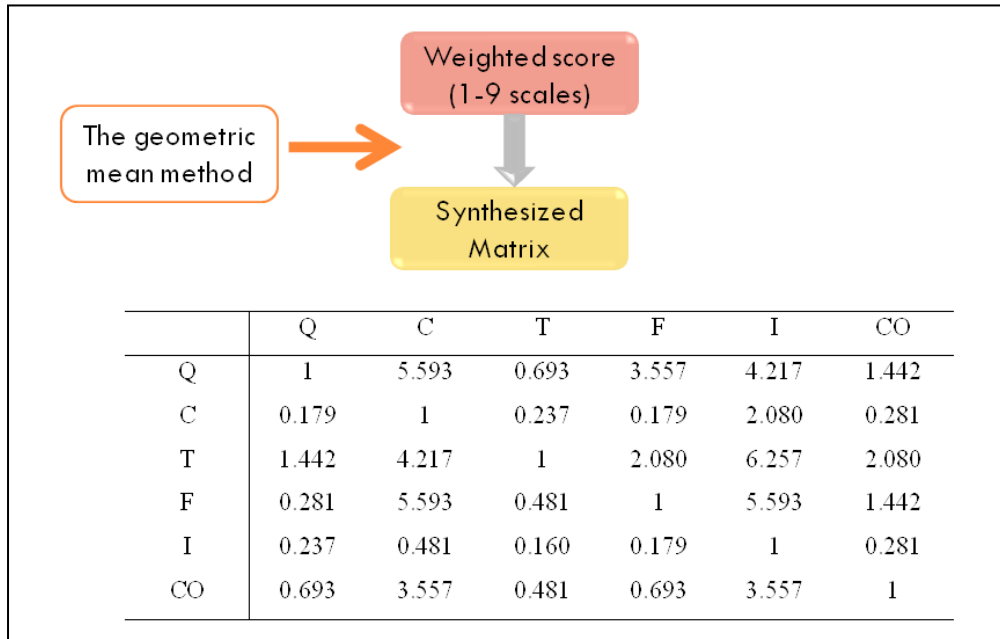


Figure 4.7 Synthesized matrix step

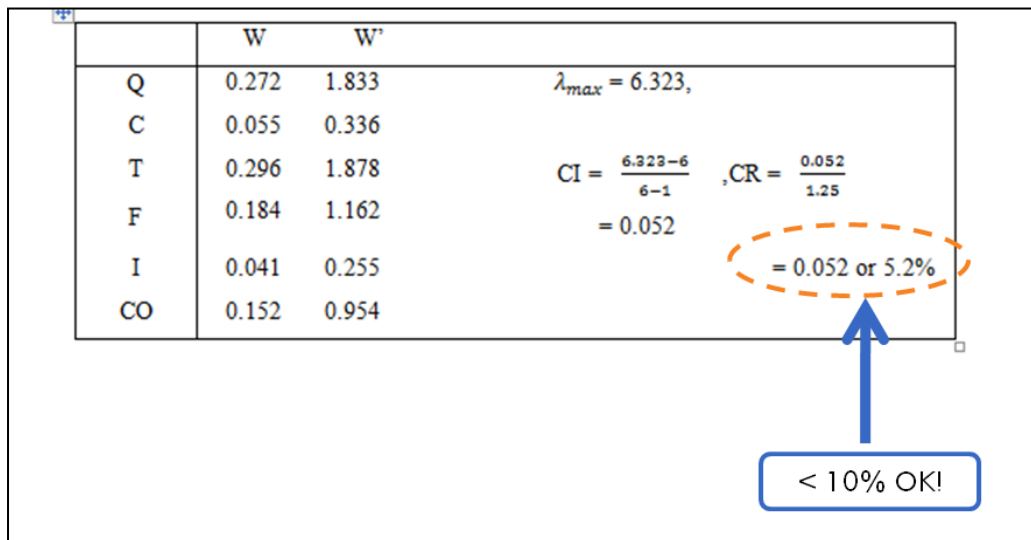


Figure 4.8 Consistency checking step

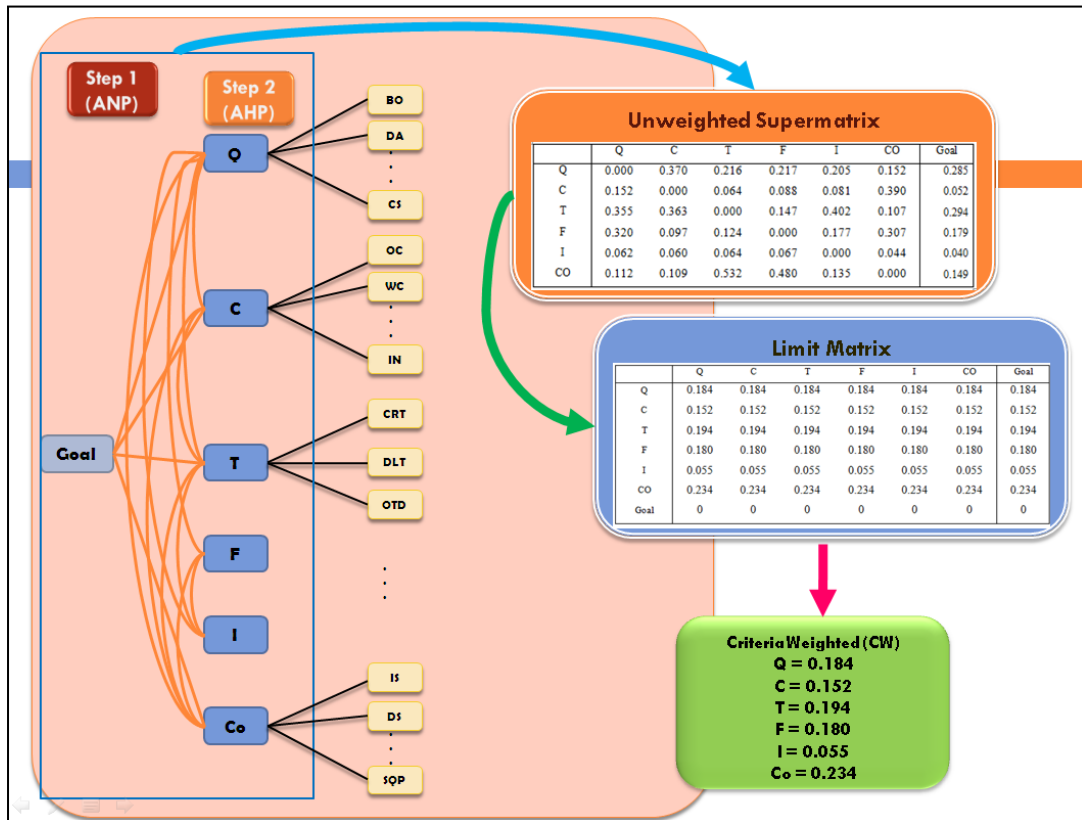


Figure 4.9 Criteria weighted (CW) calculation step

After the consistency checking step, the matrix is calculated through the ANP processes in the step 1 (Unweighted supermatrix and Limit matrix) and the final outcome is the criteria weighted (CW) according to Figure 4.9. In the step 2, the relative importance weights of the detailed criteria have calculated as Figure 4.10. For the last step, each detailed criterion weight with score as 1-5 Likert's scale is calculated and the outcome is to be the detailed criteria score (DCS) in Figure 4.11.

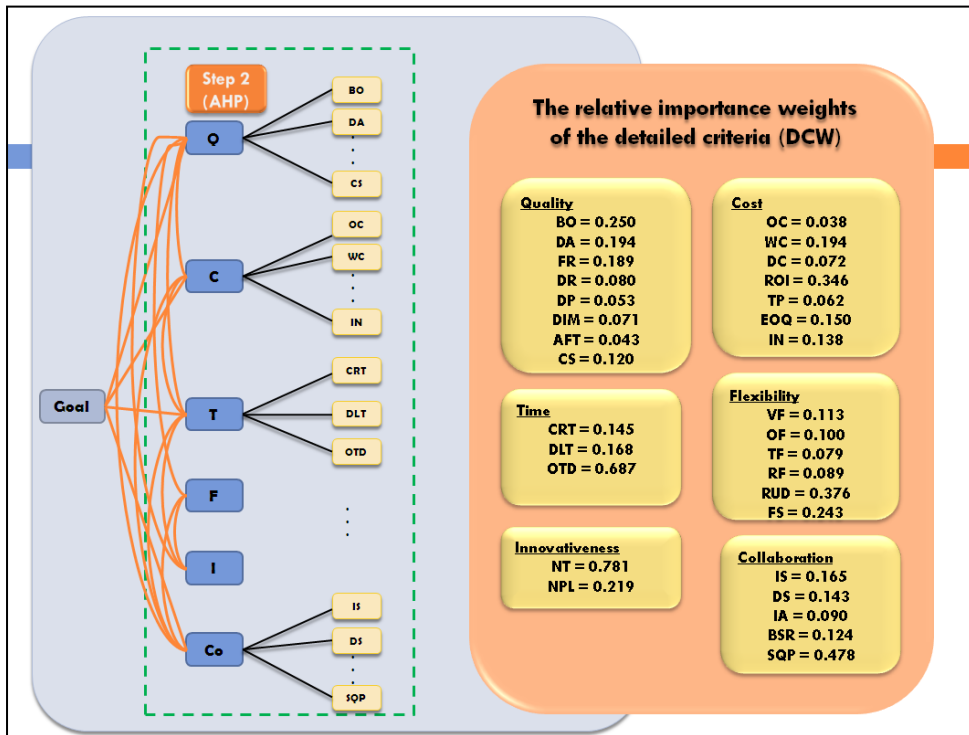


Figure 4.10 Detailed criteria weighted (DCW) calculation step

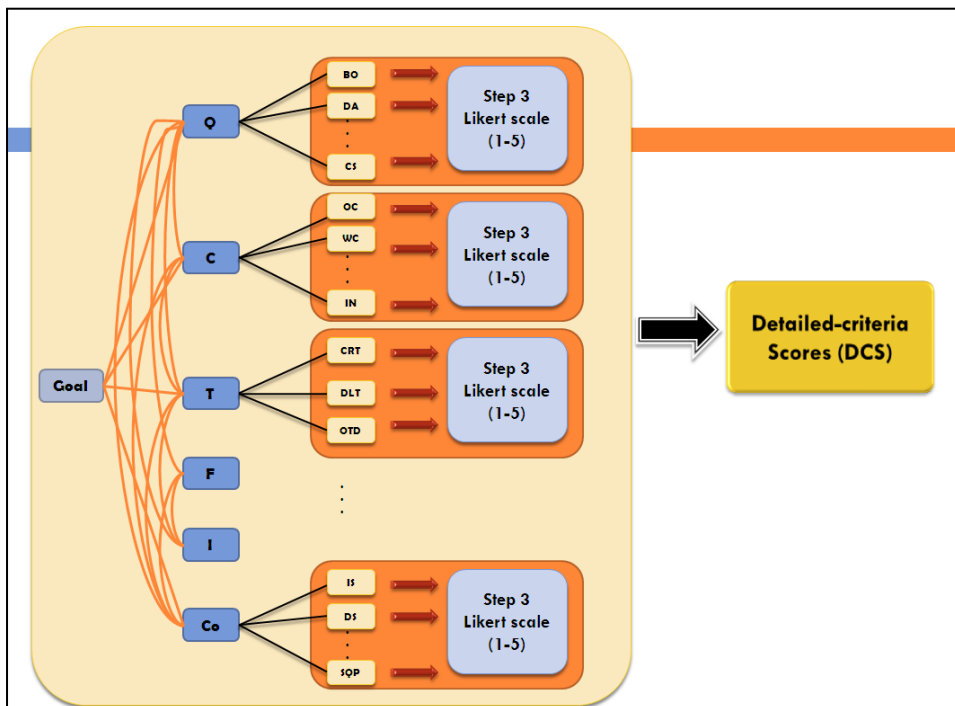


Figure 4.11 Detailed criteria scores (DCS) calculation step

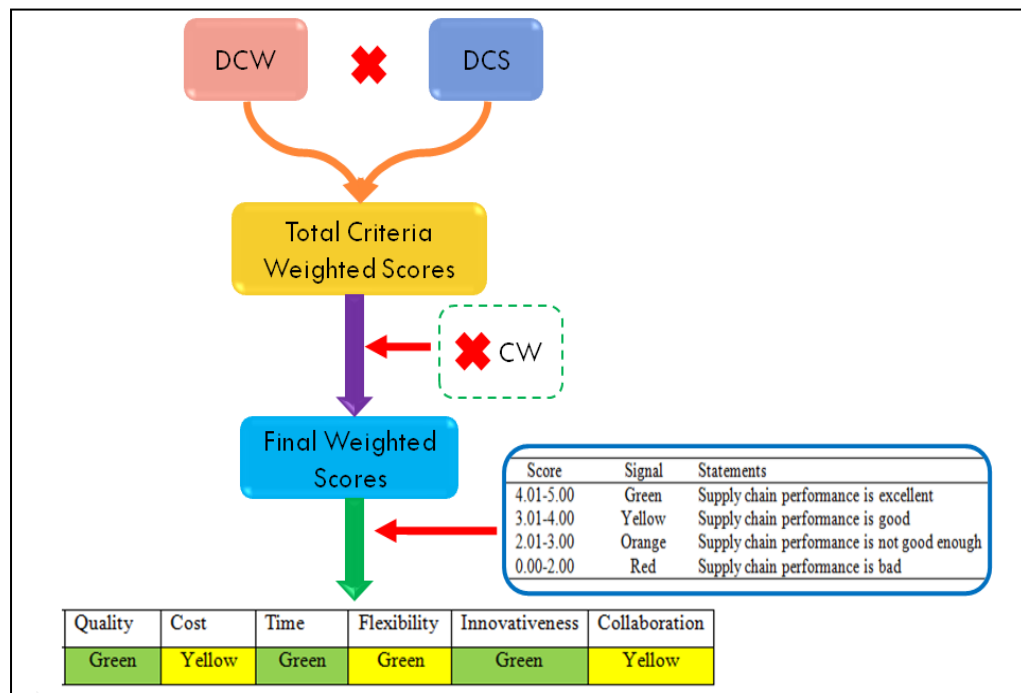


Figure 4.12 Performance calculation step

In the Figure 4.12, total criteria weighted scores, final weighted scores and criterion performance is calculated following these processes.

Table 4.24 Scores of supply chain performance

Criteria	Weight (CW)	Sub-criteria	Weight (SCW)	Score (Mean)
Quality	0.184	Backorders	0.250	4
		Delivery accuracy	0.194	3.4
		Fill rate	0.189	5
		Delivery reliability	0.080	4.6
		Distribution planning	0.053	3.2
		Delivery invoice method	0.071	2.6
		Accuracy of forecasting techniques	0.043	3.6
Cost	0.152	Customer satisfaction	0.120	4.4
		Overhead cost	0.038	4.4
		Warehouse cost	0.194	2.6
		Distribution cost	0.072	4
		Return on investment	0.346	4.4
		Transport productivity	0.062	3.6
		Economic order quantity	0.150	2.6
Time	0.194	Inventory investment	0.138	3.6
		Customer response time	0.145	4.6
		Delivery lead time	0.168	4.8
		On-time delivery	0.687	4.6

Flexibility	0.180	Volume flexibility	0.113	3.6
		Order flexibility	0.100	3.8
		Transport flexibility	0.079	4.4
		Resource flexibility	0.089	2.4
		Responsiveness to urgent deliveries	0.376	3.8
		Flexibility of service system	0.243	4.4
Innovativeness	0.055	New technology	0.781	4.8
		New product launched	0.219	4.2
Collaboration	0.234	Information sharing	0.165	2.6
		Decision synchronization	0.143	3.6
		Incentive alignment	0.090	3.8
		Buyer-supplier relations	0.124	3.2
		Supplier ability to respond to quality problem	0.478	3.8

From Table 4.24, applying Equation (3.1) and Equation (3.2) in Chapter III calculating the values of the total weighted scores of performance for each main criterion (CS) and the total final weighted scores (FWS). Overall performance of a supply chain is calculated by using the following procedure: First, a sub criterion score (DCS) is combined with a total weighted score of each main criterion (CS) and is formulated as follows (Table 4.25):

Table 4.25 Total weighted scores of performance of each main criterion (CS) and total final weighted scores (FWS)

Criterion	Total weighted score (CS)	Total final weighted scores
Quality	4.010	0.738
Cost	3.592	0.546
Time	4.634	0.899
Flexibility	3.846	0.692
Innovativeness	4.669	0.264
Collaboration	3.499	0.819
Overall performance		3.958