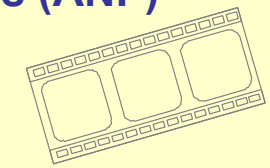
Analytic Network Process (ANP)

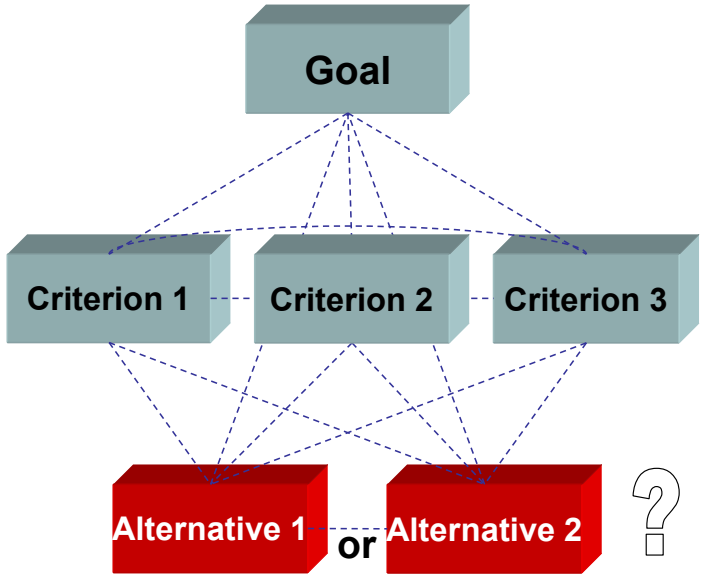


Klaus D. Goepel Feb. 2011

Analytic Network Process (ANP)

Developed by Prof. Thomas L. Saaty

1 The Analytic Network Process ANP is a **decision making method**



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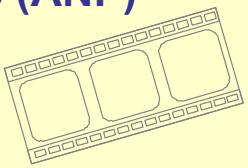

Overview

The analytic network process ANP is a decision finding method

Analytic Network Process (ANP)

Developed by Prof. Thomas L. Saaty

1. The Analytic Network Process ANP is a **decision making method**
2. ANP is a generalization of the **Analytic Hierarchy Process AHP**

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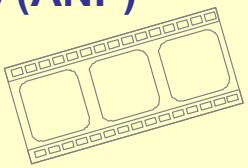

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The analytic network process ANP is a decision finding method and generalization of the analytic hierarchy process AHP.

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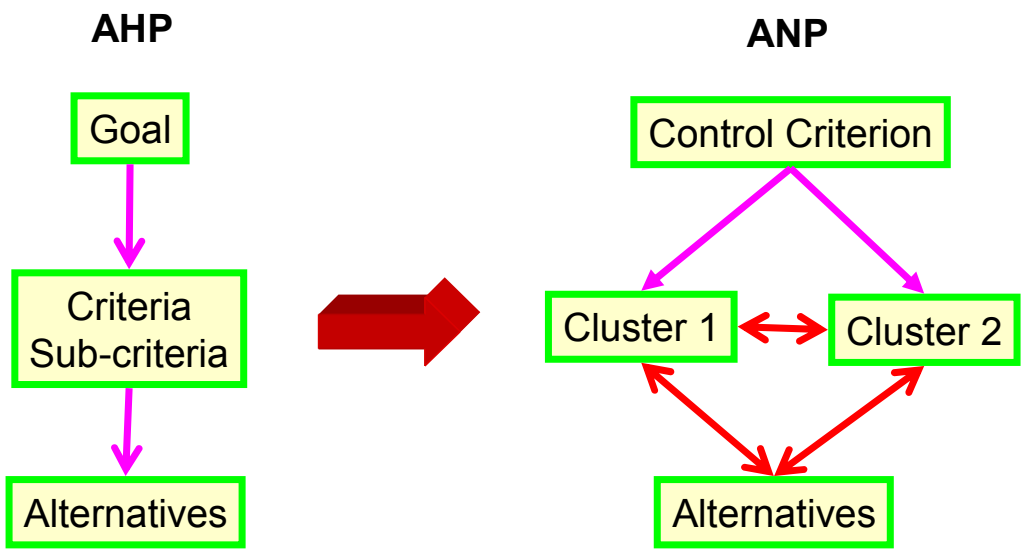

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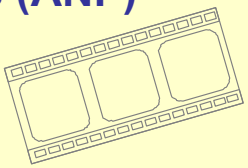

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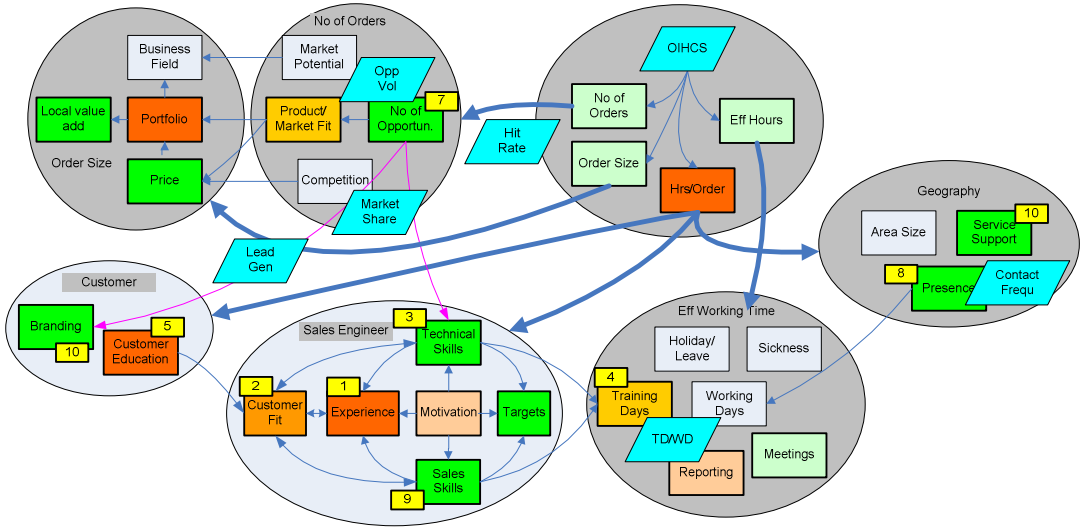

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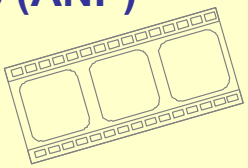

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The analytic network process ANP is a decision finding method and generalization of the analytic hierarchy process AHP.

ANP can model complex decision problems, where a hierarchical model – as used in AHP – is not sufficient.

Analytic Network Process (ANP)

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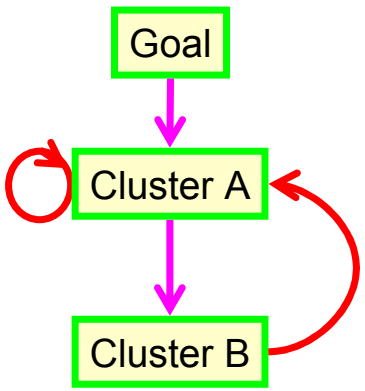

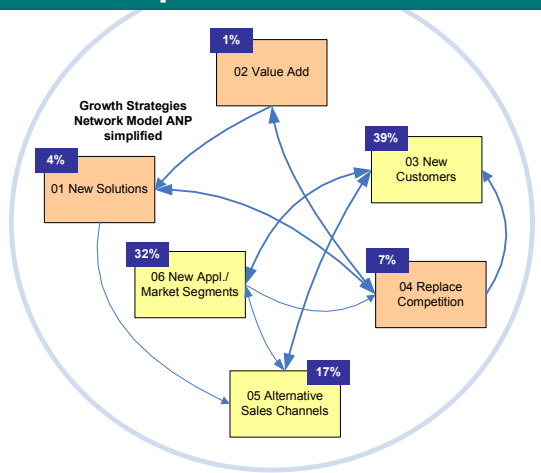

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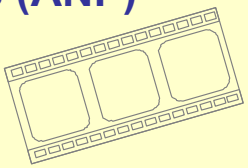

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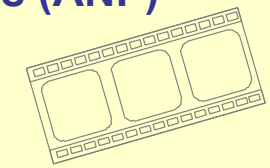

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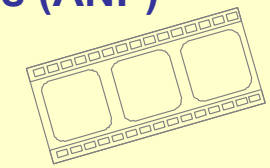
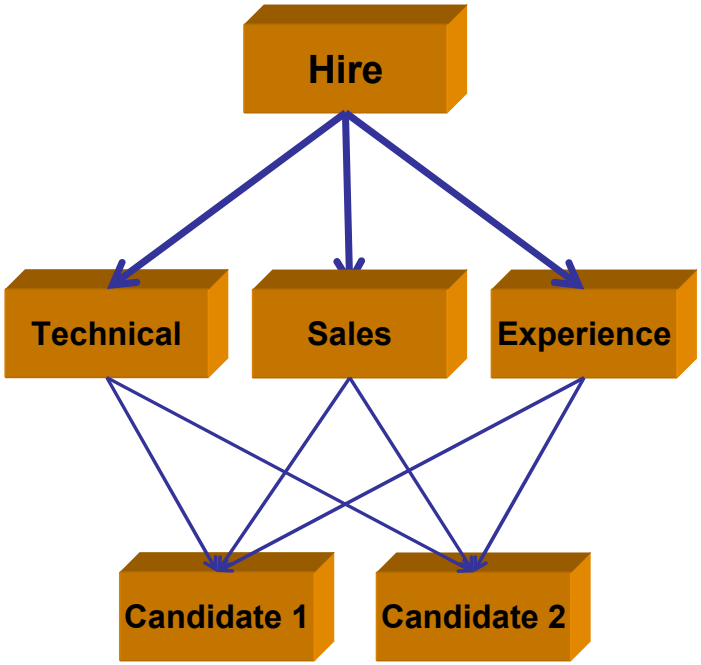


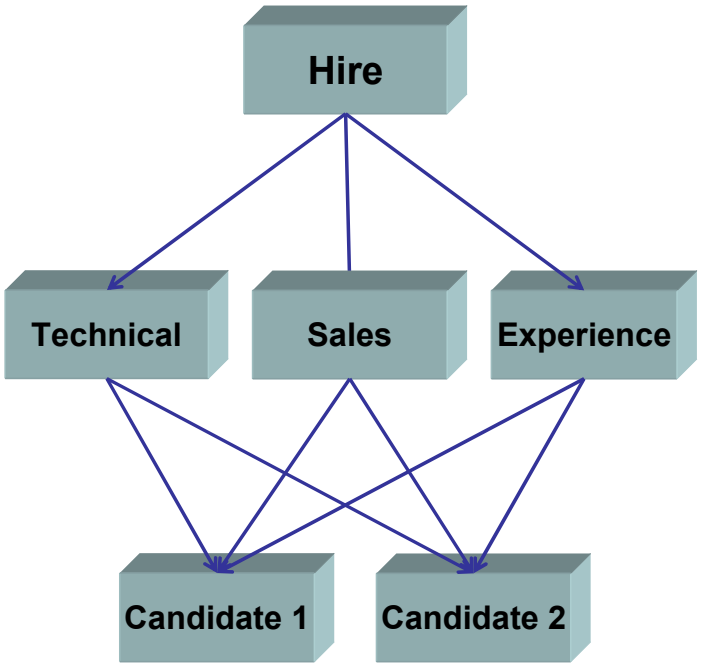
Overview

Example

Decision for the selection of a candidate in recruitment of a sales engineer



Hierarchical Model (AHP)



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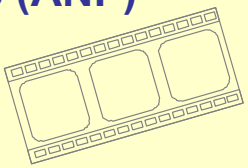

Overview

In **AHP** you do a pair-wise comparison of criteria and sub-criteria, resulting in local priorities or weighting factors.

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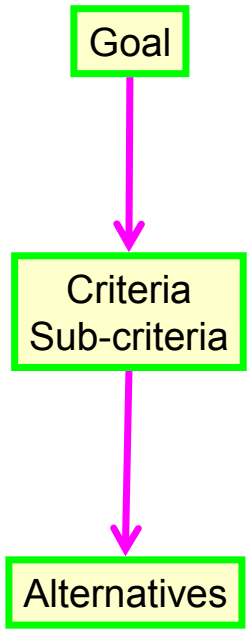

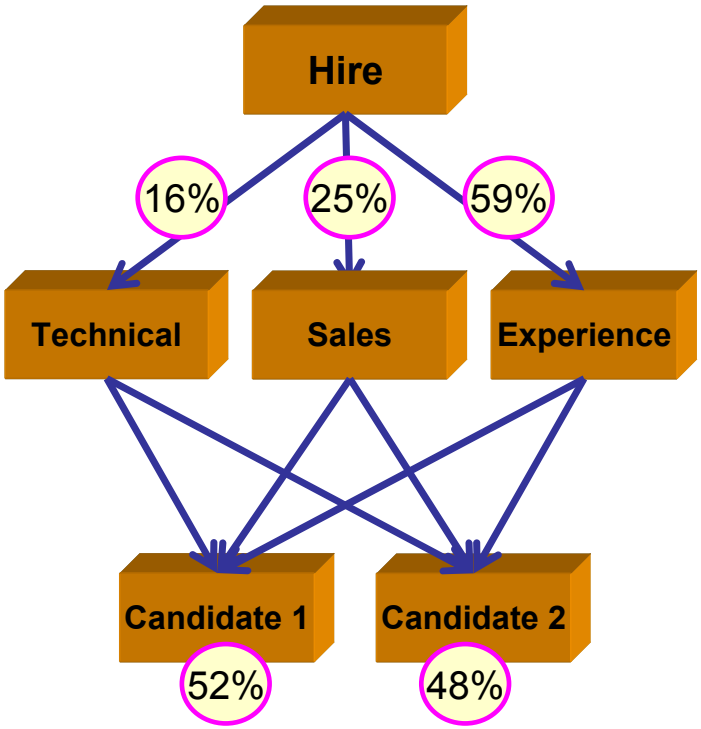

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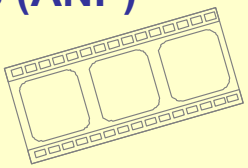


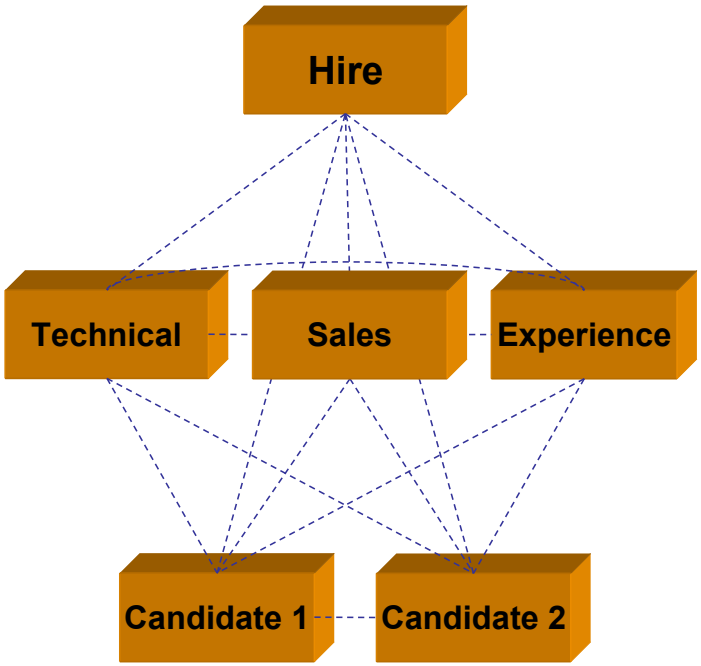
Overview

In **AHP** you do a pair-wise comparison of criteria and sub-criteria, resulting in local priorities or weighting factors.

By applying the global priorities to alternatives, you finally get a ranking of alternatives with respect to these criteria and sub-criteria.

It's a top-down structure from the overall objective to criteria, from criteria to sub-criteria down to alternatives.

Network Model (ANP)



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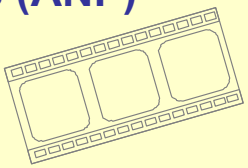


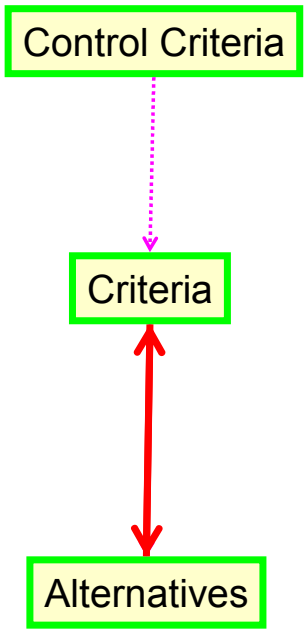
Overview

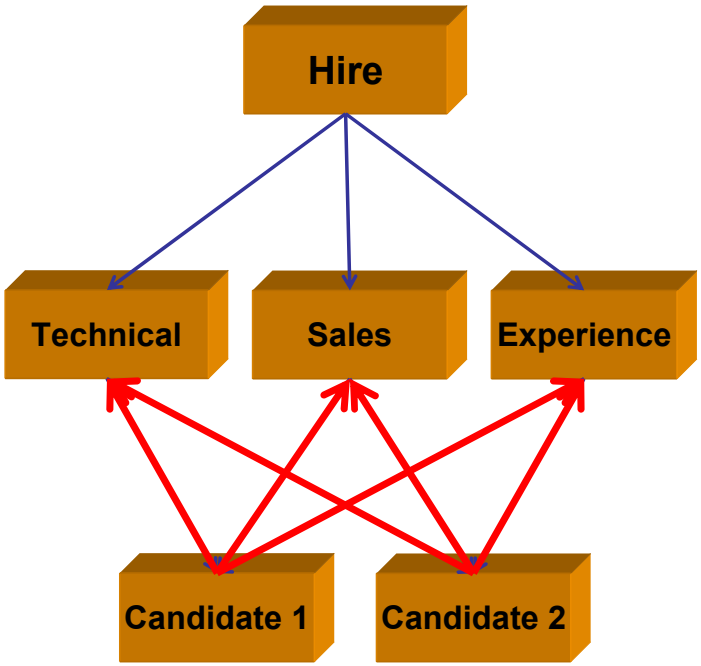
In **ANP** criteria, sub-criteria and alternatives are treated equally as **nodes** in a network.

Each of these nodes might be compared to any other node, as long as there is a relation between them.

Network Model (ANP)

Given Alternatives can influence the weighting of criteria





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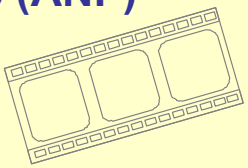


Overview

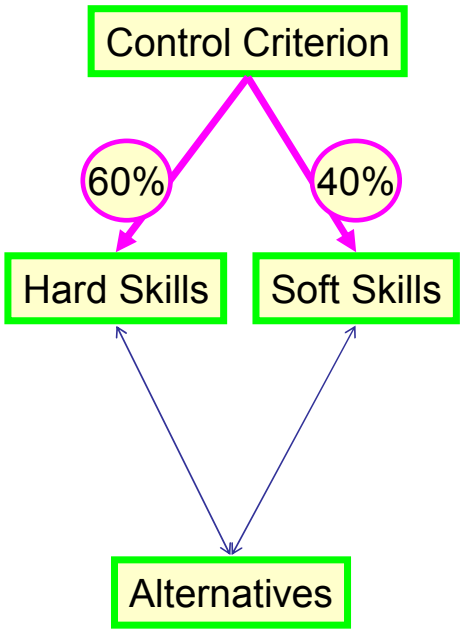
In **ANP** criteria, sub-criteria and alternatives are treated equally as **nodes** in a network.

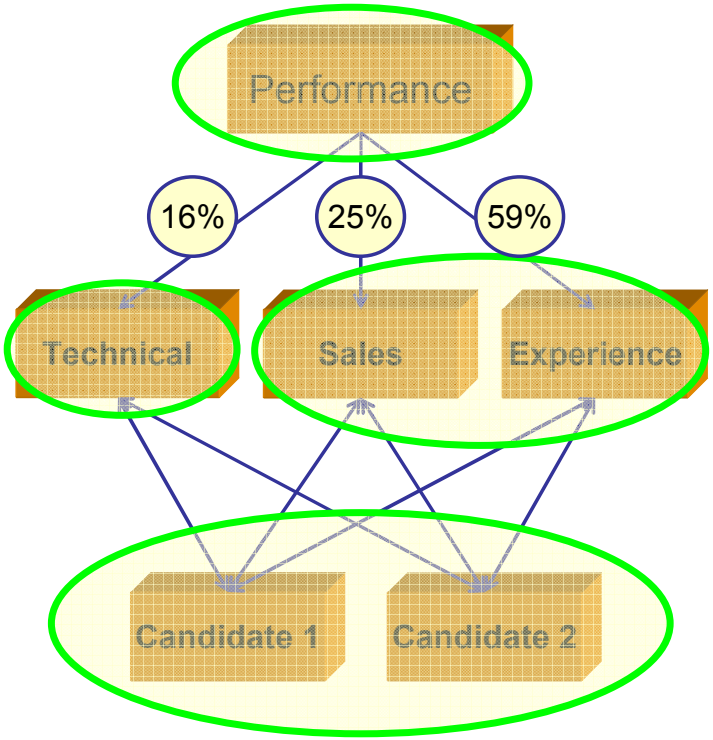
Each of these nodes might be compared to any other node, as long as there is a relation between them.

For example, the ranking of alternatives might not only depend on the weighting of criteria, but also given **alternatives can influence the ranking of criteria**.

Network Model

Clusters and Nodes





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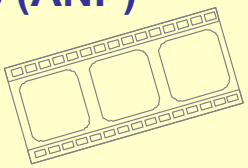
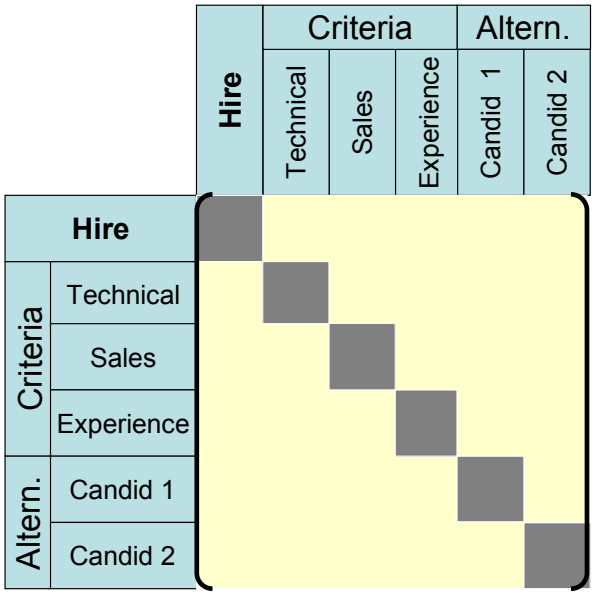
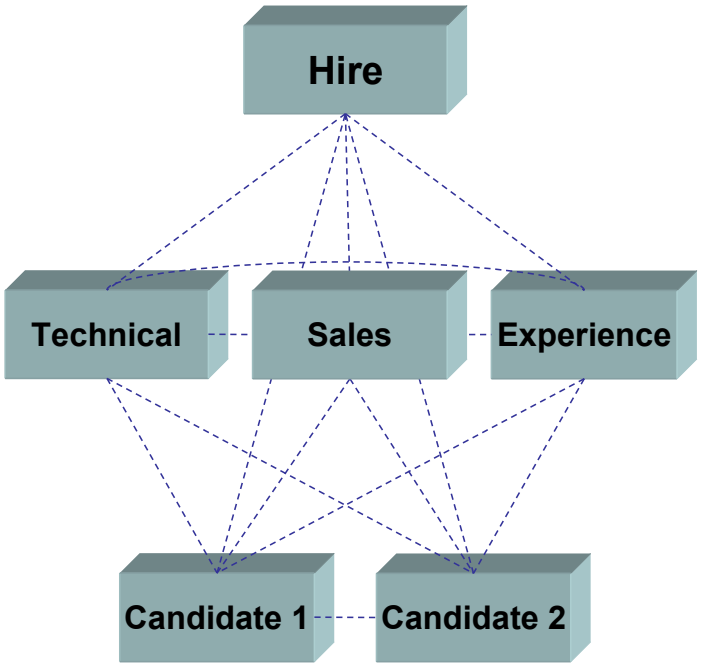


Overview

In contrast to AHP, where higher level elements connect to lower levels – i.e. criteria to sub-criteria – in ANP nodes might be grouped in **clusters**.

Beside local priorities in the comparison of one node to a set of other nodes, you might also introduce **cluster priorities** with respect to the goals.





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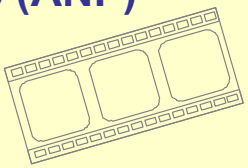
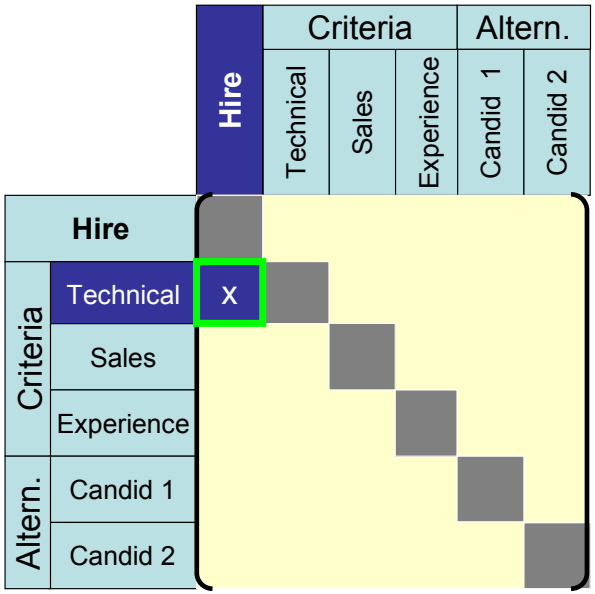
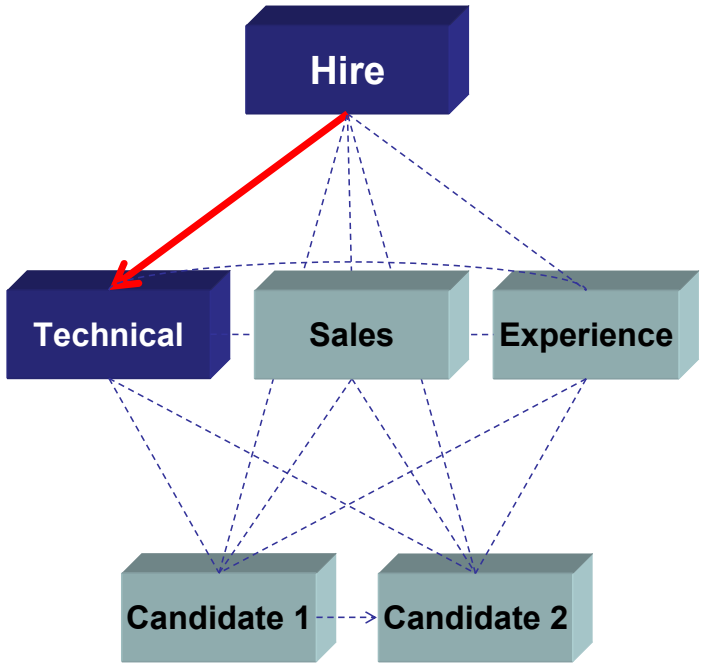


The Super Matrix

The network of ANP is represented as a matrix.

The matrix is composed by listing all nodes horizontally and vertically,





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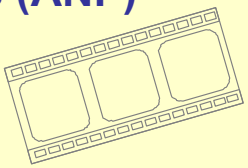

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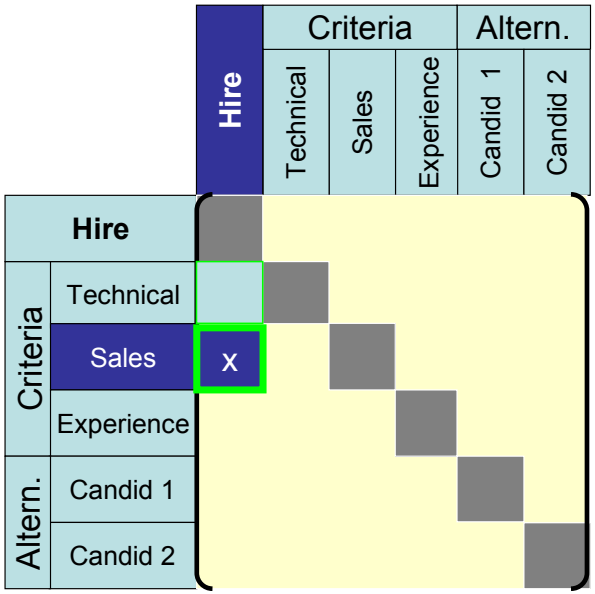

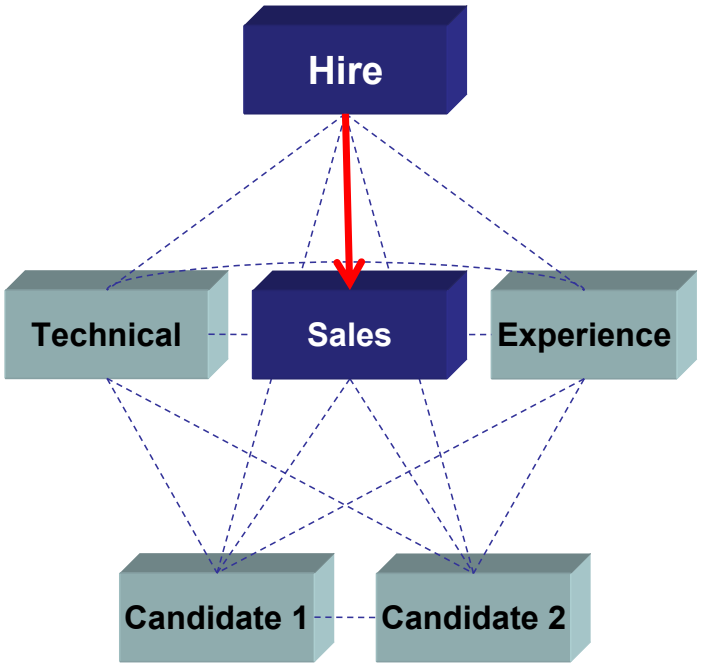

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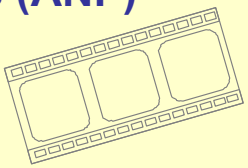

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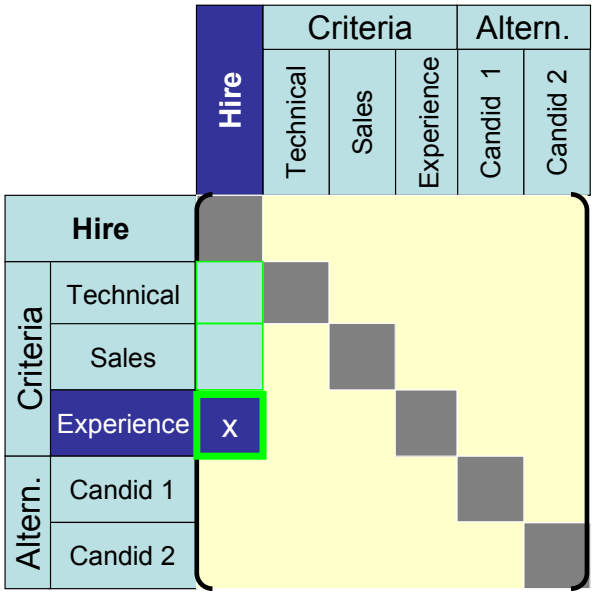

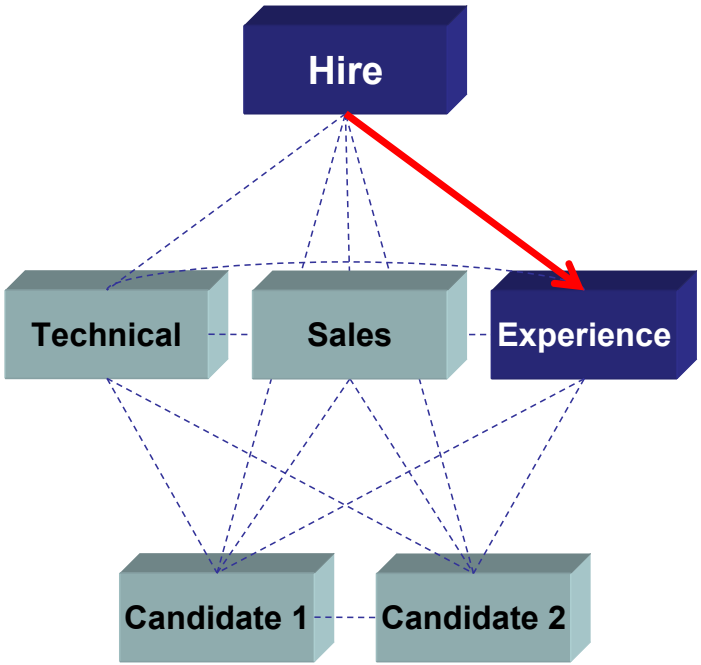

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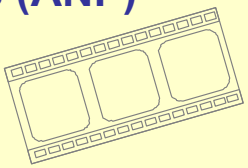

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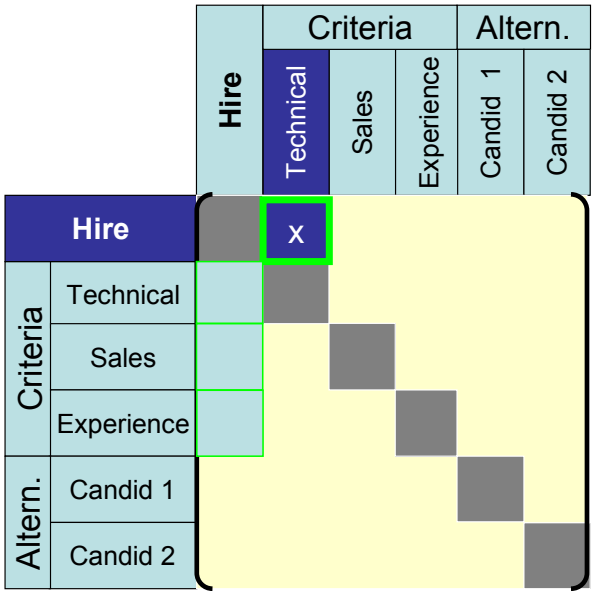

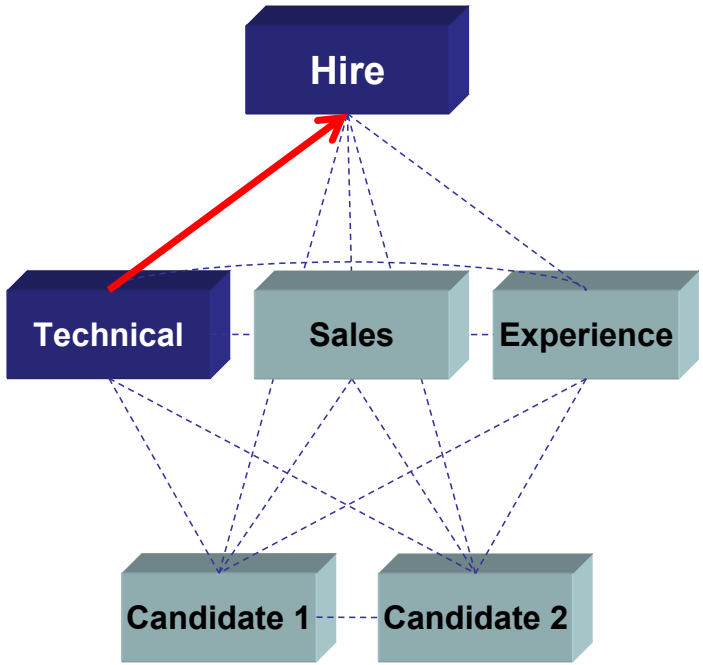

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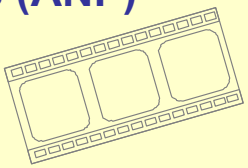

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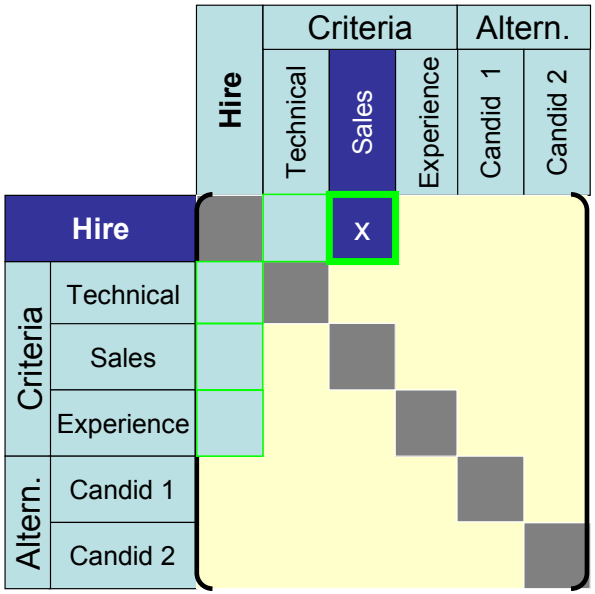

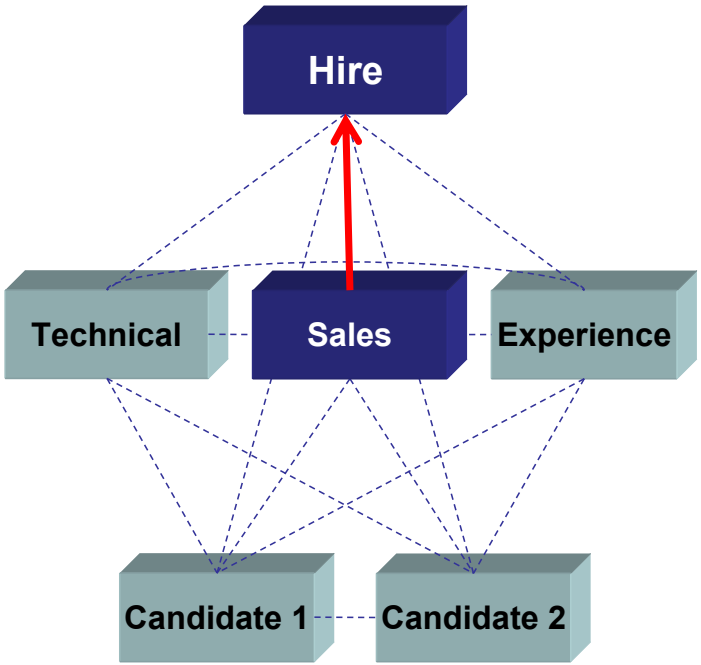

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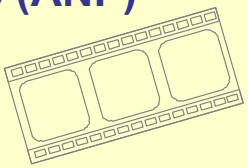

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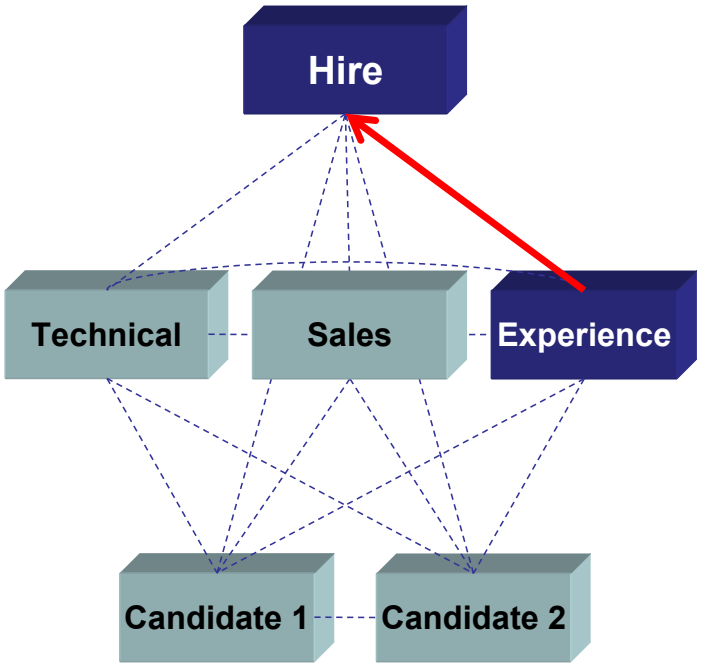
			Technical	Sales	Experience	Candid 1	Candid 2
	Hire				x		
Criteria	Technical						
	Sales						
	Experience						
Altern.	Candid 1						
	Candid 2						



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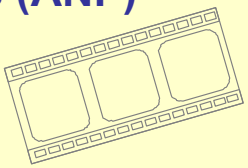

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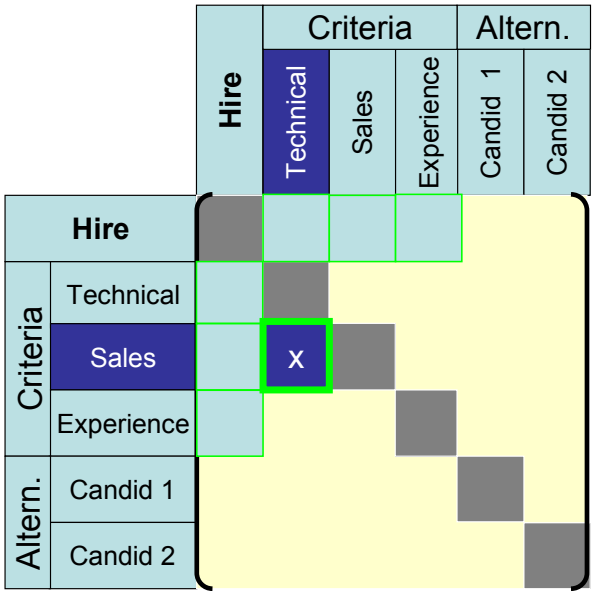
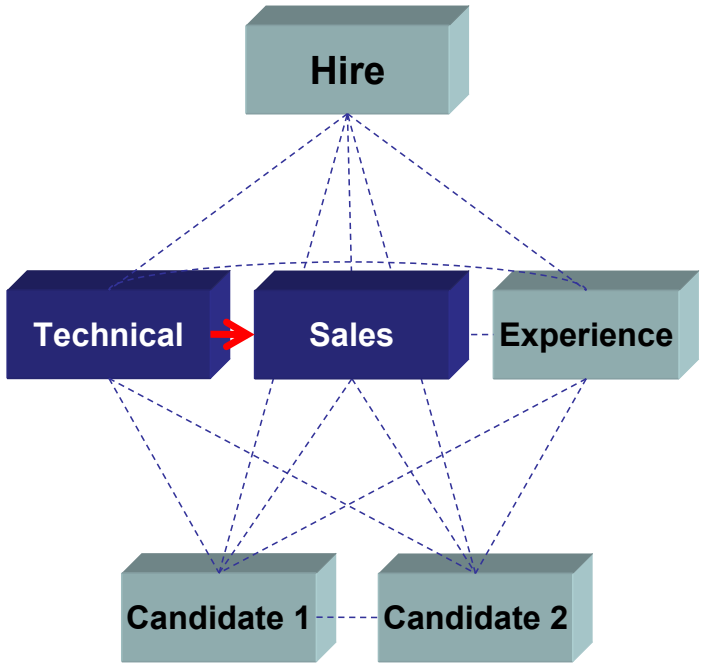
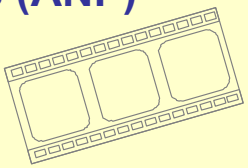




Analytic Network Process (ANP)



The Super Matrix

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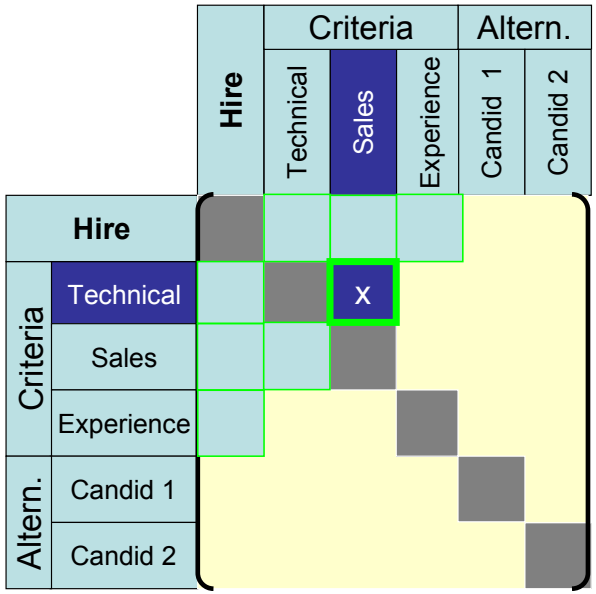

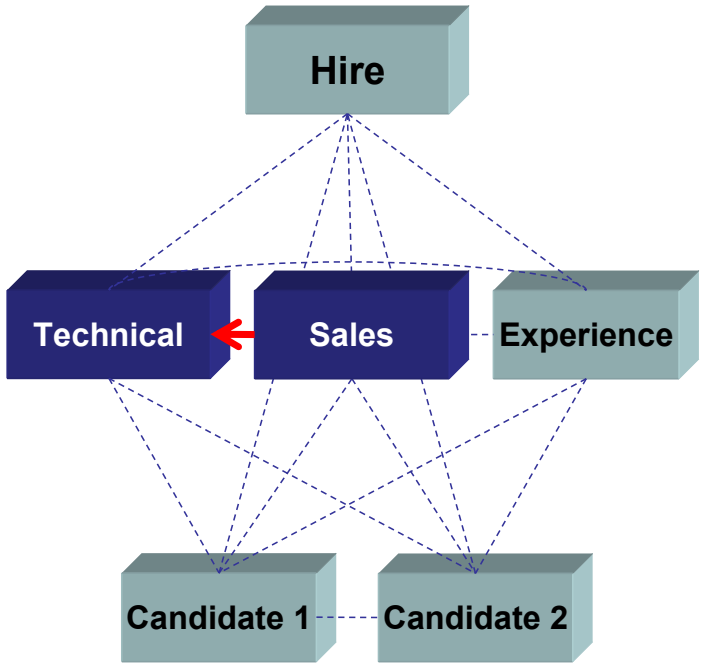

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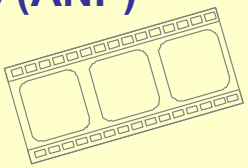

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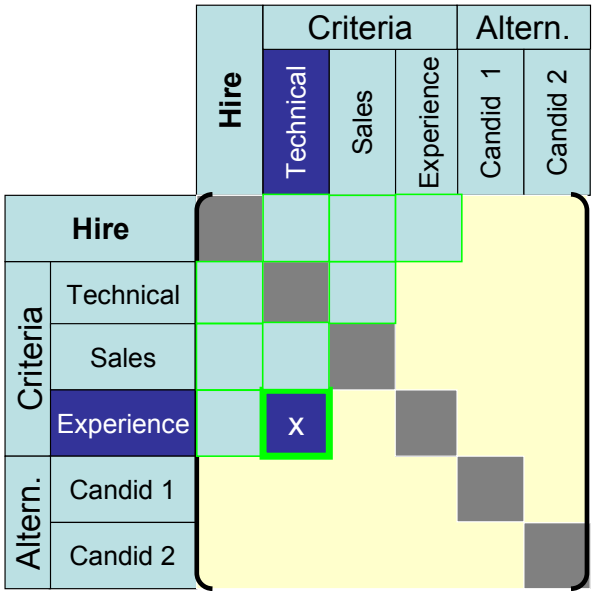

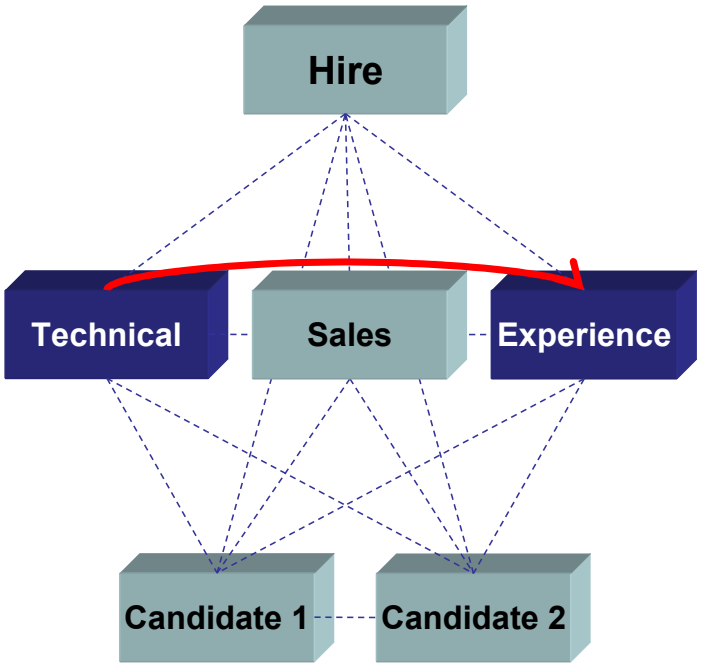

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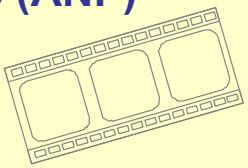

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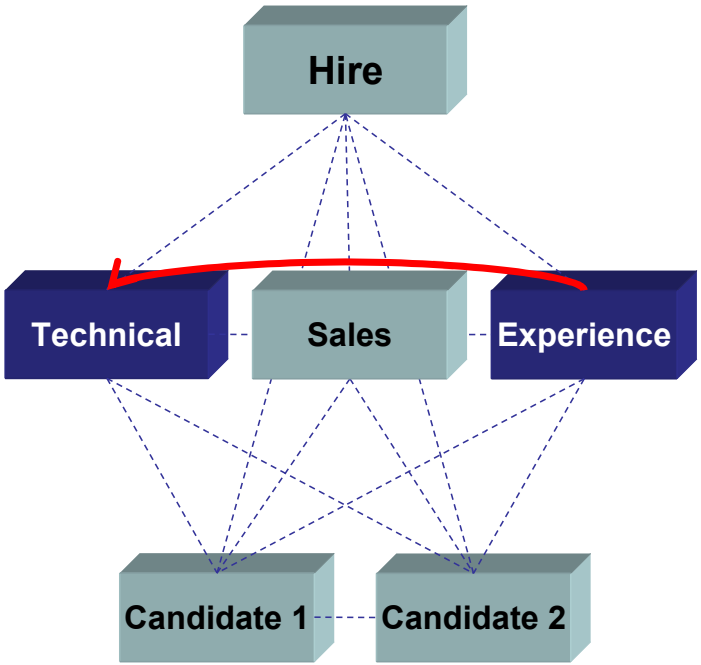
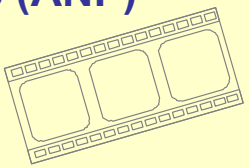
		Hire	Criteria			Altern.	
			Technical	Sales	Experience	Candid 1	Candid 2
	Hire						
Criteria	Technical				x		
	Sales						
	Experience						
Altern.	Candid 1						
	Candid 2						



Analytic Network Process (ANP)



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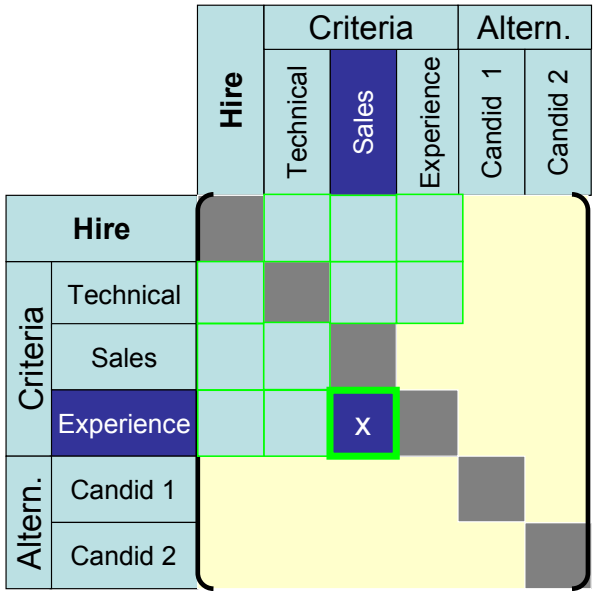
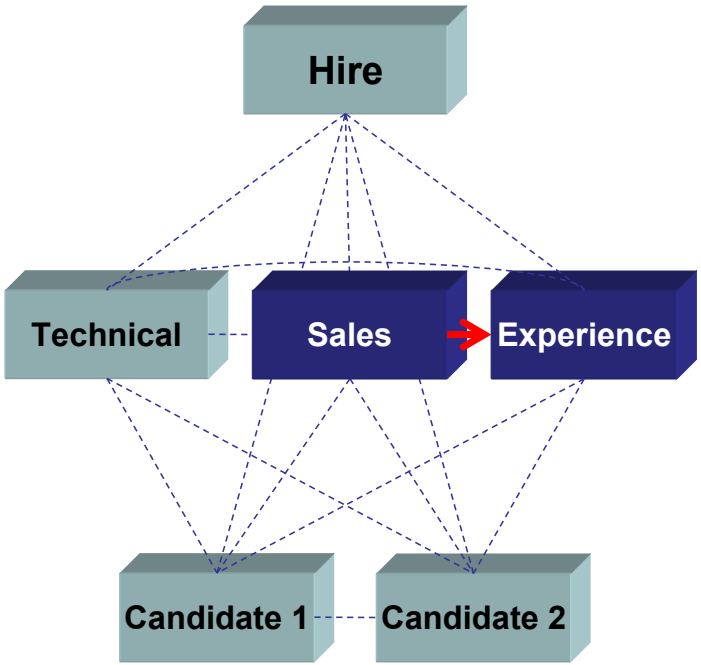
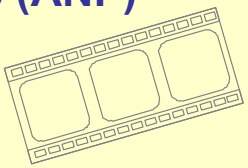




Analytic Network Process (ANP)



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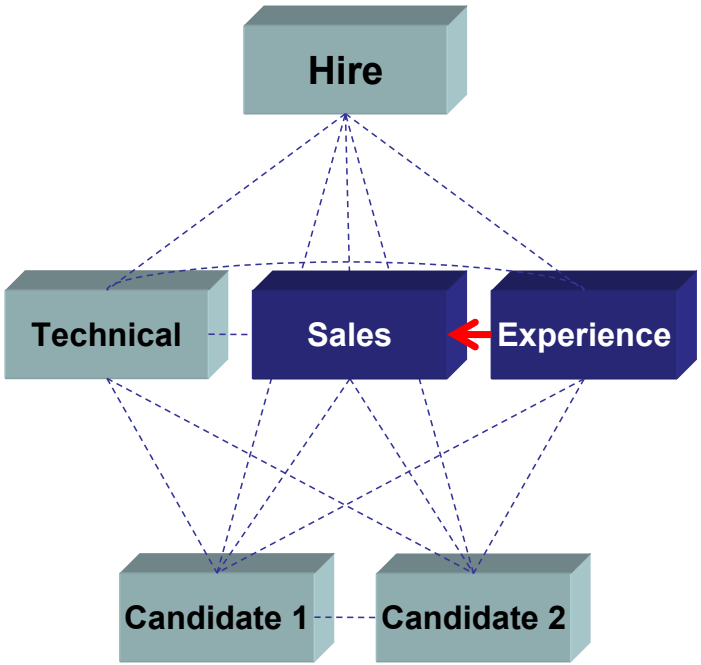
		Hire	Criteria			Altern.	
			Technical	Sales	Experience	Candid 1	Candid 2
	Hire						
Criteria	Technical						
	Sales				x		
	Experience						
Altern.	Candid 1						
	Candid 2						



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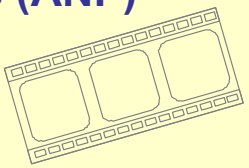

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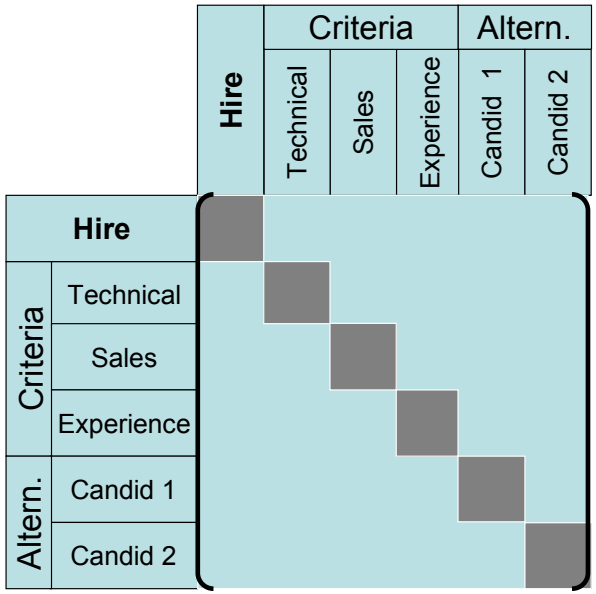
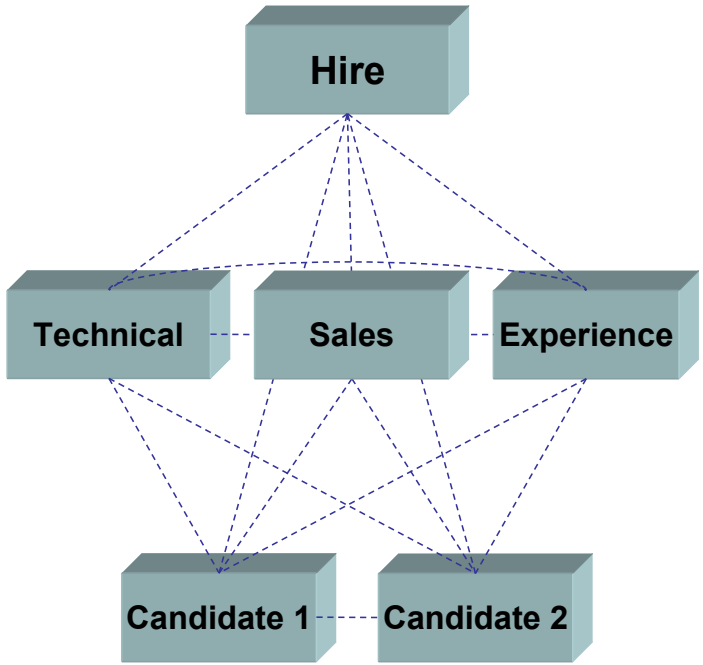
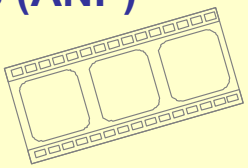


Super Matrix



Analytic Network Process (ANP)



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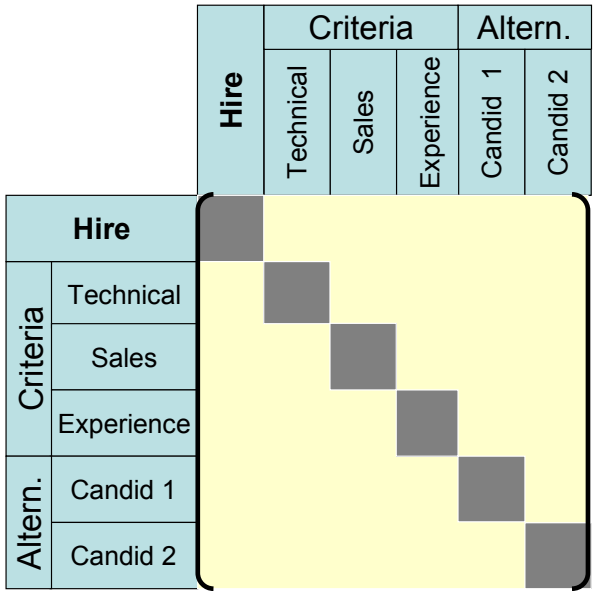
The network of ANP is represented as a matrix.

The matrix is composed by listing all nodes horizontally and vertically,

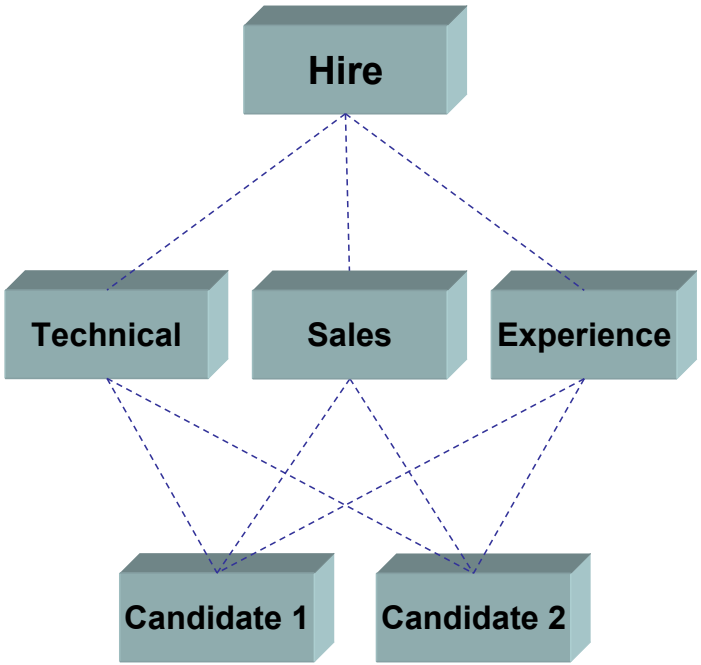
Each non-zero element of the matrix represents the con-nection & weight from one node (columns-header) to another node (row-header) of the network.

The matrix is called **Super-Matrix**

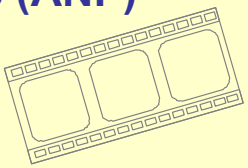


Super Matrix

Hierarchy Model

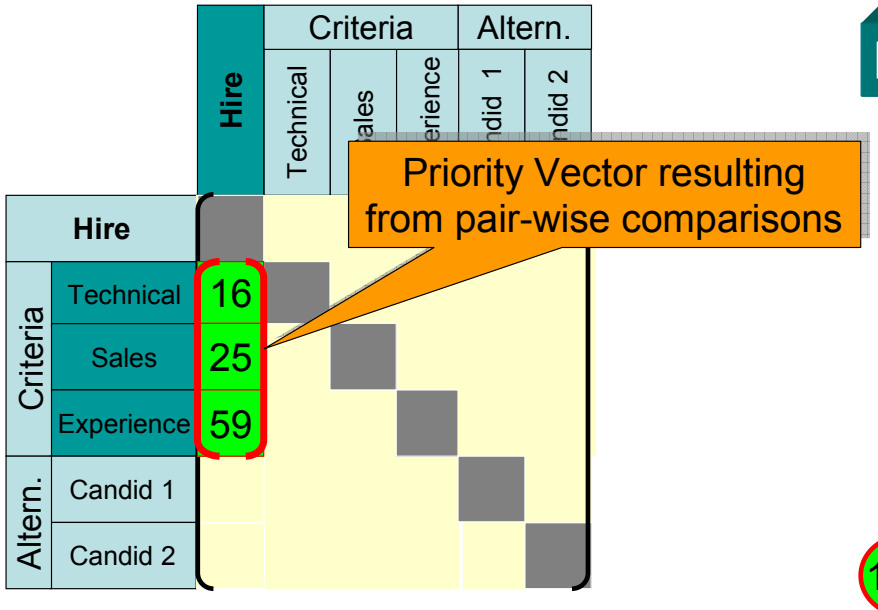


Analytic Network Process (ANP)



The Super Matrix

The **comparison of nodes** – connected to others – follows the same principal and method as in AHP.



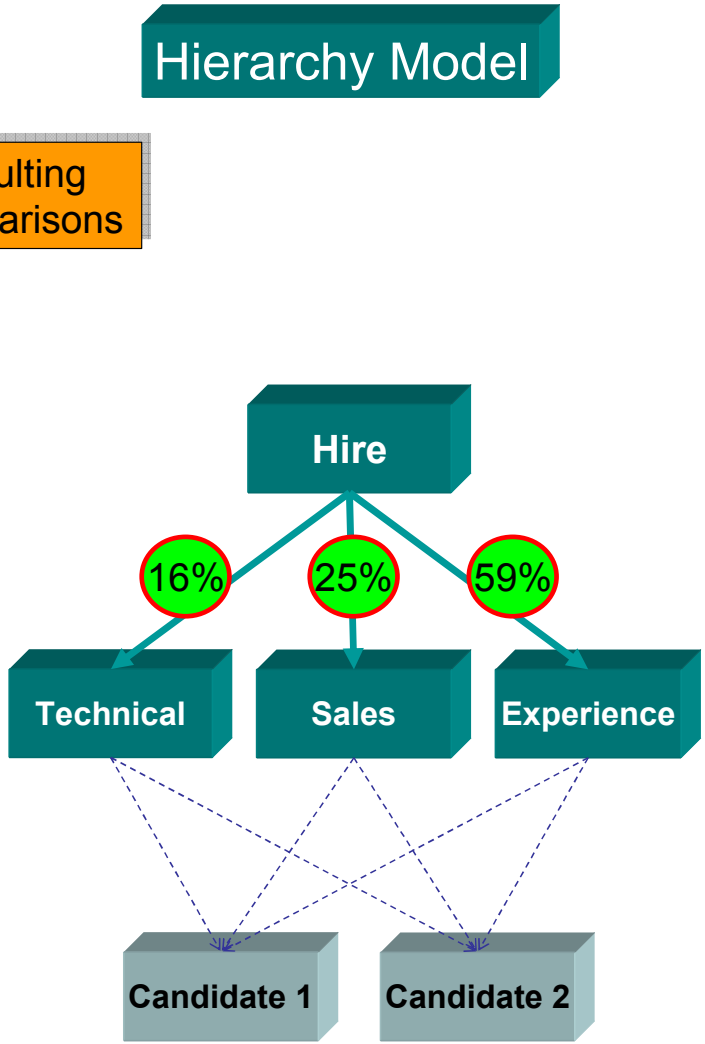
Super Matrix

Comparison of Criteria wrt Hire:

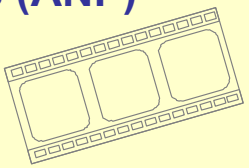
Sales Skills are equally to moderately more important than Technical Skills (2x)

Experience is moderately more important than Technical Skills (3x)

Experience is moderately more important than Sales Skills (3x)



Analytic Network Process (ANP)

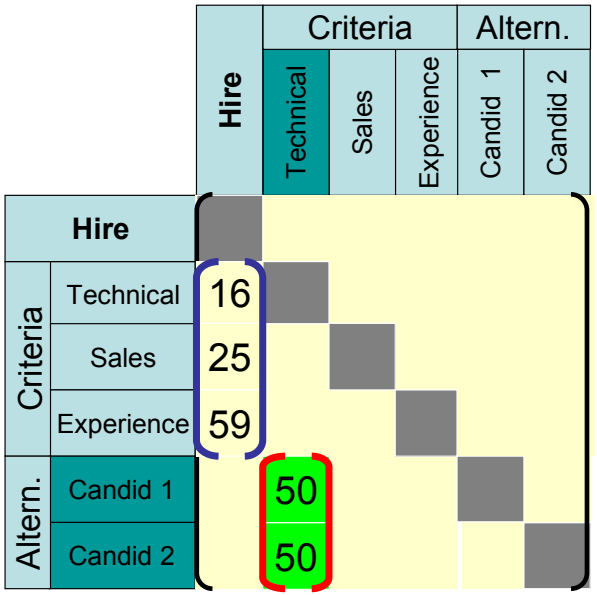


The Super Matrix

The **comparison of nodes** – connected to others – follows the same principal and method as in AHP.
Local priorities result from the **Eigenvector of the comparison matrix**.
The so found priorities are then **arranged as column vectors** in the super-matrix.

Comparison Matrix wrt Hiring

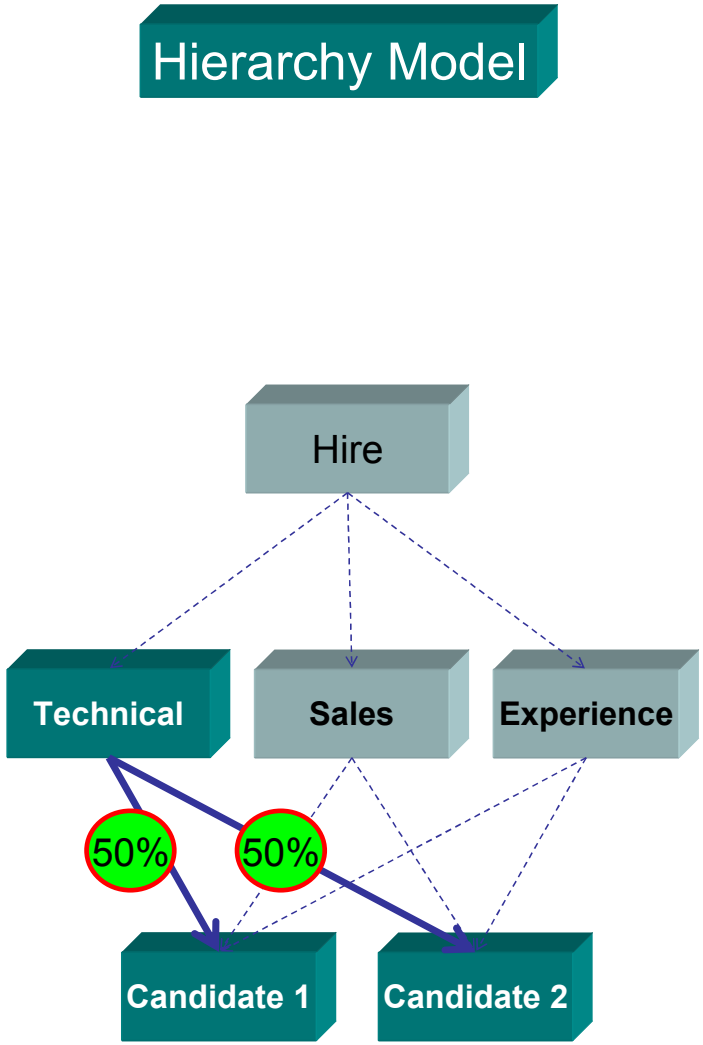
Technical		1/2	1/3
Sales	2		1/3
Experience	3	3	



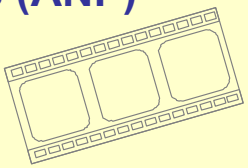
Super Matrix

Comparison of Candidates wrt Technical Skills

Candidate 1 has equally technical Skills as Candidate 2 (1)



Analytic Network Process (ANP)



The Super Matrix

The **comparison of nodes** – connected to others – follows the same principal and method as in AHP.
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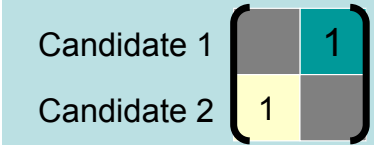
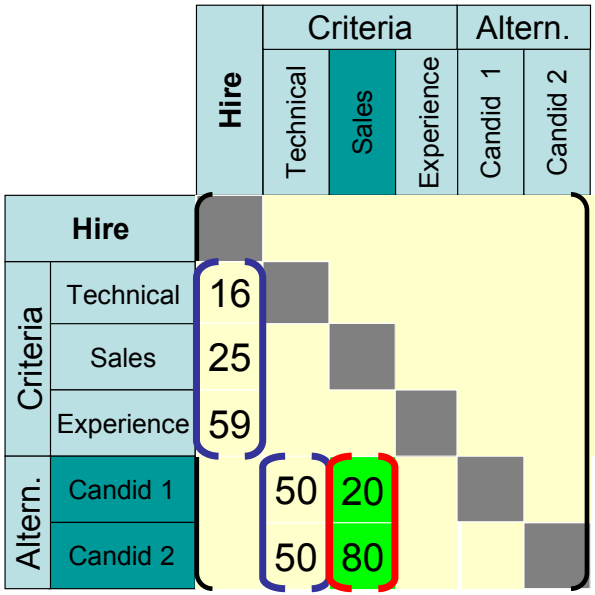
Comp. Matrix wrt Technical



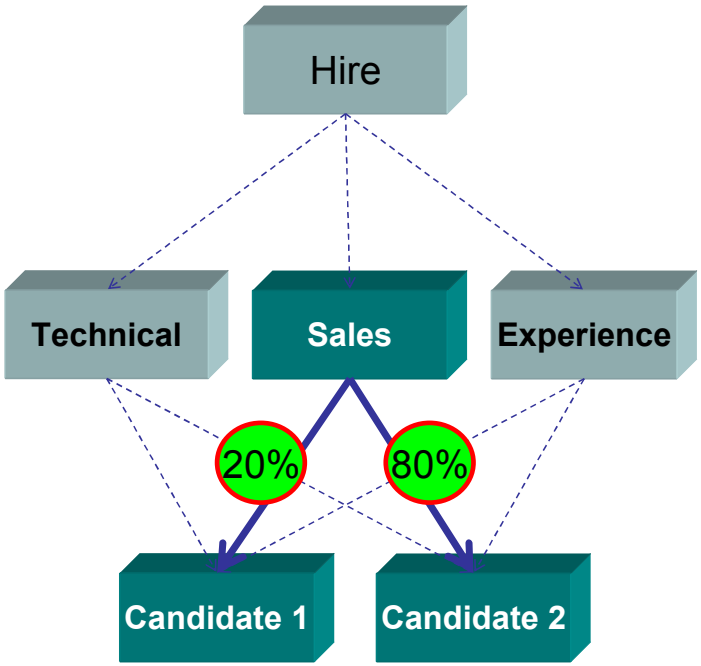


Super Matrix

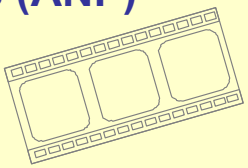
Comparison of Candidates wrt Sales Skills

Candidate 2 has moderately to strongly better Sales Skills than Candidate 1 (4x)

Hierarchy Model



Analytic Network Process (ANP)



The Super Matrix

The **comparison of nodes** – connected to others – follows the same principal and method as in AHP.
Local priorities result from the **Eigenvector of the comparison matrix**.
The so found priorities are then **arranged as column vectors** in the super-matrix.

Comp. Matrix wrt Sales

Candidate 1		1/4
Candidate 2	4	

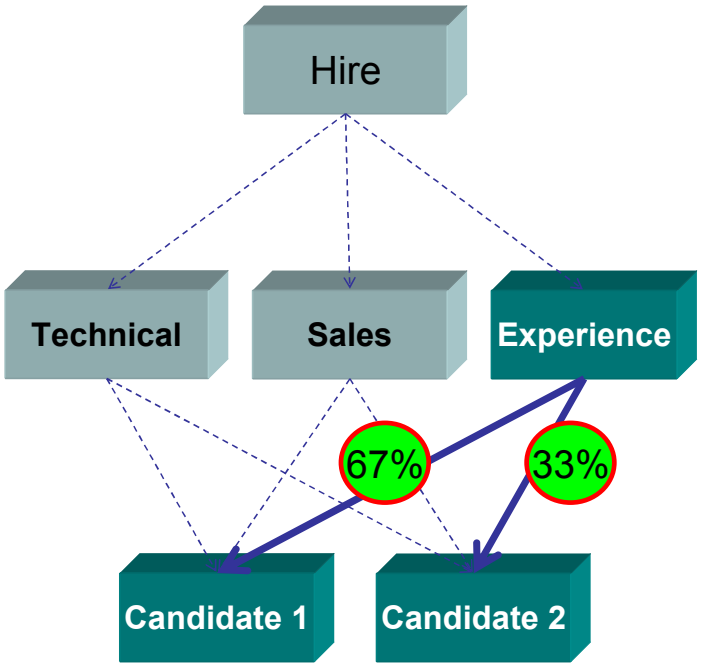
		Hire	Criteria			Altern.	
			Technical	Sales	Experience	Candid 1	Candid 2
Hire							
Criteria	Technical	16					
	Sales	25					
	Experience	59					
Altern.	Candid 1		50	20	67		
	Candid 2		50	80	33		

Super Matrix

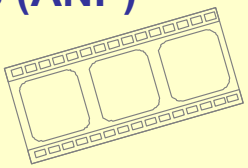
Comparison of Candidates wrt Experience

Candidate 1 has equally to Moderately better Experience than Candidate 2 (2x)

Hierarchy Model



Analytic Network Process (ANP)



The Super Matrix

The **comparison of nodes** – connected to others – follows the same principal and method as in AHP.
Local priorities result from the **Eigenvector of the comparison matrix**.
The so found priorities are then **arranged as column vectors** in the super-matrix.

Comp. Matrix wrt Experience

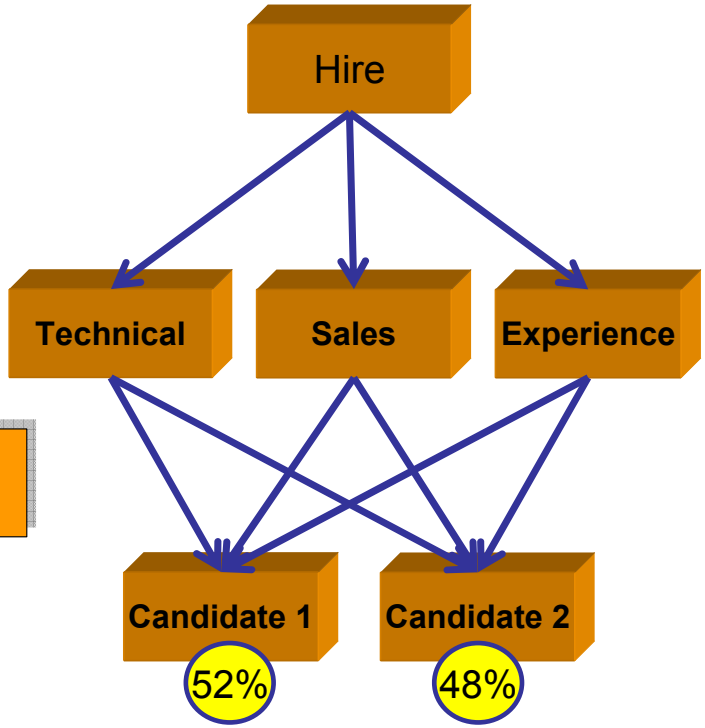
Candidate 1		2
Candidate 2	1/2	

		Hire	Criteria			Altern.	
			Technical	Sales	Experience	Candid 1	Candid 2
	Hire						
Criteria	Technical	16					
	Sales	25					
	Experience	59					
Altern.	Candid 1		50	20	67		
	Candid 2		50	80	33		

Unweighted Super Matrix

		Result: Priorities of Alternatives
Altern.	Candid 1	52
	Candid 2	48

Hierarchy Model



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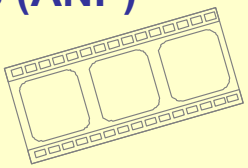

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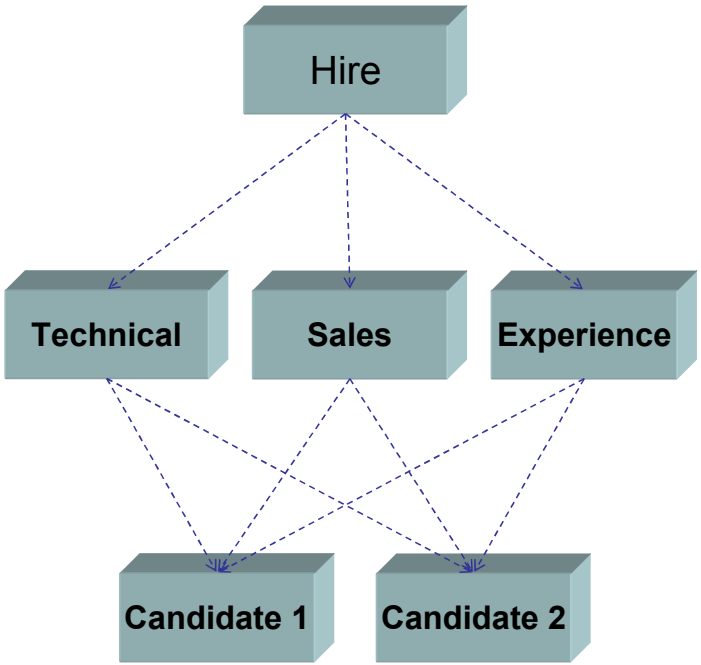
The so found priorities are then **arranged as column vectors** in the super-matrix.

		Hire	Criteria			Altern.	
			Technical	Sales	Experience	Candid 1	Candid 2
	Hire						
Criteria	Technical	16					
	Sales	25					
	Experience	59					
Altern.	Candid 1		50	20	67		
	Candid 2		50	80	33		

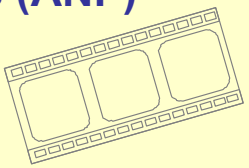
Super Matrix

Network Model

Impact of Alternatives on the priorities of criteria



Analytic Network Process (ANP)



The Super Matrix

The **comparison of nodes** – connected to others – follows the same principal and method as in AHP.
Local priorities result from the **Eigenvector of the comparison matrix**.
The so found priorities are then **arranged as column vectors** in the super-matrix.

		Hire	Criteria			Altern.	
			Technical	Sales	Experience	Candid 1	Candid 2
Hire							
Criteria	Technical	16				75	
	Sales	25				13	
	Experience	59				13	
Altern.	Candid 1		50	20	67		
	Candid 2		50	80	33		

Super Matrix

Comparison of Criteria wrt Candidate 1

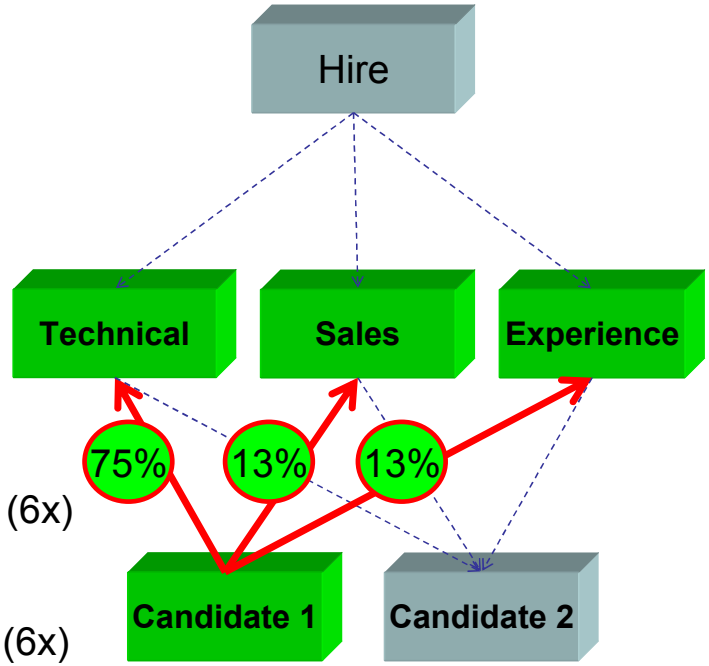
Technical Skills are strongly to very strongly more prevalent than Sales Skills (6x)

Technical Skills are strongly to very strongly more prevalent than Experience (6x)

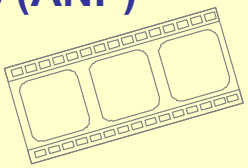
Sales Skills are equally to Experience (1)

Network Model

Impact of Alternatives on the priorities of criteria



Analytic Network Process (ANP)



The Super Matrix

The **comparison of nodes** – connected to others – follows the same principal and method as in AHP.
Local priorities result from the **Eigenvector of the comparison matrix**.
The so found priorities are then **arranged as column vectors** in the super-matrix.

Comp. Matrix wrt Candidate 1

Technical		6	6
Sales	1/6		1
Experience	1/6	1	

		Hire	Criteria			Altern.	
			Technical	Sales	Experience	Candid 1	Candid 2
Hire							
Criteria	Technical	16				75	13
	Sales	25				13	75
	Experience	59				13	13
Altern.	Candid 1		50	20	67		
	Candid 2		50	80	33		

Super Matrix

Comparison of Criteria wrt Candidate 2

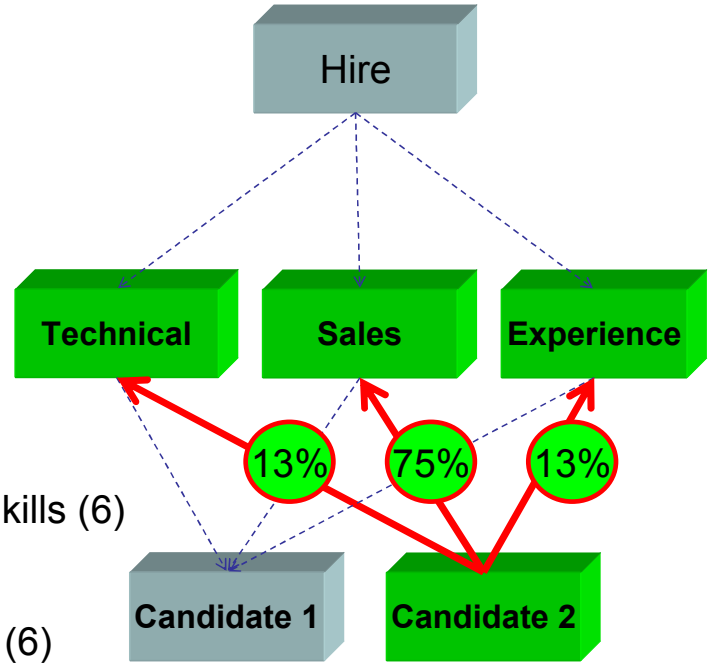
Sales Skills are strongly to very strongly more prevalent than Technical Skills (6)

Sales Skills are strongly to very strongly more prevalent than Experience (6)

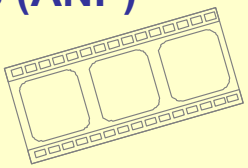
Technical Skills are equally to Experience (1)

Network Model

Impact of Alternatives on the priorities of criteria



Analytic Network Process (ANP)



The Super Matrix

The **comparison of nodes** – connected to others – follows the same principal and method as in AHP.
Local priorities result from the **Eigenvector of the comparison matrix**.
The so found priorities are then **arranged as column vectors** in the super-matrix.

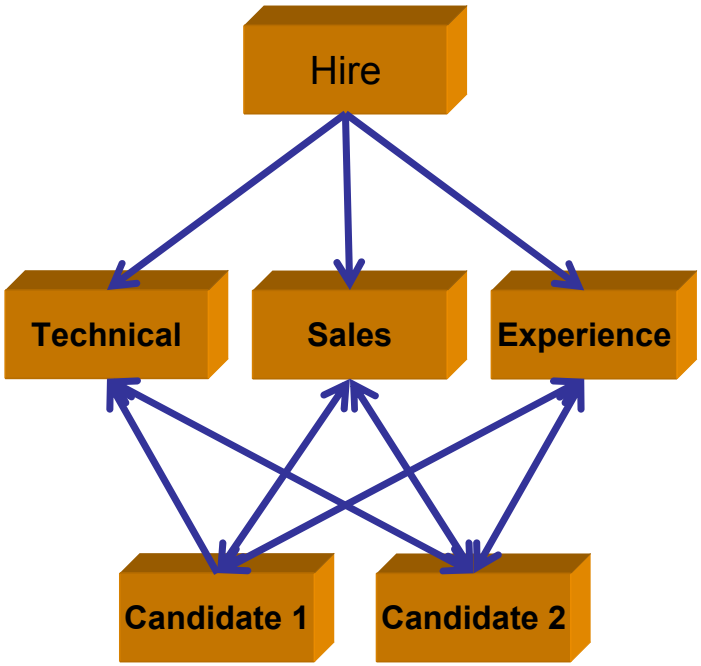
Comp. Matrix wrt Candidate 2

Technical		1/6	1
Sales	6		6
Experience	1	1/6	

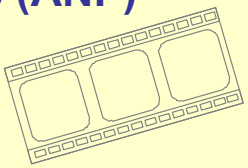
		Hire	Criteria			Altern.	
			Technical	Sales	Experience	Candid 1	Candid 2
	Hire						
Criteria	Technical	16				75	13
	Sales	25				13	75
	Experience	59				13	13
Altern.	Candid 1		50	20	67		
	Candid 2		50	80	33		
		100	100	100	100	100	100

Weighted Super Matrix

Network Model



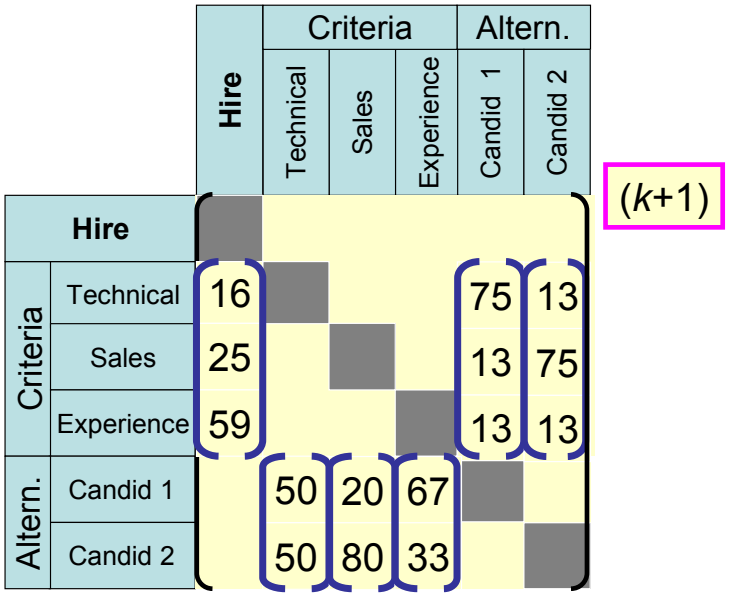
Analytic Network Process (ANP)



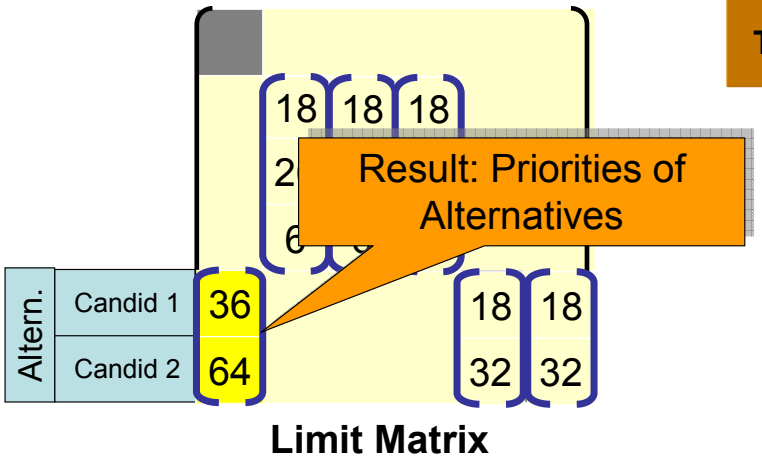
The Super Matrix

After all comparisons are done, we get the "**Unweighted Super Matrix**"

This matrix is then normalized i.e. the sum of all columns is scaled to 1

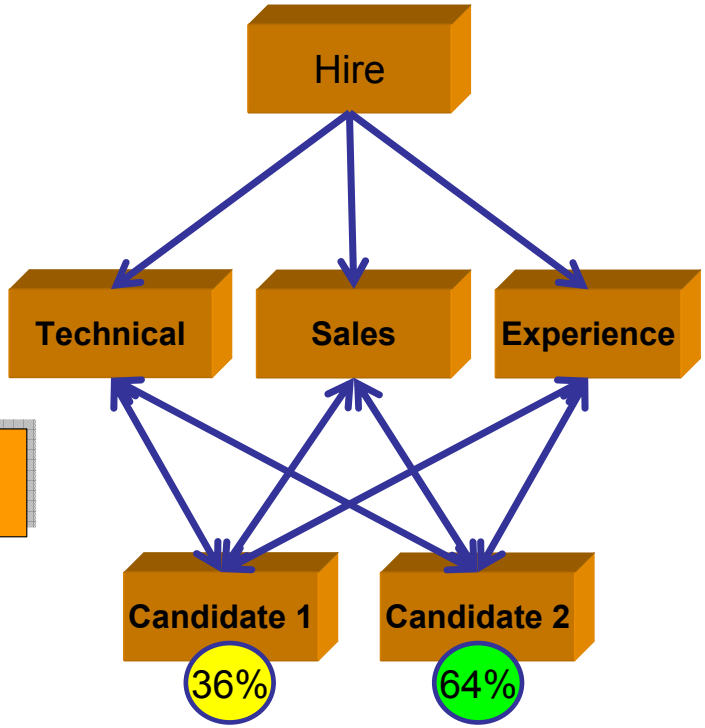


Weighted Super Matrix

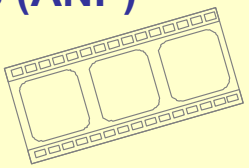


Limit Matrix

Network Model



Analytic Network Process (ANP)



The Super Matrix

After all comparisons are done, we get the "Unweighted Super Matrix"

This matrix is then normalized i.e. the sum of all columns is scaled to 1

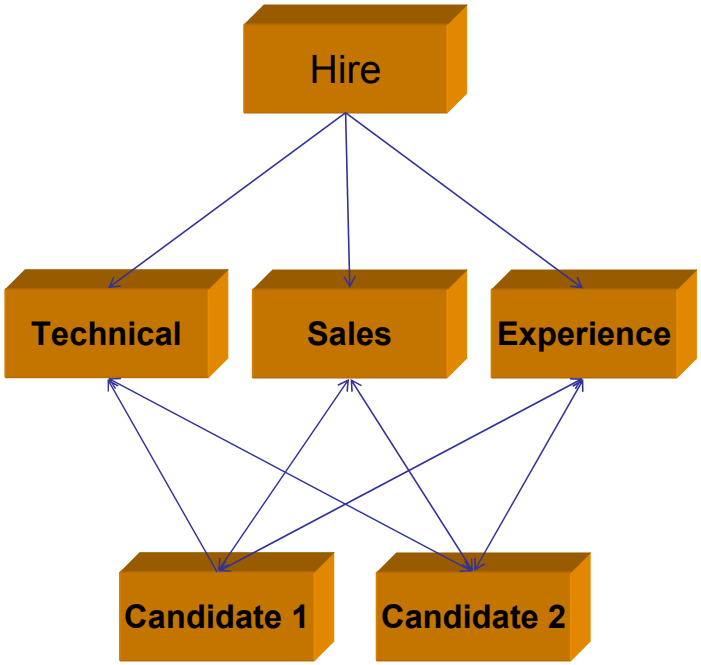
The whole model is synthesized by calculating the "**Limit Matrix**". The Limit Matrix is the weighted Super matrix, taken to the power of k+1, where k is an arbitrary number.

		Hire	Criteria			Altern.	
			Technical	Sales	Experience	Candid 1	Candid 2
	Hire						
Criteria	Technical	16				75	13
	Sales	25				13	75
	Experience	59				13	13
Altern.	Candid 1		50	20	67		
	Candid 2		50	80	33		

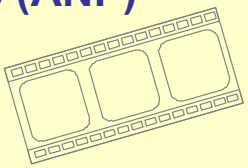
Weighted Super Matrix

Why changes the ranking of Candidate 2 from **two** in the Hierarchy model to **one** in the Network model

?



Analytic Network Process (ANP)



Overview

Why changes the ranking of Candidate 2 from two in the hierarchy model to one in the Network model?

		Hire	Criteria			Altern.	
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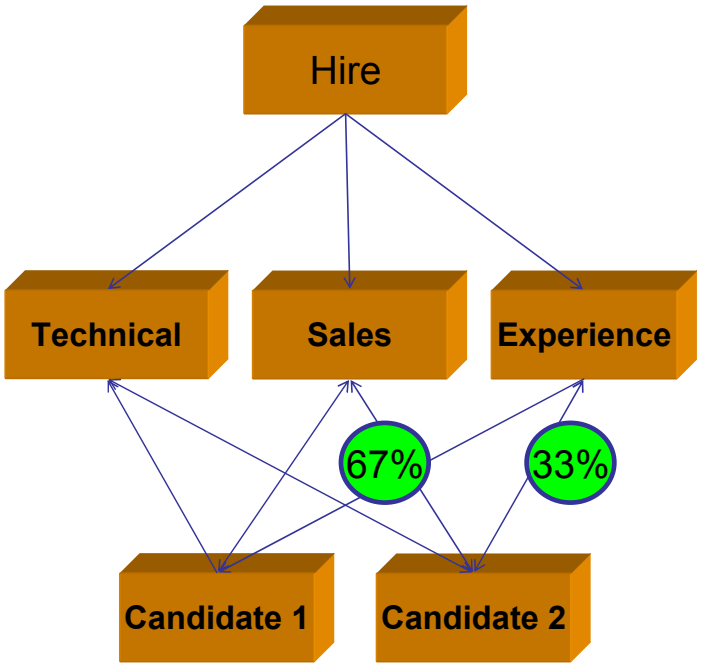
Weighted Super Matrix



Why changes the ranking of Candidate 2 from **two** in the Hierarchy model to **one** in the Network model

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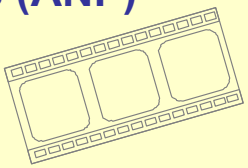
Analytic Network Process (ANP)



Overview

Both candidates have the required experience

		Hire	Criteria			Altern.	
			Technical	Sales	Experience	Candid 1	Candid 2
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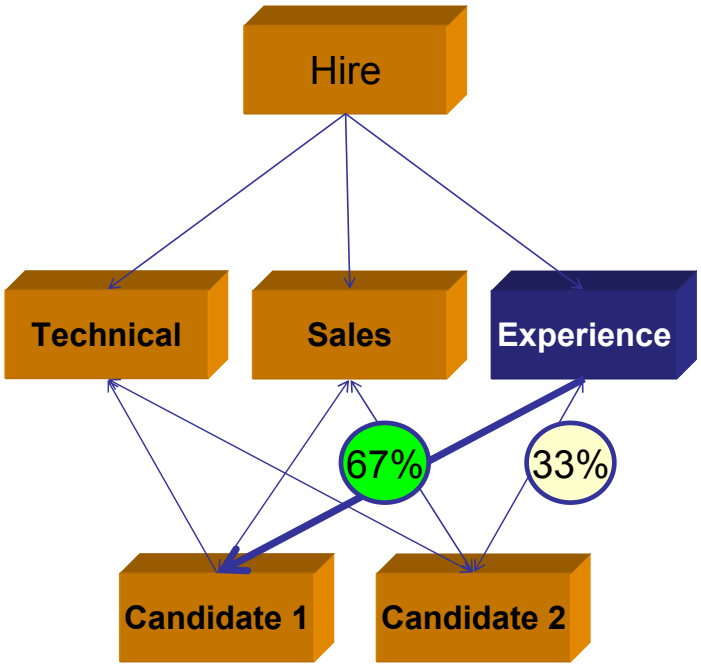
Weighted Super Matrix



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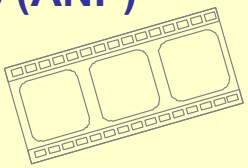
Analytic Network Process (ANP)



Overview

Both candidates have the required experience

- candidate 1 slightly more than candidate 2.

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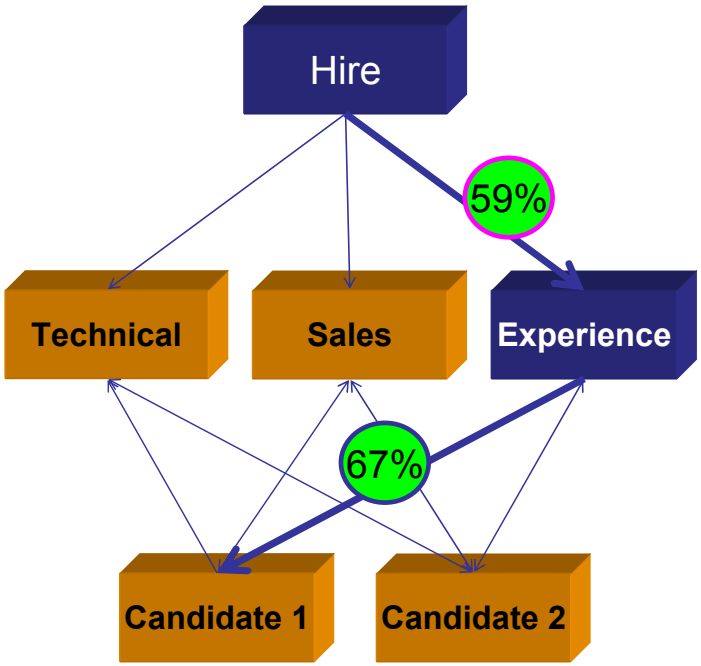

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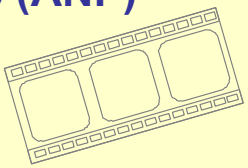
Analytic Network Process (ANP)



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Both candidates have the required experience

- candidate 1 slightly more than candidate 2.

Experience is given a relative high weight

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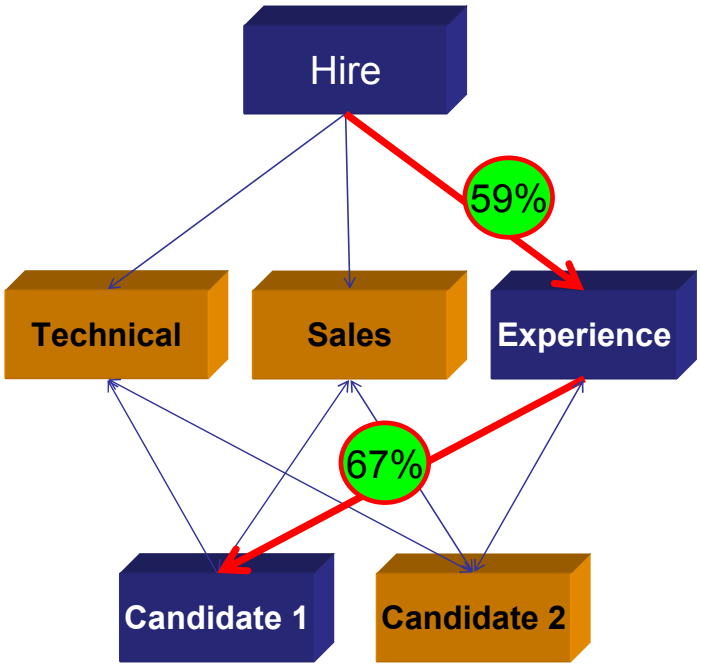

Why changes the ranking of Candidate 2 from **two** in the Hierarchy model to **one** in the Network model

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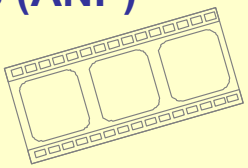
Analytic Network Process (ANP)



Overview

Both candidates have the required experience

- candidate 1 slightly more than candidate 2.

Experience is given a relative high weight

Resulting in the slightly higher ranking for candidate 1 in the hierarchical model.

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	Hire						
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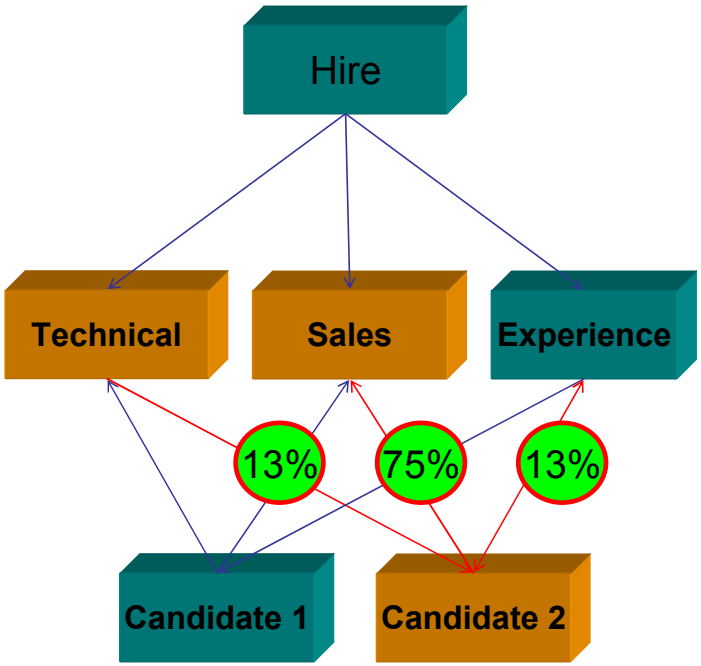
Weighted Super Matrix



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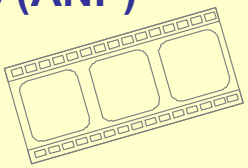
Analytic Network Process (ANP)



Overview

In the network model we also look at each candidate's skills independent from the other candidate

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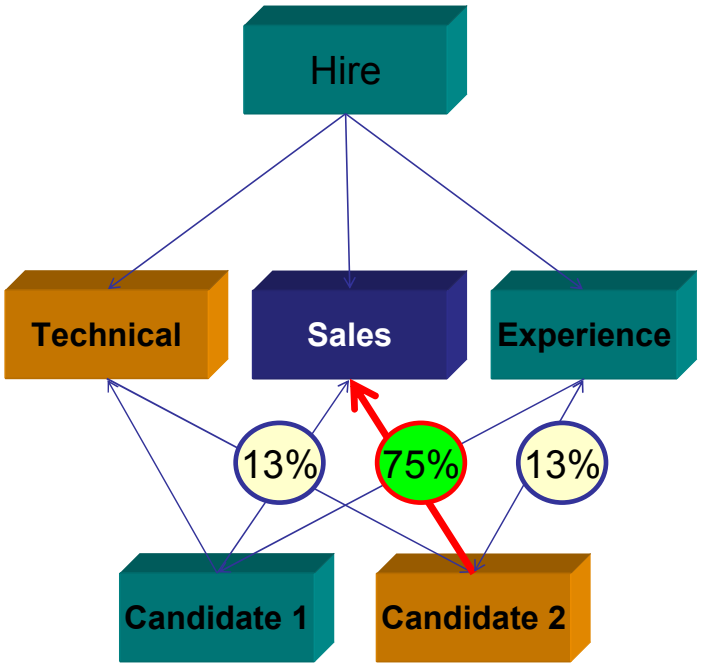

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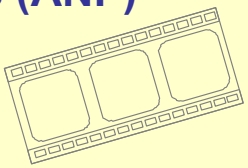
Analytic Network Process (ANP)



Overview

In the network model we also look at each candidate's skills independent from the other candidate

Now we see the outstanding sales skills of candidates 2

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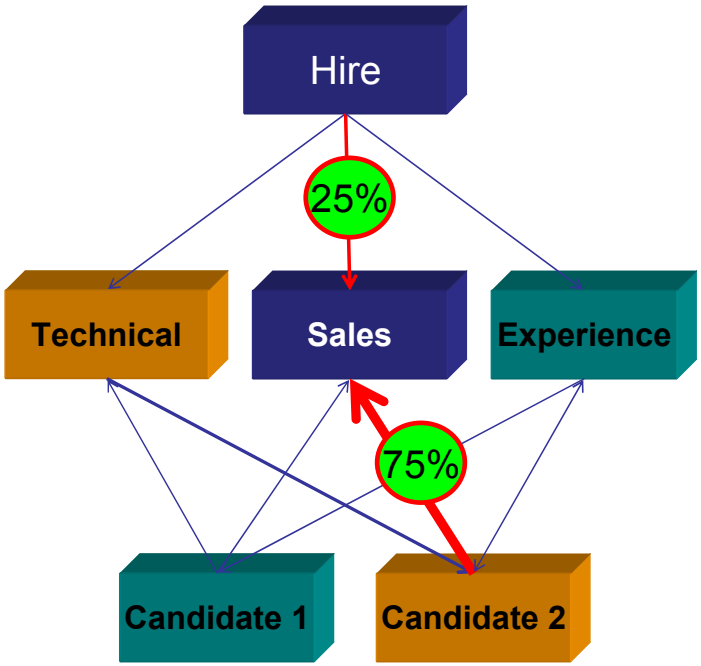

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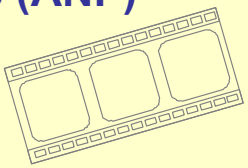

Overview

In the network model we also look at each candidate's skills independent from the other candidate

Now we see the outstanding sales skills of candidates 2

Finally in the network model, sales skills get more weight in the decision than the excellent technical skills of candidate 1

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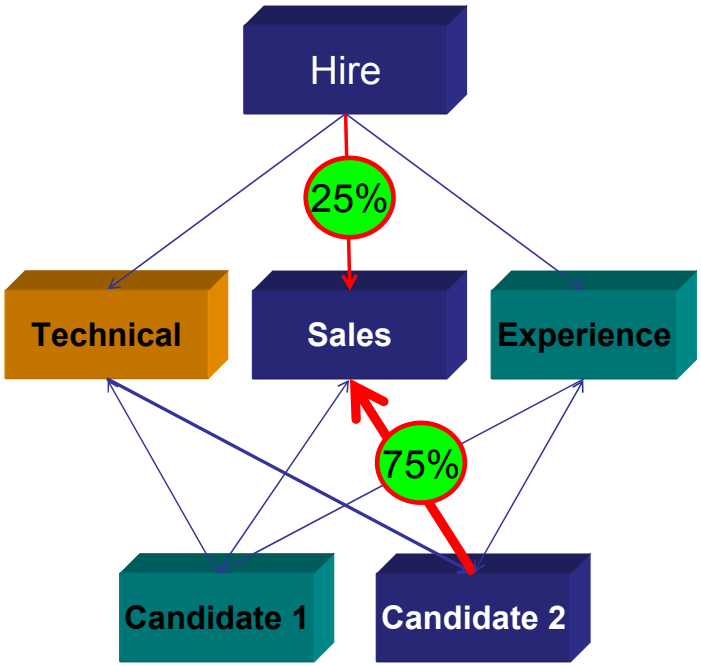

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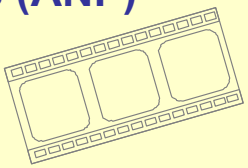

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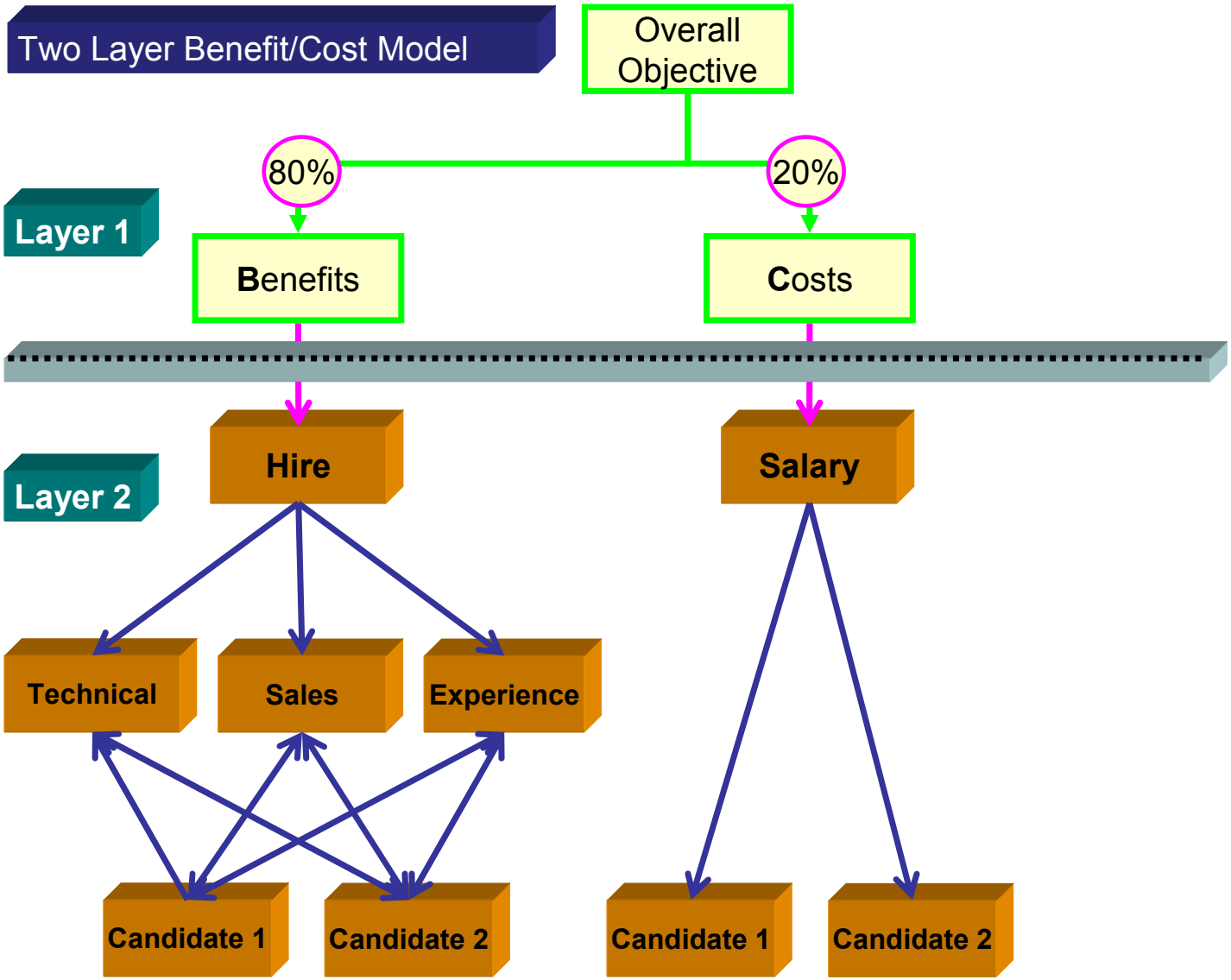
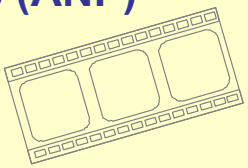


Analytic Network Process (ANP)



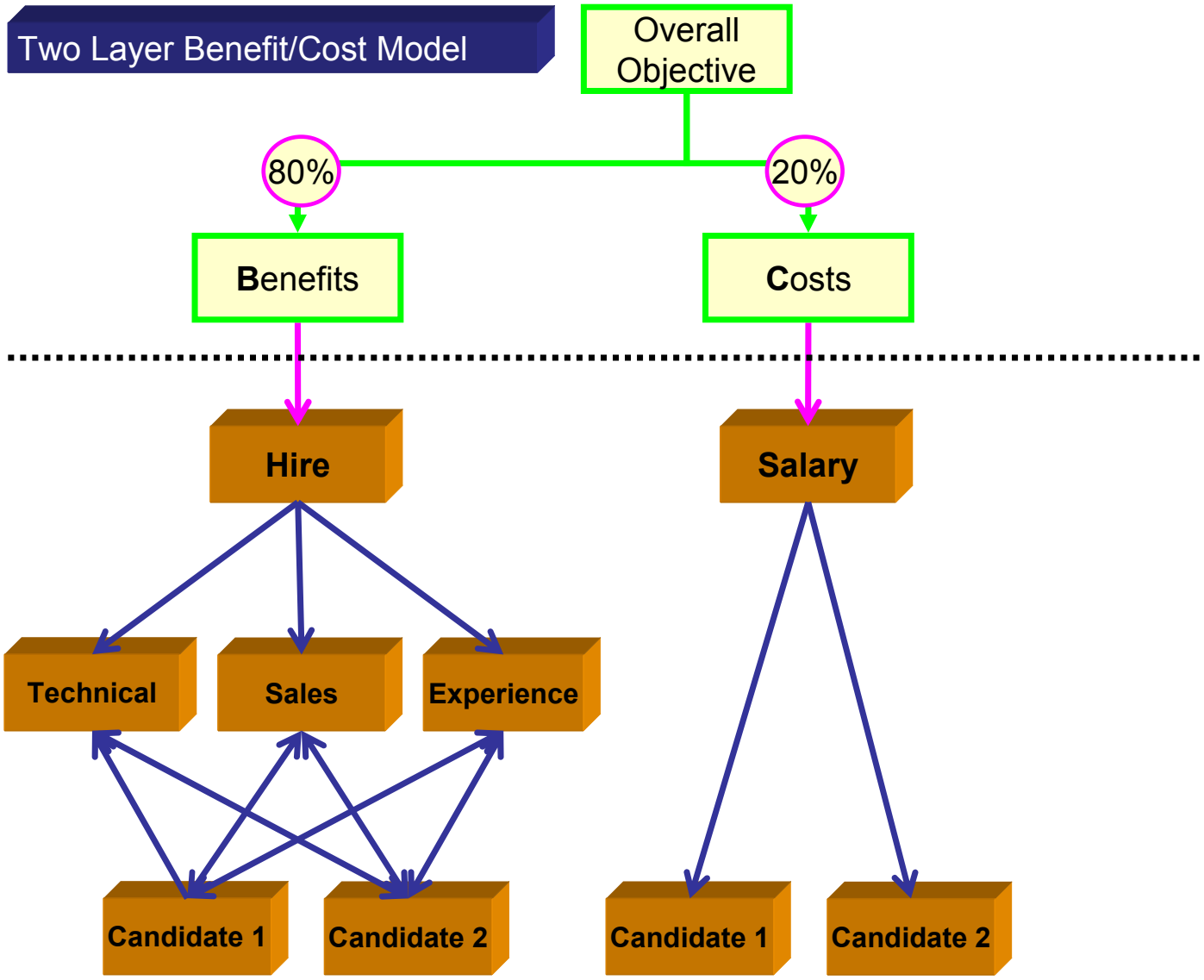
Control Hierarchies

A decision network can be arranged under a control hierarchy of benefits and costs

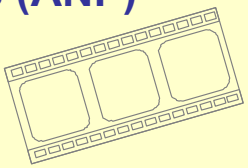
In our example here, we already evaluated the benefits of hiring – with respect to the hard – and soft-skills of the two candidates.

We can now evaluate the requested salary of both candidates under control criterion costs.

Depending on our overall objective, either benefits or costs could be assigned a higher weighting.



Analytic Network Process (ANP)



Control Hierarchies

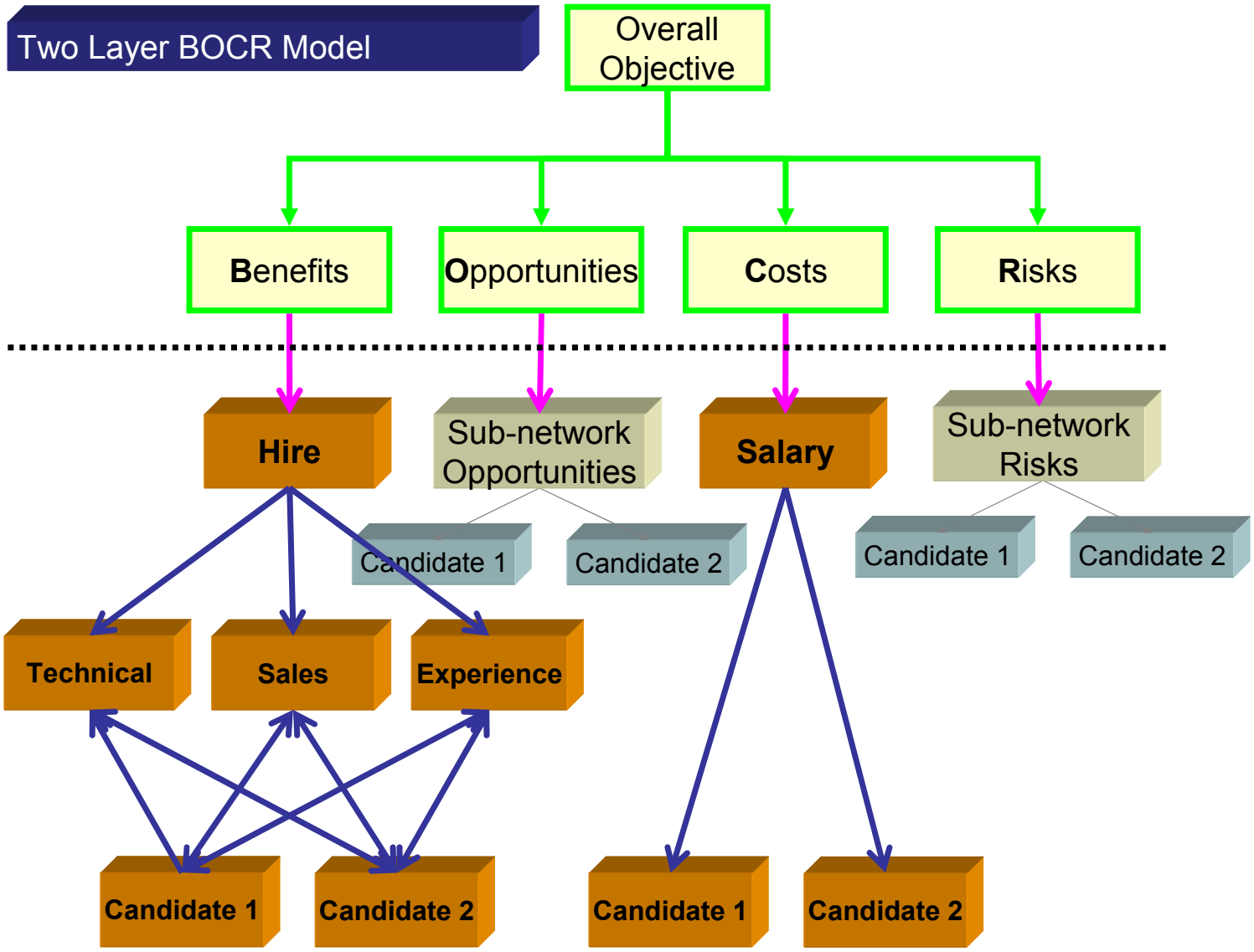
We have now a two layer model with a control hierarchy – benefits and costs – and a sub-network under benefits and a hierarchy under costs.

Ranking of alternatives in a two layer model can be evaluated using a ratio formula Benefit/Cost or an additive formula (B-C)

Evaluation Formulas

Benefits/Costs (B/C)

Benefits - Costs (B-C)



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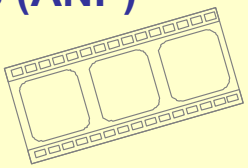


Control Hierarchies

The control hierarchy could be extended with additional control parameter, e.g. opportunities and risks, to build a two layer BOCR model.

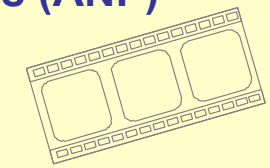
Evaluation Formulas

(B*O) / (C*R)

(B+O)- (C-R)

Thank You!

Analytic Network Process (ANP)



Klaus D. Goepel Feb. 2011