CHAPTER IV
RESULTS AND DISCUSSION

In this chapter, the criteria and sub-criteria gathered through the modified Delphi method and criteria and sub-criteria can be structured in section 4.1. Section 4.2 shows evaluate of strategic weight, criteria and sub-criteria by experts in field of material handling system.

4.1 The final criteria from the Delphi method

Result's Delphi in the close ended section is important factor for support selection conveyor system as show in Table 4.1.

Table 4.1 The criteria in the process of the Delphi method

Main criteria	Sub Criteria	
	Delphi #2	Delphi #3
Benefits (Technical)	• Description of product • System & Functionality • Priority process of order • Speed & Process capacity • Compatibility • Variety of product • Space • Ease of usage • Ease of improvement • Safety • Maintenance • Ease of purchase spare part • Energy saving	• Description of product • System & Functionality • Priority process of order • Compatibility • Space • Ease of usage • Ease of improvement • Safety • Maintenance • Ease of purchase spare part • Energy saving

Table 4.1 The criteria in the process of the Delphi method (cont.)

Main criteria	Sub Criteria	
	Delphi #2	Delphi #3
Benefits (Used)	• Save cost • Stability • Reduce mistake & defect • Space utilization • Quality system or stability of quality • Reducing activities • Reduce unit cost • Reduce process human activity • Image • Distance of transport	• Save cost • Stability • Reduce mistake & defect • Space utilization • Reducing activities • Image • Distance of transport
O	• Increase productivity • Increase efficiency • Reduce defect • Reduce human resource • Customer satisfaction • Reduce mistake • On time delivery	• Increase productivity • Increase efficiency • Reduce defect • Reduce human resource • Customer satisfaction • Reduce mistake • On time delivery
C	• Initial investment • Software cost • Upgrade & improvement cost • Hidden cost • After sale service • Maintenance cost • Labor cost & Operation cost	• Initial investment • Software cost • Upgrade & improvement cost • Hidden cost • After sale service • Maintenance cost • Labor cost & Operation cost
R	• Global economy • Financial risk • New process or New description of product • Own readiness • Maintenance	• Global economy • Financial risk • New process or New description of product • Own readiness • Maintenance

4.2 The network structure of criteria and sub-criteria

Model in this research were designed base on Analytic Network Process (ANP) with BOCR model. The network model was developed by using the results of The Delphi method as a sub-factor in the ANP model.

The first level of the control network contains the goal, the selection of the best conveyor system. In the second level, six strategic criteria are considered; namely, flexibility, manufacture, future plan, productivity, safety and quality. Flexibility is related with the quality of being adaptable or variable. Manufacture is related with reputation, relationship. Future plan related with capacity plan and process plan.

Productivity is related with the quality of being productive or having the power to produce. Safety related with Safety device design ergonomics design level. Quality related with fulfilling the customer's requirements and expectations, at all times. In the third level, there are four merits: benefits (B), opportunity (O), Cost (C), Risk (R). They can be showed as followed in Figure 4.1. The criteria affecting the decision and invested in transport by conveyor system from result of Delphi Method have 37 criteria as show in sub-criteria Figure 4.2.

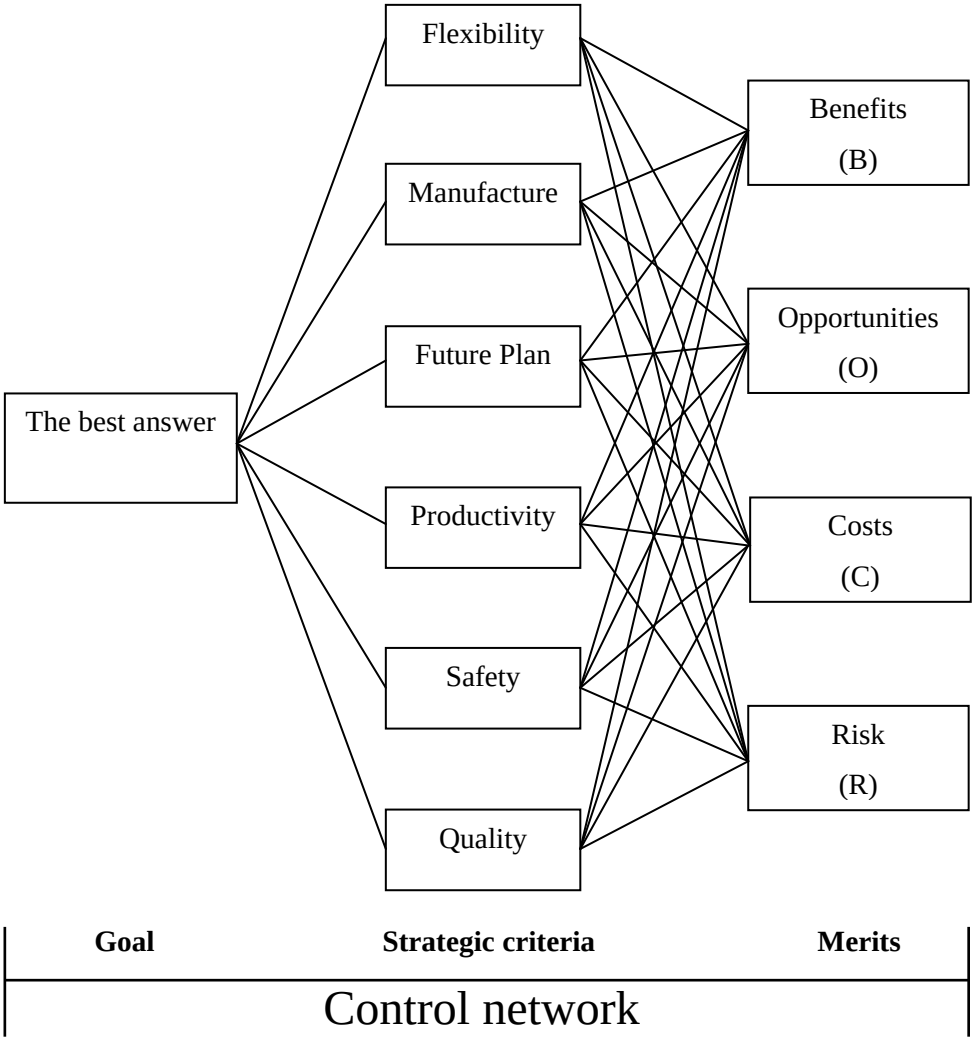

Figure 4.1 Control network

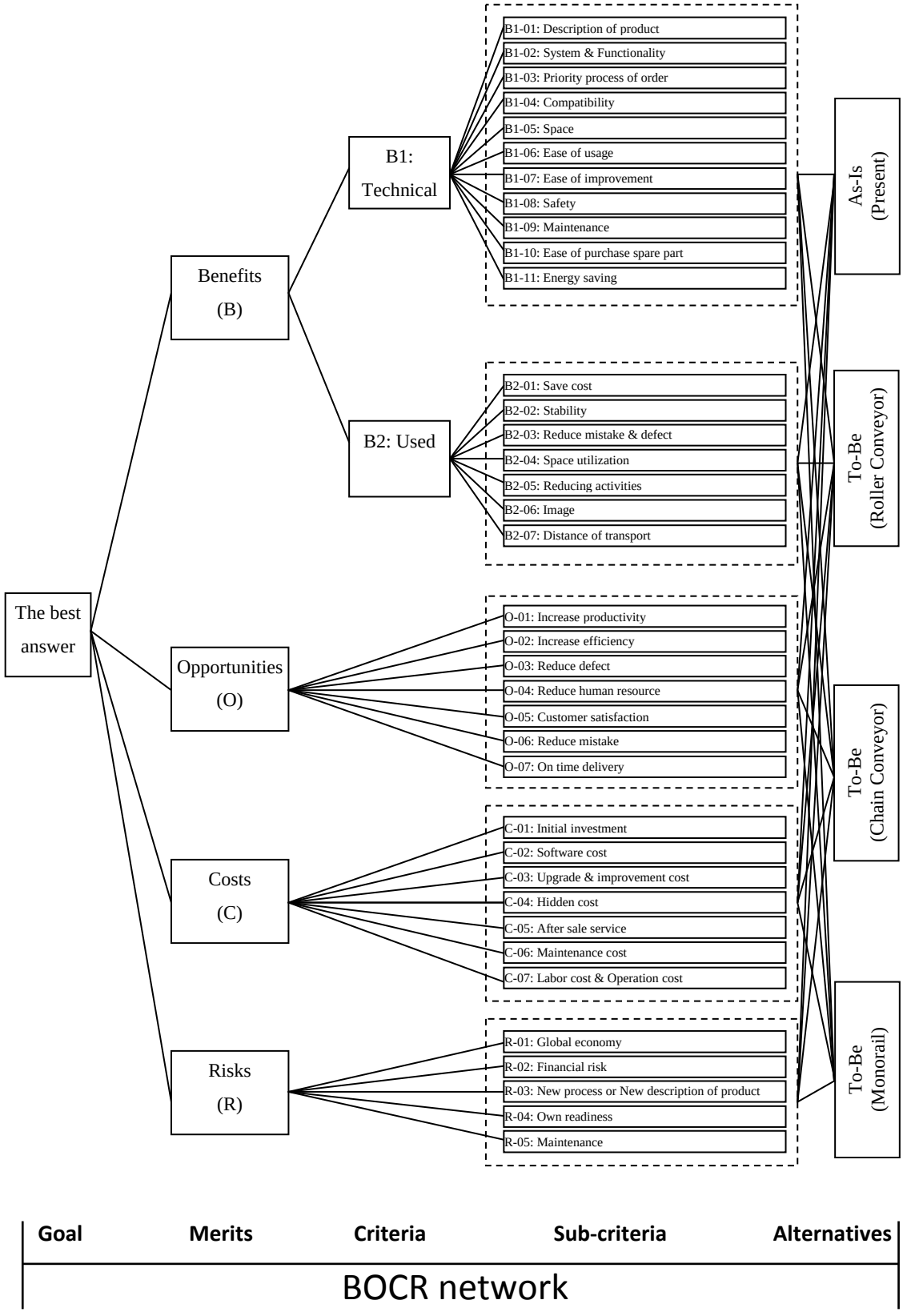

Figure 4.2 The analytic network process with BOCR

Benefits: Technical and Used benefits were allocated for the benefits model (Figure 4.3).

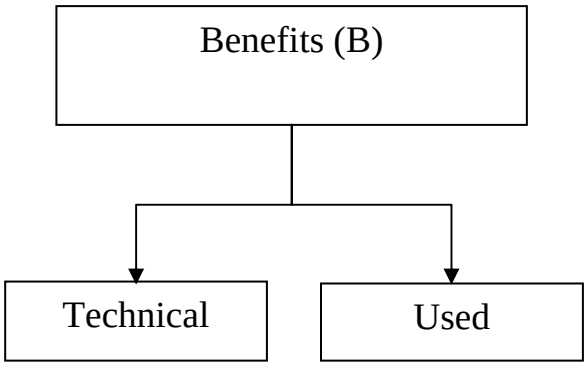

Figure 4.3 Benefits model

Under Benefits/Technical criteria, there is a cluster. This cluster includes the following nodes (Figure 4.4). Technical nodes divided into eleven criteria.

- Description of product (B1-01): Variations in the nature of the products to be transported, such as size, shape, temperature or variations of the product.
- System and Functionality (B1-02): Technical factors related to material handling systems, whether in technology or infrastructure.
- Priority process of order (B1-03): The priority of a process or product to be unloaded.
- Compatibility (B1-04): Easiness of equipment interface at source, easiness of equipment interface at destination.
- Space (B1-05): Area or areas that are used to structure the material handling systems.
- Ease of usage (B1-06): Easy to use and easy to install, the system will be installed.
- Ease of improvement (B1-07): Ease of modifying the system to be installed.
- Safety (B1-08): Safety’s factor of the system to be installed.
- Maintenance (B1-09): Spare parts supply, durability, repair easiness, after service level.

- Ease of purchase spare part (B1-10): The easy-to-order parts.
- Energy saving (B1-11): The nature of energy and energy efficiency.

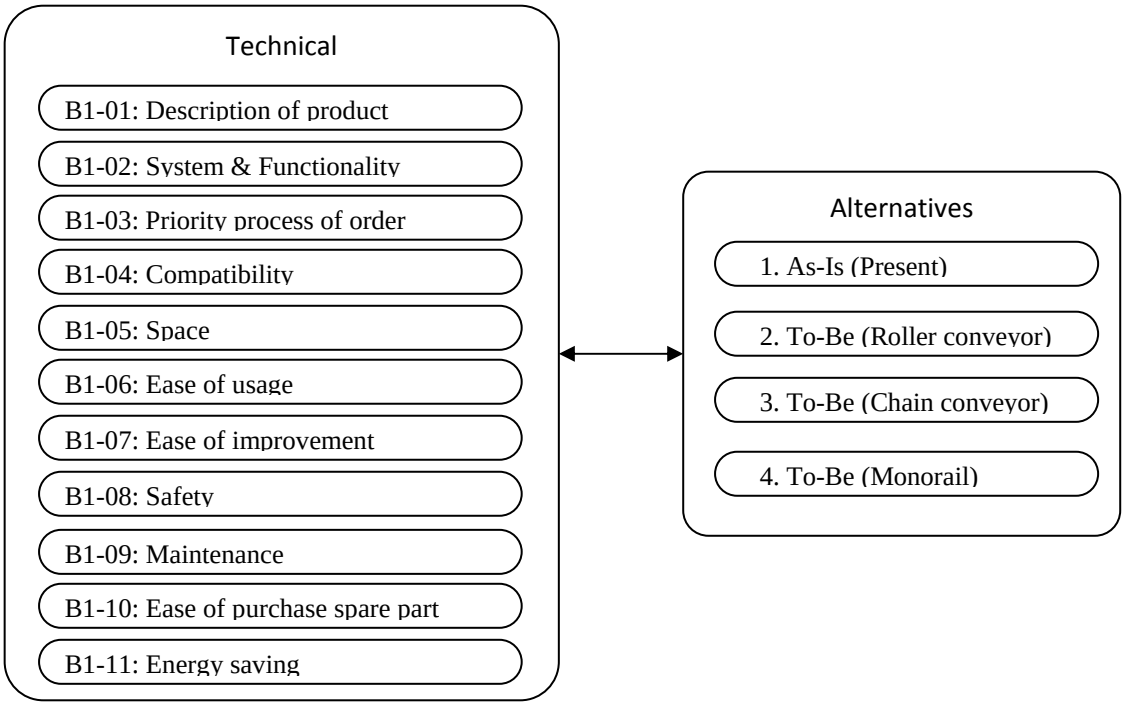

Figure 4.4 Clusters with element under Technical Benefits

There is a cluster under Benefit/Used criteria which includes the following nodes as Figure 4.5. Used node has divided into seven criteria.

- Save costs (B2-01): Cost is reduced.
- Stability activities (B2-02): A stable influence over the choice between the current system is any system with a roller conveyor system, and how much more or less the same score.
- Reduce mistake and defect (B2-03): The benefits of reducing the amount of waste and errors, whether before or misdirected or late due to transport.
- Space utilization (B2-04): Areas are managed effectively and get maximum benefit.
- Reducing activities (B2-05): The reduction of activities or repetitive activities.

- Image (B2-06): The image of the company, its customers or third parties to provide visibility and credibility in the system.
- Distance of transport (B2-07): The distance of transportation routes.

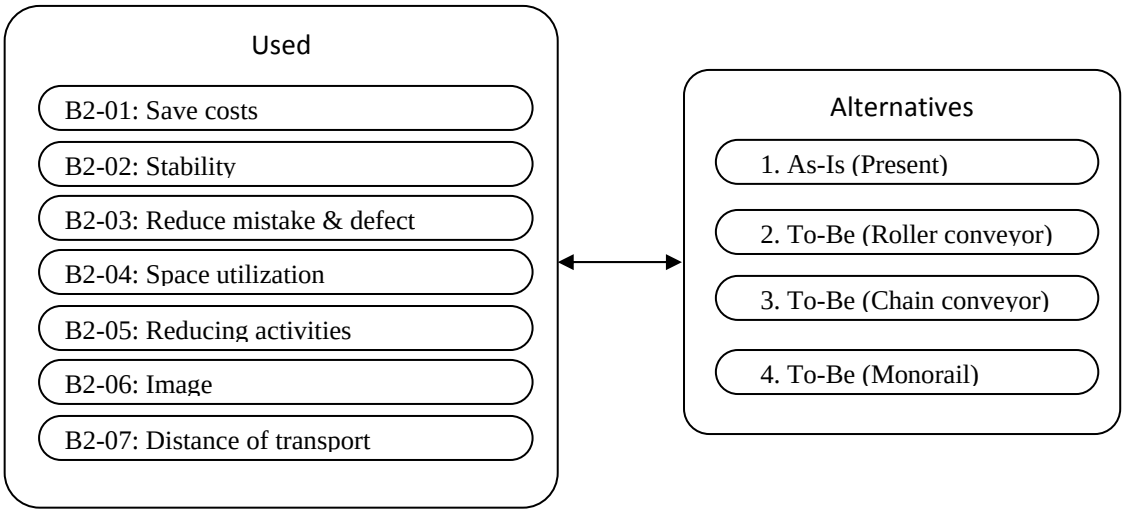

Figure 4.5 Clusters with element under Used Benefits

Under Opportunities, there is a cluster. This cluster includes the following nodes (Figure 4.6). Opportunities nodes divided into seven criteria.

- Increase productivity (O-01): Opportunity to increase the overall speed of the production system.
- Increase efficiency (O-02): Opportunity to increase the efficiency of loading and unloading of materials to be more.
- Reduce defect (O-03): Reducing the number of defects and errors, whether before or misdirected or late due to transport.
- Reduce human resource (O-04): Reduce the number of employees involved in transporting and unloading of materials.
- Customer satisfaction (O-05): The satisfaction of our customers.
- Reduce mistake (O-06): Reducing the number of errors caused by transportation.
- On time delivery (O-07): In stock at specified times, not too fast or too slow.

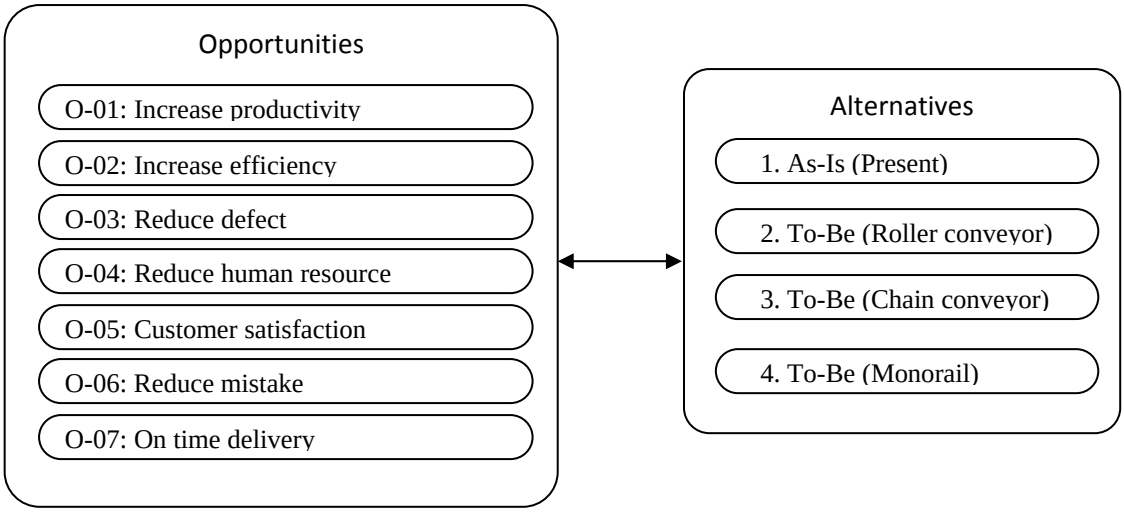

Figure 4.6 Clusters with element under Opportunities

Under Costs, there is a cluster. This cluster includes the following nodes (Figure 4.7). Costs nodes divided into seven criteria.

- Initial investment (C-01): Equipment cost and set-up cost.
- Software cost (C-02): Cost of Software for control system or support system.
- Upgrade and improvement cost (C-03): Cost for upgrade or improvement system in the future.
- Hidden cost (C-04): Costs that are not in the form of actual costs, but may lose the opportunity to make money or add costs to the other.
- After sale service (C-05): Services after installation in the first period successfully.
- Maintenance cost (C-06): The structural maintenance of equipment or systems.
- Labor cost and Operation cost (C-07): Expenses related to labor and overhead to run.

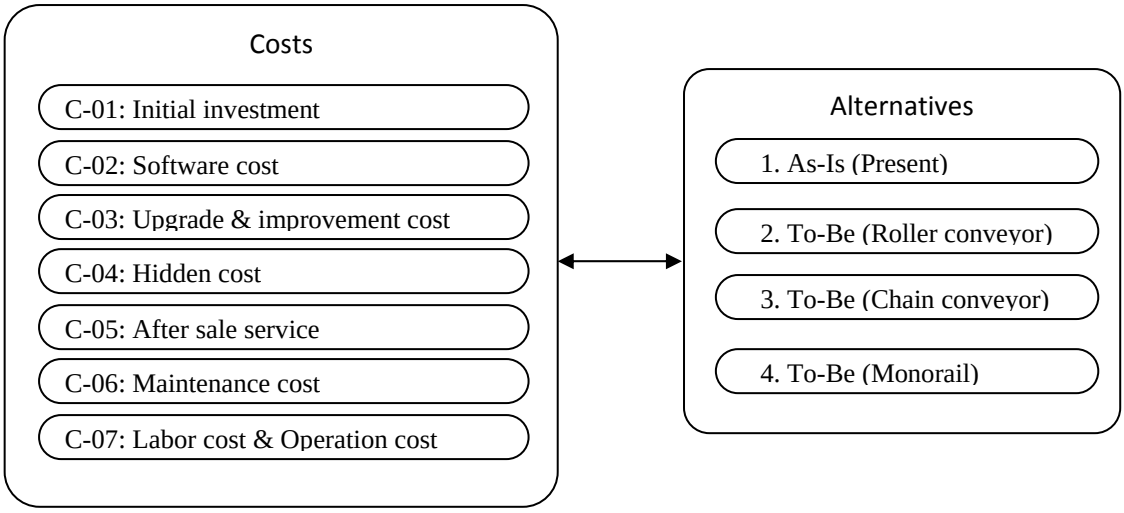

Figure 4.7 Clusters with element under Costs

Under Risks, there is a cluster. This cluster includes the following nodes (Figure 4.8). Risks nodes divided into five criteria.

- Global economy (R-01): Risk for economic of the domestic investor and global economy.
- Financial risk (R-02): Financial risk and liquidity to the financial.
- New process or new description of product (R-03): The risk of a process or route the flow of work. This may be changed. Or change shape. It can not be used on systems that have installed them.
- Own readiness (R-04): The risk to investors is also not ready to invest, whether it's the skills of personnel, stability of the transport system.
- Maintenance (R-05): The risk of maintaining a supply of spare parts or maintenance reliability.

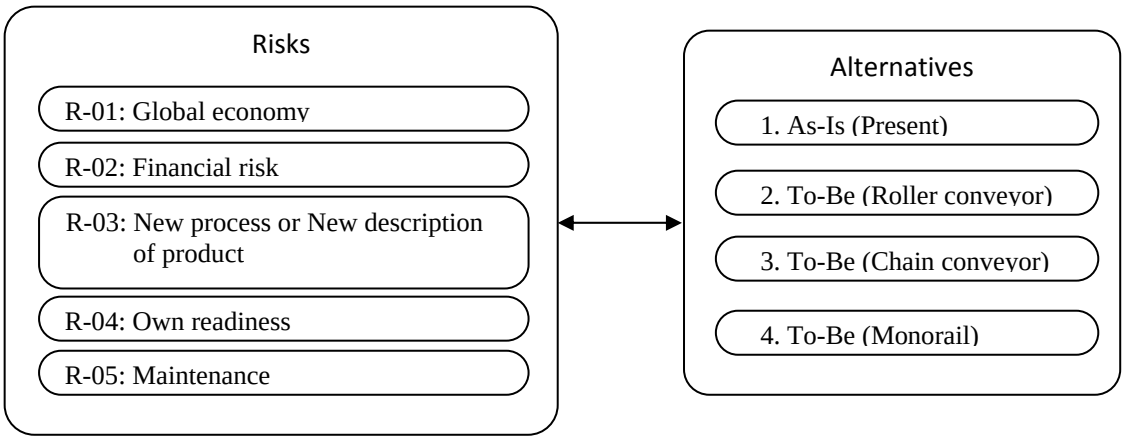

Figure 4.8 Clusters with element under Risks

4.3 Evaluation of criteria, sub-criteria and strategic weight

An anonymous factory in Thailand willing to select the best conveyor system was used as an example to examine the practicality of the conveyor system selection model (Chan et al., 2001; Lee et al., 2009). In the first step, two managers of factory and one design engineer manager's material handling service were chosen to represent the respondents with the questionnaire (Appendix D).

For this case study come from a factory in which the transport system is used Forklift. It used for transfer material from store building to another building in waiting zone for wait to support assembly line. The entrepreneur had the idea to improve the material handling system to conveyor system. The factory was selected for testing model ANP with BOCR.

Each expert was asked to assess BOCR according to strategic criteria by the five step scale. The five step scale and values of it are very high (0.42), high (0.26), medium (0.16), low (0.10) and very low (0.06). The panelist opinions are accumulate by the geometric mean method, and combined rating is:

$$[\text{Very high } (0.42) \times \text{Very high } (0.42) \times \text{High } (0.26)]^{1/3} = 0.36.$$

The overall combined rating score of all on strategic criteria are shown in Table 4.2.

Table 4.2 The overall combined rating score of all on strategic criteria

	Flexibility	Manufacturer	Future Plan	Productivity	Safety	Quality
Benefit	High	High	High	Very High	High	High
Opportunity	High	High	Medium	High	High	VH
Cost	Low	High	High	Medium	Low	Low
Risk	High	High	Very High	Medium	Low	High

For, the final values of comparison matrix for the strategic criteria are as shown in Table 4.3 and Table 4.4.

Table 4.3 Comparison matrix for the strategic criteria

	Flexibility	Manufacturer	Future Plan	Productivity	Safety	Quality	Synthesized priorities
Flexibility	1	4.2172	2.0801	2.4662	2.0801	1.0000	0.2934
Manufacturer	0.2371	1	2.0801	1.0000	1.0000	1.0000	0.1415
Future Plan	0.4807	0.4807	1	0.4807	1.4422	0.5503	0.1025
Productivity	0.4055	1.0000	2.0801	1	2.0801	1.0000	0.1662
Safety	0.4807	1.0000	0.6934	0.4807	1	0.3333	0.0928
Quality	1.0000	1.0000	1.8171	1.0000	3.0000	1	0.2037

Table 4.4 Priorities of Benefits, Opportunities, Costs and Risks

	Flexibility (0.2934)	Manufacturer (0.1415)	Future Plan (0.1025)	Productivity (0.1662)	Safety (0.0928)	Quality (0.2037)	Priorities for BOCR merits	Normalized Priorities
Benefit	High	High	High	Very High	High	High	0.2866	0.2977 (b)
Opportunity	High	High	Medium	High	High	Very High	0.2823	0.2932 (o)
Cost	Low	High	High	Medium	Low	Low	0.1490	0.1547 (c)
Risk	High	High	Very High	Medium	Low	High	0.2449	0.2544 (r)

Table 4.5 Unweighted supermatrix under Benefits/Technical subnet

	Alternatives				**Benefits/Technical**										
	Alter1	**Alter2**	**Alter3**	**Alter4**	**B1-01**	**B1-02**	**B1-03**	**B1-04**	**B1-05**	**B1-06**	**B1-07**	**B1-08**	**B1-09**	**B1-10**	**B1-11**
Alter_1	0	0	0	0	0.2500	0.0359	0.2500	0.0790	0.1096	0.2500	0.0944	0.2500	0.1048	0.0919	0.2500
Alter_2	0	0	0	0	0.2500	0.1980	0.2500	0.2051	0.2943	0.2500	0.3039	0.2500	0.2443	0.2003	0.2500
Alter_3	0	0	0	0	0.2500	0.2048	0.2500	0.2677	0.2873	0.2500	0.3075	0.2500	0.2234	0.2586	0.2500
Alter_4	0	0	0	0	0.2500	0.5613	0.2500	0.4482	0.3088	0.2500	0.2942	0.2500	0.4275	0.4492	0.2500
B1-01	0.0587	0.0317	0.0554	0.0814	0	0	0	0	0	0	0	0	0	0	0
B1-02	0.0841	0.1097	0.1437	0.1390	0	0	0	0	0	0	0	0	0	0	0
B1-03	0.0878	0.0746	0.0765	0.1316	0	0	0	0	0	0	0	0	0	0	0
B1-04	0.1031	0.1576	0.1530	0.1710	0	0	0	0	0	0	0	0	0	0	0
B1-05	0.0390	0.0922	0.0737	0.0847	0	0	0	0	0	0	0	0	0	0	0
B1-06	0.0669	0.1315	0.1279	0.0977	0	0	0	0	0	0	0	0	0	0	0
B1-07	0.1302	0.0594	0.0349	0.0495	0	0	0	0	0	0	0	0	0	0	0
B1-08	0.1368	0.1140	0.1276	0.0781	0	0	0	0	0	0	0	0	0	0	0
B1-09	0.1061	0.1093	0.0953	0.0927	0	0	0	0	0	0	0	0	0	0	0
B1-10	0.0583	0.0675	0.0702	0.0402	0	0	0	0	0	0	0	0	0	0	0
B1-11	0.1292	0.0526	0.0417	0.0341	0	0	0	0	0	0	0	0	0	0	0

Table 4.6 Weighted supermatrix under Benefits/Technical subnet

	Alternatives				Benefits/Technical										
	Alter1	**Alter2**	**Alter3**	**Alter4**	**B1-01**	**B1-02**	**B1-03**	**B1-04**	**B1-05**	**B1-06**	**B1-07**	**B1-08**	**B1-09**	**B1-10**	**B1-11**
Alter_1	0	0	0	0	0.2500	0.0359	0.2500	0.0790	0.1096	0.2500	0.0944	0.2500	0.1048	0.0919	0.2500
Alter_2	0	0	0	0	0.2500	0.1980	0.2500	0.2051	0.2943	0.2500	0.3039	0.2500	0.2443	0.2003	0.2500
Alter_3	0	0	0	0	0.2500	0.2048	0.2500	0.2677	0.2873	0.2500	0.3075	0.2500	0.2234	0.2586	0.2500
Alter_4	0	0	0	0	0.2500	0.5613	0.2500	0.4482	0.3088	0.2500	0.2942	0.2500	0.4275	0.4492	0.2500
B1-01	0.0587	0.0317	0.0554	0.0814	0	0	0	0	0	0	0	0	0	0	0
B1-02	0.0841	0.1097	0.1437	0.1390	0	0	0	0	0	0	0	0	0	0	0
B1-03	0.0878	0.0746	0.0765	0.1316	0	0	0	0	0	0	0	0	0	0	0
B1-04	0.1031	0.1576	0.1530	0.1710	0	0	0	0	0	0	0	0	0	0	0
B1-05	0.0390	0.0922	0.0737	0.0847	0	0	0	0	0	0	0	0	0	0	0
B1-06	0.0669	0.1315	0.1279	0.0977	0	0	0	0	0	0	0	0	0	0	0
B1-07	0.1302	0.0594	0.0349	0.0495	0	0	0	0	0	0	0	0	0	0	0
B1-08	0.1368	0.1140	0.1276	0.0781	0	0	0	0	0	0	0	0	0	0	0
B1-09	0.1061	0.1093	0.0953	0.0927	0	0	0	0	0	0	0	0	0	0	0
B1-10	0.0583	0.0675	0.0702	0.0402	0	0	0	0	0	0	0	0	0	0	0
B1-11	0.1292	0.0526	0.0417	0.0341	0	0	0	0	0	0	0	0	0	0	0

Table 4.7 The limit supermatrix under Benefits subnet

	Alternatives				**Benefits/Technical**										
	Alter1	**Alter2**	**Alter3**	**Alter4**	**B1-01**	**B1-02**	**B1-03**	**B1-04**	**B1-05**	**B1-06**	**B1-07**	**B1-08**	**B1-09**	**B1-10**	**B1-11**
Alter_1	0.0768	0.0768	0.0768	0.0768	0.0768	0.0768	0.0768	0.0768	0.0768	0.0768	0.0768	0.0768	0.0768	0.0768	0.0768
Alter_2	0.1200	0.1200	0.1200	0.1200	0.1200	0.1200	0.1200	0.1200	0.1200	0.1200	0.1200	0.1200	0.1200	0.1200	0.1200
Alter_3	0.1256	0.1256	0.1256	0.1256	0.1256	0.1256	0.1256	0.1256	0.1256	0.1256	0.1256	0.1256	0.1256	0.1256	0.1256
Alter_4	0.1777	0.1777	0.1777	0.1777	0.1777	0.1777	0.1777	0.1777	0.1777	0.1777	0.1777	0.1777	0.1777	0.1777	0.1777
B1-01	0.0297	0.0297	0.0297	0.0297	0.0297	0.0297	0.0297	0.0297	0.0297	0.0297	0.0297	0.0297	0.0297	0.0297	0.0297
B1-02	0.0624	0.0624	0.0624	0.0624	0.0624	0.0624	0.0624	0.0624	0.0624	0.0624	0.0624	0.0624	0.0624	0.0624	0.0624
B1-03	0.0487	0.0487	0.0487	0.0487	0.0487	0.0487	0.0487	0.0487	0.0487	0.0487	0.0487	0.0487	0.0487	0.0487	0.0487
B1-04	0.0764	0.0764	0.0764	0.0764	0.0764	0.0764	0.0764	0.0764	0.0764	0.0764	0.0764	0.0764	0.0764	0.0764	0.0764
B1-05	0.0384	0.0384	0.0384	0.0384	0.0384	0.0384	0.0384	0.0384	0.0384	0.0384	0.0384	0.0384	0.0384	0.0384	0.0384
B1-06	0.0543	0.0543	0.0543	0.0543	0.0543	0.0543	0.0543	0.0543	0.0543	0.0543	0.0543	0.0543	0.0543	0.0543	0.0543
B1-07	0.0303	0.0303	0.0303	0.0303	0.0303	0.0303	0.0303	0.0303	0.0303	0.0303	0.0303	0.0303	0.0303	0.0303	0.0303
B1-08	0.0541	0.0541	0.0541	0.0541	0.0541	0.0541	0.0541	0.0541	0.0541	0.0541	0.0541	0.0541	0.0541	0.0541	0.0541
B1-09	0.0497	0.0497	0.0497	0.0497	0.0497	0.0497	0.0497	0.0497	0.0497	0.0497	0.0497	0.0497	0.0497	0.0497	0.0497
B1-10	0.0285	0.0285	0.0285	0.0285	0.0285	0.0285	0.0285	0.0285	0.0285	0.0285	0.0285	0.0285	0.0285	0.0285	0.0285
B1-11	0.0275	0.0275	0.0275	0.0275	0.0275	0.0275	0.0275	0.0275	0.0275	0.0275	0.0275	0.0275	0.0275	0.0275	0.0275

Priority weights calculated from pairwise comparison are located properly into unweight supermatirx and weight supermatrix. The weighted supermatrix is stochastic, and expect the columns under alternatives cluster, each column sums to 1. By raising the weighted supermatrix to a large power, we obtain a limit matrix, as shown in Table 4.5 to 4.7. Table 4.8 gives the synthesized results for Benefits/Technical.

Table 4.8 Priorities of the alternatives for Benefits/Technical in Ideal and Form

Alternatives	**Priorities (ideal form)**	**Priorities (Normals)**	**Priorities (Limiting)**
Alternatives 1 (As-Is: Present)	0.4320	0.1535	0.0768
Alternatives 2 (To-Be: Roller Conveyor)	0.6752	0.2399	0.1200
Alternatives 3 (To-Be: Chain Conveyor)	0.7071	0.2513	0.1256
Alternatives 4 (To-Be: Monorail)	1.0000	0.3553	0.1777

The first supermatrix is the unweighted under benefits/used subnet, shown in Table 4.9. It has in it all the priorities from all the pairwise comparisons done with respect to benefits/used subnet. Because the unweighted supermatrix includes interaction between clusters, not each of the columns sums to one. Therefore, a weighted supermatrix is transformed first to be stochastic as shown in Table 4.10. The priorities of the alternatives can be seen from the block of the limit supermatrix under benefits/used subnet in Table 4.11.

Table 4.9 Unweighted supermatrix under Benefits/Used subnet

	Alternatives				Benefits/Used						
	Alter1	**Alter2**	**Alter3**	**Alter4**	**B2-01**	**B2-02**	**B2-03**	**B2-04**	**B2-05**	**B2-06**	**B2-07**
Alter_1	0	0	0	0	0.0935	0.0786	0.0844	0.0562	0.0973	0.081	0.1081
Alter_2	0	0	0	0	0.2151	0.1876	0.2711	0.4412	0.082	0.154	0.3206
Alter_3	0	0	0	0	0.2149	0.3389	0.4063	0.2435	0.3266	0.3885	0.3104
Alter_4	0	0	0	0	0.4765	0.3949	0.2382	0.2591	0.4942	0.3765	0.2609
B2-01	0.2054	0.3318	0.2498	0.3039	0	0	0	0	0	0	0
B2-02	0.1561	0.2205	0.2164	0.1738	0	0	0	0	0	0	0
B2-03	0.1224	0.0877	0.1399	0.1149	0	0	0	0	0	0	0
B2-04	0.139	0.1051	0.158	0.1817	0	0	0	0	0	0	0
B2-05	0.0559	0.0539	0.0957	0.0561	0	0	0	0	0	0	0
B2-06	0.0853	0.036	0.0611	0.0679	0	0	0	0	0	0	0
B2-07	0.236	0.1651	0.0792	0.1018	0	0	0	0	0	0	0

Table 4.10 Weighted supermatrix under Benefits/Used subnet

	Alternatives				Benefits/Used						
	Alter1	**Alter2**	**Alter3**	**Alter4**	**B2-01**	**B2-02**	**B2-03**	**B2-04**	**B2-05**	**B2-06**	**B2-07**
Alter_1	0	0	0	0	0.0935	0.0786	0.0844	0.0562	0.0973	0.081	0.1081
Alter_2	0	0	0	0	0.2151	0.1876	0.2711	0.4412	0.082	0.154	0.3206
Alter_3	0	0	0	0	0.2149	0.3389	0.4063	0.2435	0.3266	0.3885	0.3104
Alter_4	0	0	0	0	0.4765	0.3949	0.2382	0.2591	0.4942	0.3765	0.2609
B2-01	0.2054	0.3318	0.2498	0.3039	0	0	0	0	0	0	0
B2-02	0.1561	0.2205	0.2164	0.1738	0	0	0	0	0	0	0
B2-03	0.1224	0.0877	0.1399	0.1149	0	0	0	0	0	0	0
B2-04	0.139	0.1051	0.158	0.1817	0	0	0	0	0	0	0
B2-05	0.0559	0.0539	0.0957	0.0561	0	0	0	0	0	0	0
B2-06	0.0853	0.036	0.0611	0.0679	0	0	0	0	0	0	0
B2-07	0.236	0.1651	0.0792	0.1018	0	0	0	0	0	0	0

Table 4.11 The limit supermatrix under Benefits/Used subnet

	Alternatives				Benefits/Used						
	Alter1	**Alter2**	**Alter3**	**Alter4**	**B2-01**	**B2-02**	**B2-03**	**B2-04**	**B2-05**	**B2-06**	**B2-07**
Alter_1	0.0426	0.0426	0.0426	0.0426	0.0426	0.0426	0.0426	0.0426	0.0426	0.0426	0.0426
Alter_2	0.1254	0.1254	0.1254	0.1254	0.1254	0.1254	0.1254	0.1254	0.1254	0.1254	0.1254
Alter_3	0.1477	0.1477	0.1477	0.1477	0.1477	0.1477	0.1477	0.1477	0.1477	0.1477	0.1477
Alter_4	0.1843	0.1843	0.1843	0.1843	0.1843	0.1843	0.1843	0.1843	0.1843	0.1843	0.1843
B2-01	0.1433	0.1433	0.1433	0.1433	0.1433	0.1433	0.1433	0.1433	0.1433	0.1433	0.1433
B2-02	0.0983	0.0983	0.0983	0.0983	0.0983	0.0983	0.0983	0.0983	0.0983	0.0983	0.0983
B2-03	0.0581	0.0581	0.0581	0.0581	0.0581	0.0581	0.0581	0.0581	0.0581	0.0581	0.0581
B2-04	0.0759	0.0759	0.0759	0.0759	0.0759	0.0759	0.0759	0.0759	0.0759	0.0759	0.0759
B2-05	0.0336	0.0336	0.0336	0.0336	0.0336	0.0336	0.0336	0.0336	0.0336	0.0336	0.0336
B2-06	0.0297	0.0297	0.0297	0.0297	0.0297	0.0297	0.0297	0.0297	0.0297	0.0297	0.0297
B2-07	0.0612	0.0612	0.0612	0.0612	0.0612	0.0612	0.0612	0.0612	0.0612	0.0612	0.0612

Table 4.12 Priorities of the alternatives for Benefits/Used in Ideal and Form

Alternatives	**Priorities (ideal form)**	**Priorities (Normals)**	**Priorities (Limiting)**
Alternatives 1 (As-Is: Present)	0.2309	0.0851	0.0426
Alternatives 2 (To-Be: Roller Conveyor)	0.6804	0.2509	0.1254
Alternatives 3 (To-Be: Chain Conveyor)	0.8011	0.2953	0.1477
Alternatives 4 (To-Be: Monorail)	1.0000	0.3687	0.1843

Table 4.12 gives the synthesized results for Benefits/Technical is transformed by used value from alternatives of Table 4.11 to normal and ideal form.

The first supermatrix is the unweighted under opportunities subnet, shown in Table 4.13. It has in it all the priorities from all the pairwise comparisons done with respect to opportunities subnet. Because the unweighted supermatrix includes interaction between clusters, not each of the columns sums to one. Therefore, a weighted supermatrix is transformed first to be stochastic as shown in Table 4.15. The priorities of the alternatives can be seen from the block of the limit supermatrix under opportunities subnet in Table 4.16.

Table 4.13 Unweighted supermatrix under Opportunities subnet

	Alternatives				Opportunities						
	Alter1	**Alter2**	**Alter3**	**Alter4**	**O-01**	**O-02**	**O-03**	**O-04**	**O-05**	**O-06**	**O-07**
Alter_1	0	0	0	0	0.0750	0.0827	0.0568	0.049	0.0568	0.1219	0.2222
Alter_2	0	0	0	0	0.2147	0.1834	0.1926	0.2565	0.2214	0.2569	0.2812
Alter_3	0	0	0	0	0.2979	0.3192	0.3395	0.2702	0.2254	0.3157	0.2450
Alter_4	0	0	0	0	0.4123	0.4147	0.4111	0.4244	0.4964	0.3056	0.2515
O-01	0.1492	0.1327	0.1776	0.1859	0	0	0	0	0	0	0
O-02	0.1514	0.1834	0.2470	0.2112	0	0	0	0	0	0	0
O-03	0.0560	0.0682	0.1178	0.0679	0	0	0	0	0	0	0
O-04	0.0457	0.0427	0.0629	0.0424	0	0	0	0	0	0	0
O-05	0.1261	0.2287	0.1826	0.2418	0	0	0	0	0	0	0
O-06	0.1436	0.1374	0.1010	0.1111	0	0	0	0	0	0	0
O-07	0.3281	0.2069	0.1111	0.1396	0	0	0	0	0	0	0

Table 4.14 Weighted supermatrix under Opportunities subnet

	Alternatives				Opportunities						
	Alter1	**Alter2**	**Alter3**	**Alter4**	**O-01**	**O-02**	**O-03**	**O-04**	**O-05**	**O-06**	**O-07**
Alter_1	0	0	0	0	0.0750	0.0827	0.0568	0.049	0.0568	0.1219	0.2222
Alter_2	0	0	0	0	0.2147	0.1834	0.1926	0.2565	0.2214	0.2569	0.2812
Alter_3	0	0	0	0	0.2979	0.3192	0.3395	0.2702	0.2254	0.3157	0.2450
Alter_4	0	0	0	0	0.4123	0.4147	0.4111	0.4244	0.4964	0.3056	0.2515
O-01	0.1492	0.1327	0.1776	0.1859	0	0	0	0	0	0	0
O-02	0.1514	0.1834	0.2470	0.2112	0	0	0	0	0	0	0
O-03	0.0560	0.0682	0.1178	0.0679	0	0	0	0	0	0	0
O-04	0.0457	0.0427	0.0629	0.0424	0	0	0	0	0	0	0
O-05	0.1261	0.2287	0.1826	0.2418	0	0	0	0	0	0	0
O-06	0.1436	0.1374	0.1010	0.1111	0	0	0	0	0	0	0
O-07	0.3281	0.2069	0.1111	0.1396	0	0	0	0	0	0	0

Table 4.15 The limit supermatrix under Opportunities subnet

	Alternatives				Opportunities						
	Alter1	**Alter2**	**Alter3**	**Alter4**	**O-01**	**O-02**	**O-03**	**O-04**	**O-05**	**O-06**	**O-07**
Alter_1	0.0500	0.0500	0.0500	0.0500	0.0500	0.0500	0.0500	0.0500	0.0500	0.0500	0.0500
Alter_2	0.1129	0.1129	0.1129	0.1129	0.1129	0.1129	0.1129	0.1129	0.1129	0.1129	0.1129
Alter_3	0.1412	0.1412	0.1412	0.1412	0.1412	0.1412	0.1412	0.1412	0.1412	0.1412	0.1412
Alter_4	0.1959	0.1959	0.1959	0.1959	0.1959	0.1959	0.1959	0.1959	0.1959	0.1959	0.1959
O-01	0.0839	0.0839	0.0839	0.0839	0.0839	0.0839	0.0839	0.0839	0.0839	0.0839	0.0839
O-02	0.1045	0.1045	0.1045	0.1045	0.1045	0.1045	0.1045	0.1045	0.1045	0.1045	0.1045
O-03	0.0404	0.0404	0.0404	0.0404	0.0404	0.0404	0.0404	0.0404	0.0404	0.0404	0.0404
O-04	0.0243	0.0243	0.0243	0.0243	0.0243	0.0243	0.0243	0.0243	0.0243	0.0243	0.0243
O-05	0.1053	0.1053	0.1053	0.1053	0.1053	0.1053	0.1053	0.1053	0.1053	0.1053	0.1053
O-06	0.0587	0.0587	0.0587	0.0587	0.0587	0.0587	0.0587	0.0587	0.0587	0.0587	0.0587
O-07	0.0828	0.0828	0.0828	0.0828	0.0828	0.0828	0.0828	0.0828	0.0828	0.0828	0.0828

Table 4.16 Priorities of the alternatives for Opportunities in Ideal and Form

Alternatives	**Priorities (ideal form)**	**Priorities (Normals)**	**Priorities (Limiting)**
Alternatives 1 (As-Is: Present)	0.2550	0.0999	0.0500
Alternatives 2 (To-Be: Roller Conveyor)	0.5762	0.2258	0.1129
Alternatives 3 (To-Be: Chain Conveyor)	0.7208	0.2824	0.1412
Alternatives 4 (To-Be: Monorail)	1.0000	0.3918	0.1959

Table 4.17 gives the synthesized results for Benefits/Technical is transformed by used value from alternatives of Table 4.16 to normal and ideal form.

The first supermatrix is the unweighted under opportunities subnet, shown in Table 4.14. It has in it all the priorities from all the pairwise comparisons done with respect to opportunities subnet. Because the unweighted supermatrix includes interaction between clusters, not each of the columns sums to one. Therefore, a weighted supermatrix is transformed first to be stochastic as shown in Table 4.15. The priorities of the alternatives can be seen from the block of the limit supermatrix under opportunities subnet in Table 4.16.

Table 4.17 Unweighted supermatrix under Costs subnet

	Alternatives				Costs						
	Alter1	**Alter2**	**Alter3**	**Alter4**	**C-01**	**C-02**	**C-03**	**C-04**	**C-05**	**C-06**	**C-07**
Alter_1	0	0	0	0	0.0779	0.0722	0.0803	0.0857	0.1106	0.0651	0.0978
Alter_2	0	0	0	0	0.2313	0.2655	0.2585	0.2373	0.2296	0.2526	0.2411
Alter_3	0	0	0	0	0.2795	0.275	0.2278	0.2258	0.2734	0.2255	0.2344
Alter_4	0	0	0	0	0.4114	0.3873	0.4334	0.4512	0.3864	0.4568	0.4267
C-01	0.3575	0.2869	0.3186	0.3456	0	0	0	0	0	0	0
C-02	0.0605	0.1228	0.1524	0.1457	0	0	0	0	0	0	0
C-03	0.0864	0.0665	0.055	0.1488	0	0	0	0	0	0	0
C-04	0.1191	0.1633	0.1116	0.1284	0	0	0	0	0	0	0
C-05	0.0356	0.0415	0.0457	0.0415	0	0	0	0	0	0	0
C-06	0.2247	0.2041	0.2273	0.1258	0	0	0	0	0	0	0
C-07	0.1163	0.1151	0.0895	0.0643	0	0	0	0	0	0	0

Table 4.18 Weighted supermatrix under Costs subnet

	Alternatives				Costs						
	Alter1	**Alter2**	**Alter3**	**Alter4**	**C-01**	**C-02**	**C-03**	**C-04**	**C-05**	**C-06**	**C-07**
Alter_1	0	0	0	0	0.0779	0.0722	0.0803	0.0857	0.1106	0.0651	0.0978
Alter_2	0	0	0	0	0.2313	0.2655	0.2585	0.2373	0.2296	0.2526	0.2411
Alter_3	0	0	0	0	0.2795	0.275	0.2278	0.2258	0.2734	0.2255	0.2344
Alter_4	0	0	0	0	0.4114	0.3873	0.4334	0.4512	0.3864	0.4568	0.4267
C-01	0.3575	0.2869	0.3186	0.3456	0	0	0	0	0	0	0
C-02	0.0605	0.1228	0.1524	0.1457	0	0	0	0	0	0	0
C-03	0.0864	0.0665	0.055	0.1488	0	0	0	0	0	0	0
C-04	0.1191	0.1633	0.1116	0.1284	0	0	0	0	0	0	0
C-05	0.0356	0.0415	0.0457	0.0415	0	0	0	0	0	0	0
C-06	0.2247	0.2041	0.2273	0.1258	0	0	0	0	0	0	0
C-07	0.1163	0.1151	0.0895	0.0643	0	0	0	0	0	0	0

Table 4.19 The limit supermatrix under Costs subnet

	Alternatives				Costs						
	Alter1	**Alter2**	**Alter3**	**Alter4**	**C-01**	**C-02**	**C-03**	**C-04**	**C-05**	**C-06**	**C-07**
Alter_1	0.0396	0.0396	0.0396	0.0396	0.0396	0.0396	0.0396	0.0396	0.0396	0.0396	0.0396
Alter_2	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122	0.122
Alter_3	0.1264	0.1264	0.1264	0.1264	0.1264	0.1264	0.1264	0.1264	0.1264	0.1264	0.1264
Alter_4	0.212	0.212	0.212	0.212	0.212	0.212	0.212	0.212	0.212	0.212	0.212
C-01	0.1627	0.1627	0.1627	0.1627	0.1627	0.1627	0.1627	0.1627	0.1627	0.1627	0.1627
C-02	0.0675	0.0675	0.0675	0.0675	0.0675	0.0675	0.0675	0.0675	0.0675	0.0675	0.0675
C-03	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
C-04	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066
C-05	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021
C-06	0.0892	0.0892	0.0892	0.0892	0.0892	0.0892	0.0892	0.0892	0.0892	0.0892	0.0892
C-07	0.0436	0.0436	0.0436	0.0436	0.0436	0.0436	0.0436	0.0436	0.0436	0.0436	0.0436

Table 4.20 Priorities of the alternatives for Costs in Ideal and Form

Alternatives	**Priorities (ideal form)**	**Priorities (Normals)**	**Priorities (Limiting)**
Alternatives 1 (As-Is: Present)	0.1869	0.0792	0.0396
Alternatives 2 (To-Be: Roller Conveyor)	0.5755	0.2440	0.1220
Alternatives 3 (To-Be: Chain Conveyor)	0.5963	0.2528	0.1264
Alternatives 4 (To-Be: Monorail)	1.0000	0.4240	0.2120

Table 4.21 gives the synthesized results for Benefits/Technical is transformed by used value from alternatives of Table 4.19 to normal and ideal form.

The first supermatrix is the unweighted under costs subnet, shown in Table 4.22. It has in it all the priorities from all the pairwise comparisons done with respect to costs subnet. Because the unweighted supermatrix includes interaction between clusters, not each of the columns sums to one. Therefore, a weighted supermatrix is transformed first to be stochastic as shown in Table 4.23. The priorities of the alternatives can be seen from the block of the limit supermatrix under costs subnet in Table 4.24.

Result’s weighted supermatrix of Risk subnet us stochastic and except the columns under alternatives cluster as shown in Table 4.22, each column sums to 1.

Table 4.21 Unweighted supermatrix under Risks subnet

	Alternatives				Risks				
	Alter1	**Alter2**	**Alter3**	**Alter4**	**R-01**	**R-02**	**R-03**	**R-04**	**R-05**
Alter_1	0	0	0	0	0.0675	0.0668	0.0872	0.0664	0.1092
Alter_2	0	0	0	0	0.2536	0.2642	0.2252	0.2523	0.2563
Alter_3	0	0	0	0	0.2391	0.2417	0.2851	0.238	0.2041
Alter_4	0	0	0	0	0.4398	0.4273	0.4026	0.4433	0.4304
R-01	0.3198	0.4378	0.3773	0.2948	0	0	0	0	0
R-02	0.3098	0.2341	0.2672	0.3142	0	0	0	0	0
R-03	0.0703	0.0867	0.0625	0.0551	0	0	0	0	0
R-04	0.1824	0.1112	0.1525	0.1635	0	0	0	0	0
R-05	0.1177	0.1302	0.1406	0.1725	0	0	0	0	0

Table 4.22 Weighted supermatrix under Risks subnet

	Alternatives				Risks				
	Alter1	**Alter2**	**Alter3**	**Alter4**	**R-01**	**R-02**	**R-03**	**R-04**	**R-05**
Alter_1	0	0	0	0	0.0675	0.0668	0.0872	0.0664	0.1092
Alter_2	0	0	0	0	0.2536	0.2642	0.2252	0.2523	0.2563
Alter_3	0	0	0	0	0.2391	0.2417	0.2851	0.238	0.2041
Alter_4	0	0	0	0	0.4398	0.4273	0.4026	0.4433	0.4304
R-01	0.3198	0.4378	0.3773	0.2948	0	0	0	0	0
R-02	0.3098	0.2341	0.2672	0.3142	0	0	0	0	0
R-03	0.0703	0.0867	0.0625	0.0551	0	0	0	0	0
R-04	0.1824	0.1112	0.1525	0.1635	0	0	0	0	0
R-05	0.1177	0.1302	0.1406	0.1725	0	0	0	0	0

Table 4.23 The limit supermatrix under Risks subnet

	Alternatives				Risks				
	Alter1	**Alter2**	**Alter3**	**Alter4**	**R-01**	**R-02**	**R-03**	**R-04**	**R-05**
Alter_1	0.0373	0.0373	0.0373	0.0373	0.0373	0.0373	0.0373	0.0373	0.0373
Alter_2	0.1275	0.1275	0.1275	0.1275	0.1275	0.1275	0.1275	0.1275	0.1275
Alter_3	0.1187	0.1187	0.1187	0.1187	0.1187	0.1187	0.1187	0.1187	0.1187
Alter_4	0.2165	0.2165	0.2165	0.2165	0.2165	0.2165	0.2165	0.2165	0.2165
R-01	0.1764	0.1764	0.1764	0.1764	0.1764	0.1764	0.1764	0.1764	0.1764
R-02	0.1411	0.1411	0.1411	0.1411	0.1411	0.1411	0.1411	0.1411	0.1411
R-03	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.033
R-04	0.0745	0.0745	0.0745	0.0745	0.0745	0.0745	0.0745	0.0745	0.0745
R-05	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075

Table 4.24 Priorities of the alternatives for Risks in Ideal and Form

Alternatives	**Priorities (ideal form)**	**Priorities (Normals)**	**Priorities (Limiting)**
Alternatives 1 (As-Is: Present)	0.1725	0.0747	0.0373
Alternatives 2 (To-Be: Roller Conveyor)	0.5888	0.2549	0.1275
Alternatives 3 (To-Be: Chain Conveyor)	0.5485	0.2375	0.1187
Alternatives 4 (To-Be: Monorail)	1.0000	0.4329	0.2165

Table 4.25 gives the synthesized results for Benefits/Technical is transformed by used value from alternatives of Table 4.24 to normal and ideal form.

Table 4.25 Priorities of the alternatives under BOCR control criteria

Alternatives	**Benefits**		**Opportunities**	**Costs**	**Risk**
	Technical	**Used**			
Alternatives 1 (As-Is: Present)	0.4320	0.2309	0.2550	0.1869	0.1725
Alternatives 2 (To-Be: Roller Conveyor)	0.6752	0.6804	0.5762	0.5755	0.5888
Alternatives 3 (To-Be: Chain Conveyor)	0.7071	0.8011	0.7208	0.5963	0.5485
Alternatives 4 (To-Be: Monorail)	1.0000	1.0000	1.0000	1.0000	1.0000

Table 4.26 Priorities of the alternatives under BOCR

Alternatives	Benefits	Opportunities	Costs	Risk
Alternatives 1 (As-Is: Present)	0.2786	0.2550	0.1869	0.1725
Alternatives 2 (To-Be: Roller Conveyor)	0.6792	0.5762	0.5755	0.5888
Alternatives 3 (To-Be: Chain Conveyor)	0.7788	0.7208	0.5963	0.5485
Alternatives 4 (To-Be: Monorail)	1.0000	1.0000	1.0000	1.0000

Table 4.25 is show both result technical and used in the benefits and other control criteria. The combined results from the technical and used under benefit subnet are shown in Table 4.26.

The normalized performances of four alternatives under the B, O, C and R are calculated as shown in Table 4.27.

Table 4.27 Priorities of alternative under four merits

Alternative	Merits	
	Benefits (0.2977)	**Opportunities (0.2932)**
	Normalized	Normalized
As-Is: Present	0.1018	0.0999
To-Be: Roller Conveyor	0.2482	0.2258
To-Be: Chain Conveyor	0.2846	0.2824
To-Be: Monorail	0.3654	0.3918

Table 4.27 Priorities of alternative under four merits (cont.)

Alternative	Merits					
	Costs (0.1547)			Risks (0.2544)		
	Normalized	Reciprocal	Normalized reciprocal	Normalized	Reciprocal	Normalized reciprocal
As-Is: Present	0.0792	12.6228	0.5480	0.0747	13.3890	0.5618
To-Be: Roller Conveyor	0.2440	4.0985	0.1779	0.2549	3.9230	0.1646
To-Be: Chain Conveyor	0.2528	3.9555	0.1717	0.2375	4.2112	0.1767
To-Be: Monorail	0.4240	2.3586	0.1024	0.4329	2.3098	0.0969

The relative performance of alternatives with respect to each merit is shown in Table 4.27. Under the benefits merit, Monorail the best with a priority of 0.3654, followed by chain conveyor with 0.2848, a little difference of 0.0808. Under the opportunities merit, monorail the best same as benefit merit with a priority of 0.3918, followed by chain conveyor with 0.2824. The first and second of two merits are identical, monorail and chain conveyor, respectively. Nevertheless, under the cost merit, As-Is:Present becomes the best with a normalized reciprocal priority of 0.5480, followed by roller conveyor with 0.1779, a very difference. Under the risks merit, the least risk alternative becomes As-Is:Present with a priority of 0.5618, followed by chain conveyor with 0.1767.

The alternative's final ranking is combine scores under B, O, C, and R of each alternative by used the five method: additive model, probabilistic additive model, subtractive, multiplicative priority powers and multiplicative for combine score. The final ranking of the alternatives are as shown in Table 4.28. For example, the alternative 1(As-Is: Present) is calculated by the five methods.

Additive:

$P_1 = bB_1 + oO_1 + c[(1/C_1)_{Normalized}] + r[(1/R_1)_{Normalized}]$

$= 0.2977 \times 0.1018 + 0.2932 \times 0.0999 + 0.1547 \times 0.5480 + 0.2544 \times 0.5618$

$= 0.2873$

Probabilistic additive:

$P_1 = bB_1 + oO_1 + c(1- C_1) + r(1- R_1)$

$= 0.2977 \times 0.1018 + 0.2932 \times 0.0999 + 0.1547 \times (1 - 0.0792) + 0.2544 \times (1 - 0.0747)$

$= 0.4375$

Subtractive:

$P_1 = bB_1 + oO_1 - cC_1 - rR_1$

$= 0.2977 \times 0.1018 + 0.2932 \times 0.0999 - 0.1547 \times 0.0792 - 0.2544 \times 0.0747$

$= 0.0283$

Multiplicative priority powers:

$P_1 = B_1^b O_1^o [(1/ C_1)\text{Normalized}]^c [(1/ R_1)\text{Normalized}]^r$

$= (0.1018^{0.2977}) (0.0999^{0.2932}) (0.5480^{0.1547}) (0.5618^{0.2544})$

$= 0.2029$

Multiplicative:

$P_1 = B_1O_1 / C_1R_1$

$= 0.1018 \times 0.0999 /0.0792 \times 0.0747$

$= 1.7194$

Under the benefits and opportunities merits in Table 4.27, to-be: Monorail is the best with 0.3654, 0.3918, respectively. Nevertheless, under the cost and risk merits, as-is: Present is the best cost and the least risky alternative with normalized reciprocal of 0.5480 and 0.5618, respectively.

Table 4.28 Final synthesis of priorities of alternatives

Alternatives	Synthesizing methods									
	Additive		Probabilistic additive		Subtractive		Multiplicative priority powers		Multiplicative	
	Priority	Rank	Priority	Rank	Priority	Rank	Priority	Rank	Priority	Rank
As-Is: Present	0.2873	1	0.4375	4	0.0283	4	0.2029	4	1.7194	1
To-Be: Roller Conveyor	0.2095	4	0.4466	3	0.0375	3	0.2065	3	0.9010	3
To-Be: Chain Conveyor	0.2390	3	0.4771	1	0.0680	1	0.2326	1	1.3389	2
To-Be: Monorail	0.2642	2	0.4570	2	0.0479	2	0.2186	2	0.7801	4

The final calculation of alternatives is using the five methods under B, O, C and R. The result of ranking of the alternatives is as shown in Table 4.28. High recommendation from five methods is the subtractive method.

From final result, first priority of the best alternative under all five methods is chain conveyor. While roller conveyor always stay respectively as the third and the last system. Under probabilistic additive, Subtractive, and the multiplicative priority powers, chain conveyor is the first best, and monorail is the second. In addition, the ranking under multiplicative method is not the same as other, major reason is that the method does not take into account the priorities b, o, c and r. Nevertheless, with the objective of selecting two system, the first and second select chain conveyor and monorail, respectively, under all five methods.

The material handling design engineer are decision aids base on three ways depend on textbooks/handbook, equipment vendor's experience and consultant. Recommendation and suggestion of equipment vendors might have biased, because sometimes they have suggestion in their equipment or they are most familiar (Chan et al., 2001). Many times, investor will only consider in benefits of investment and investment cost, which makes the mistake of considering at the major two factors, the opportunities and risks arising from the investment. For the method presented can be utilized to reduce the bias in the selection of appropriate handling equipment.