POLITECNICO MILANO 1863

Exercise session – Multivariate statistics

AY 2024/2025 - Gloria Peggiani

Agenda

- **PCA & Cluster Analysis** – Exercises
- **PLS-SEM** – Exercises

PCA & Cluster Analysis – Exercises

01

Exercise 1: Young People Survey

Exercise: Young People Survey

Objective: to investigate music preferences of young people

Data collection: a large-scale survey among young people was conducted

Exercise: Young People Survey

The music preference was measured in a series of questions:

- I enjoy listening to music (Likert scale, 1 Not at all – 5 Very much)
- I prefer: slow or fast songs (1 Slow – 5 Fast)
- I like the following music genres (1 Not at all – 5 Very much) – 17 genres

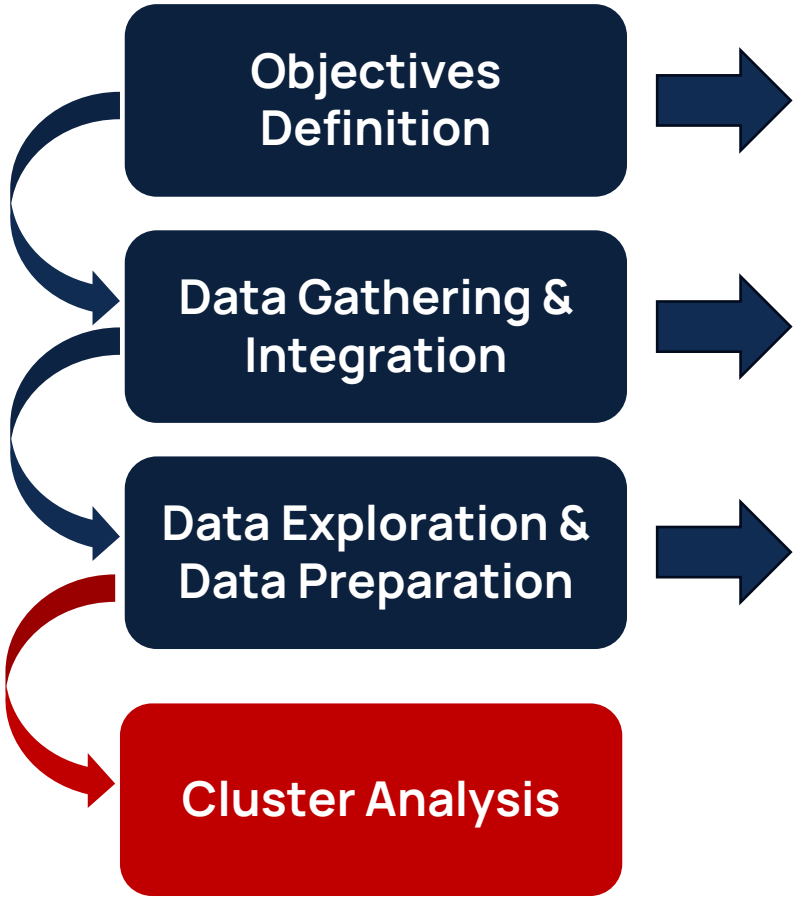
- Dance, disco, funk
- Folk
- Country
- Classical
- Musicals
- Pop
- Rock
- Metal, hard rock
- Punk
- Hip hop, rap
- Reggae, Ska
- Swing, jazz
- Rock n Roll
- Alternative
- Latin
- Techno, Trance
- Opera

Exercise: Young People Survey

982 observations

	A	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
1	ID	Punk	Hiphop, Rap	Reggae, Ska	Swing, Jazz	Rock n roll	Alternative	Latino	Techno	Opera	Age	Height	Weight	Siblings	Gender	Residence
2	1	1	1	1	1	3	1	1	1	1	20	163	48	1	2	2
3	2	4	1	3	1	4	4	2	1	1	19	163	58	2	2	1
4	3	4	1	4	3	5	5	5	1	3	20	176	67	2	2	1
5	4	4	2	2	1	2	5	1	2	1	22	172	59	1	2	1
6	5	2	5	3	2	1	2	4	2	2	20	170	59	1	2	2
7	6	3	4	3	4	4	5	3	1	3	20	186	77	1	1	1
8	7	1	3	1	1	2	3	3	5	2	20	177	50	1	2	2
9	8	2	3	2	2	3	1	2	3	2	19	184	90	1	1	1
10	10	3	2	4	4	4	4	5	1	2	19	174	60	3	2	1
11	11	1	3	2	2	3	3	3	4	2	19	175	60	2	2	1
12	12	1	1	1	2	2	5	2	1	2	17	176	60	1	2	1
13	13	2	3	1	1	4	3	2	1	2	24	168	55	10	2	1
14	14	1	2	1	3	2	1	3	1	1	19	165	55	1	2	1
15	15	5	3	4	4	4	4	1	1	1	22	175	57	1	2	1
16	16	5	2	4	2	3	3	2	1	2	18	177	77	0	1	1
17	17	3	2	3	2	3	1	1	4	1	19	175	65	2	2	1
18	19	3	4	4	4	4	4	4	4	3	18	181	78	2	1	1
19	20	2	1	4	5	4	3	4	3	2	18	188	90	1	1	1
20	21	4	4	3	5	4	5	3	3	4	20	186	77	1	1	1
21	22	4	1	2	1	4	3	2	1	2	24	186	85	1	1	1

Exercise: Young People Survey



Objective: to investigate music preferences of young people

Data collection: a large-scale survey among young people was conducted

Data exploration: descriptive analysis was performed

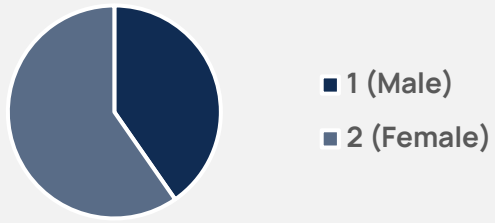
Exercise: Young People Survey

Categorical variables

- **Numerical summary** (empirical frequency)

Gender	Count	Frequency
1 (Male)	344	40%
2 (Female)	509	60%

- **Graphical summary**
(Pie Charts and Histograms)



Additional Slides: "Extra_Descriptive Statistics with SPSS"

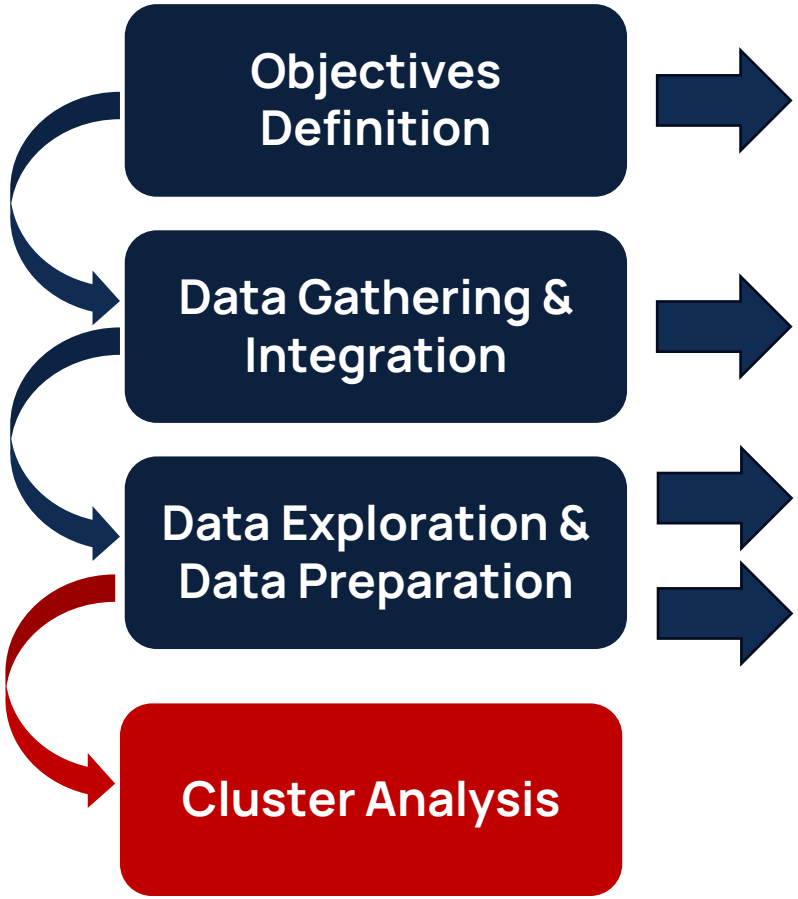
Numerical variables

- Histograms
- Analysis of the Empirical Density
- Measurement of Central Tendency
- Measurement of Dispersion
- Box-and-Whisker (Box plot)

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Country	853	1	5	2,14	1,084
Opera	853	1	5	2,16	1,207
Folk	853	1	5	2,28	1,144
Techno	853	1	5	2,32	1,324
MetalorHardrock	853	1	5	2,36	1,382
Punk	853	1	5	2,44	1,291
ReggaeSka	853	1	5	2,77	1,202
SwingJazz	853	1	5	2,77	1,261
Musical	853	1	5	2,77	1,280
Latino	853	1	5	2,86	1,329
Alternative	853	1	5	2,86	1,346
HiphopRap	853	1	5	2,89	1,362
Classicalmusic	853	1	5	2,97	1,259
Dance	853	1	5	3,09	1,174
Rocknroll	853	1	5	3,18	1,234
Fast	853	1	5	3,32	,818
Pop	853	1	5	3,47	1,167
Rock	853	1	5	3,76	1,179
Music	853	1	5	4,74	,653
Valid N (listwise)	853				

Exercise: Young People Survey



Objective: to investigate music preferences of young people

Data collection: a large-scale survey among young people was conducted

Data exploration: descriptive analysis was performed

Data preparation: anomalies and inconsistencies have been identified and removed. PCA allows to reduce the dimensionality of the dataset.

Exercise: Young People Survey

- Dance, disco, funk
- Folk
- Country
- Classical
- Musicals
- Pop
- Rock
- Metal, hard rock
- Punk
- Hip hop, rap
- Reggae, Ska
- Swing, jazz
- Rock'n Roll
- Alternative
- Latin
- Techno, Trance
- Opera

Summarizing the information in the original variables with a (substantially) lower number of components

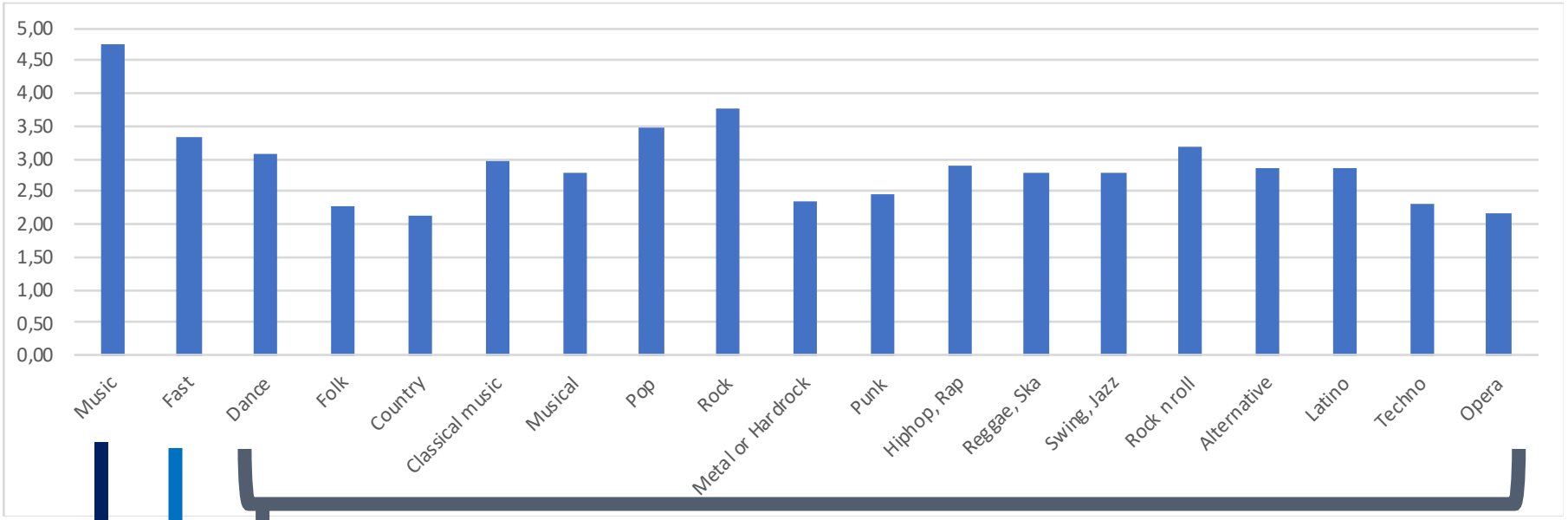
- **Component 1**
- **Component 2**
- **Component 3**
- **…**

PCA: Steps

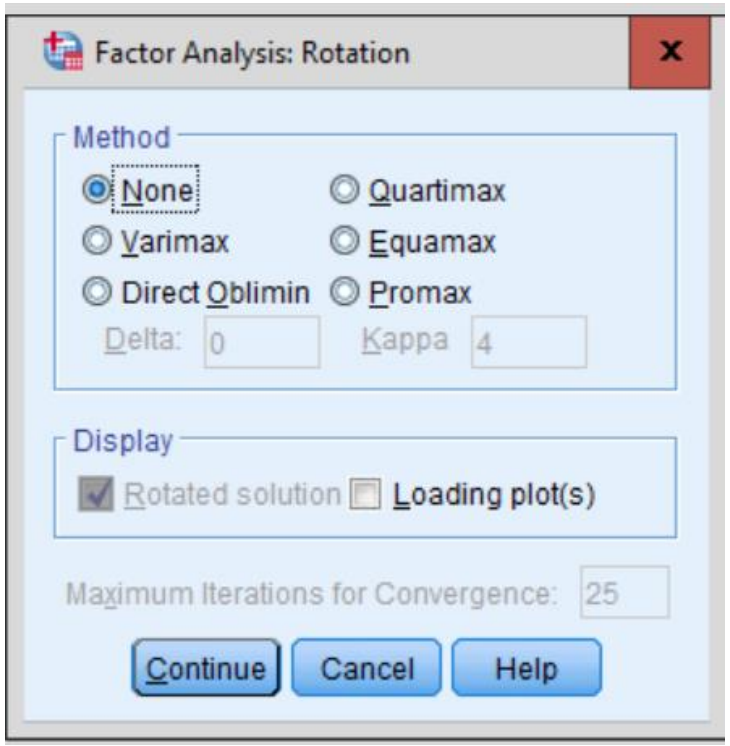
- Variables selection
- Rotation method identification
- Number of principal component definition
- Results interpretation

PCA on SPSS

PCA: Variables Selection



PCA: Rotation method identification

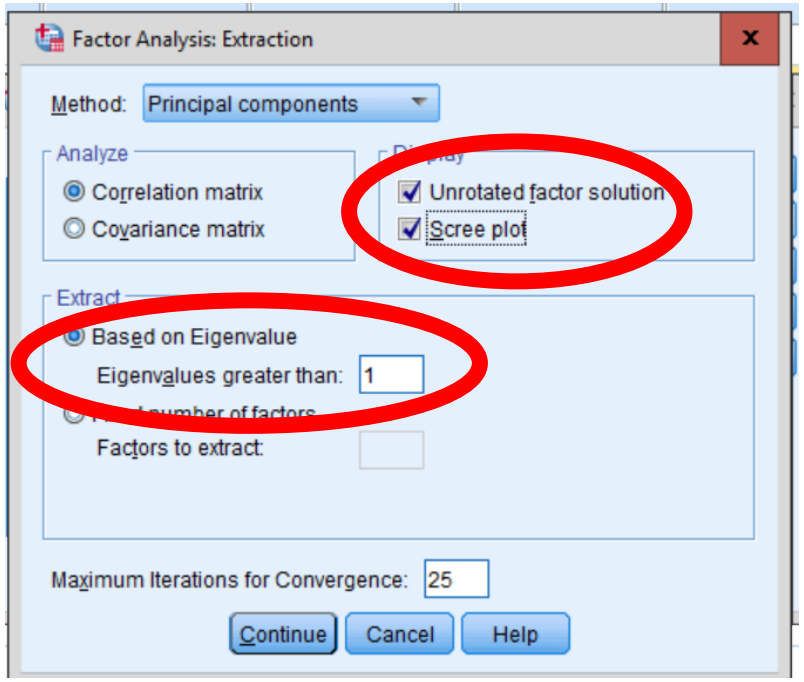


The goal of component rotation is to improve the interpretability of the factor solution by reaching simple structure

Orthogonal rotation (Varimax):
assumes that components are independent or uncorrelated with each other;

Oblique rotation (Oblimin):
assumes that components are not independent and are correlated

PCA: Number of principal component definition



As an unsupervised technique, the number of component is usually not known in advance; the «correct» number of components practically does not exist.
Though, some statistical indicators could help to define the number of components:

Factors with Eigen-value >1: the component explains more variances than a single variable

Scree plot: cut off at the «elbow» point, the value added by additional components is small

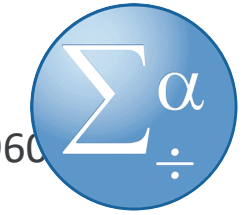
PCA: Number of principal component definition

Total Variance Explained

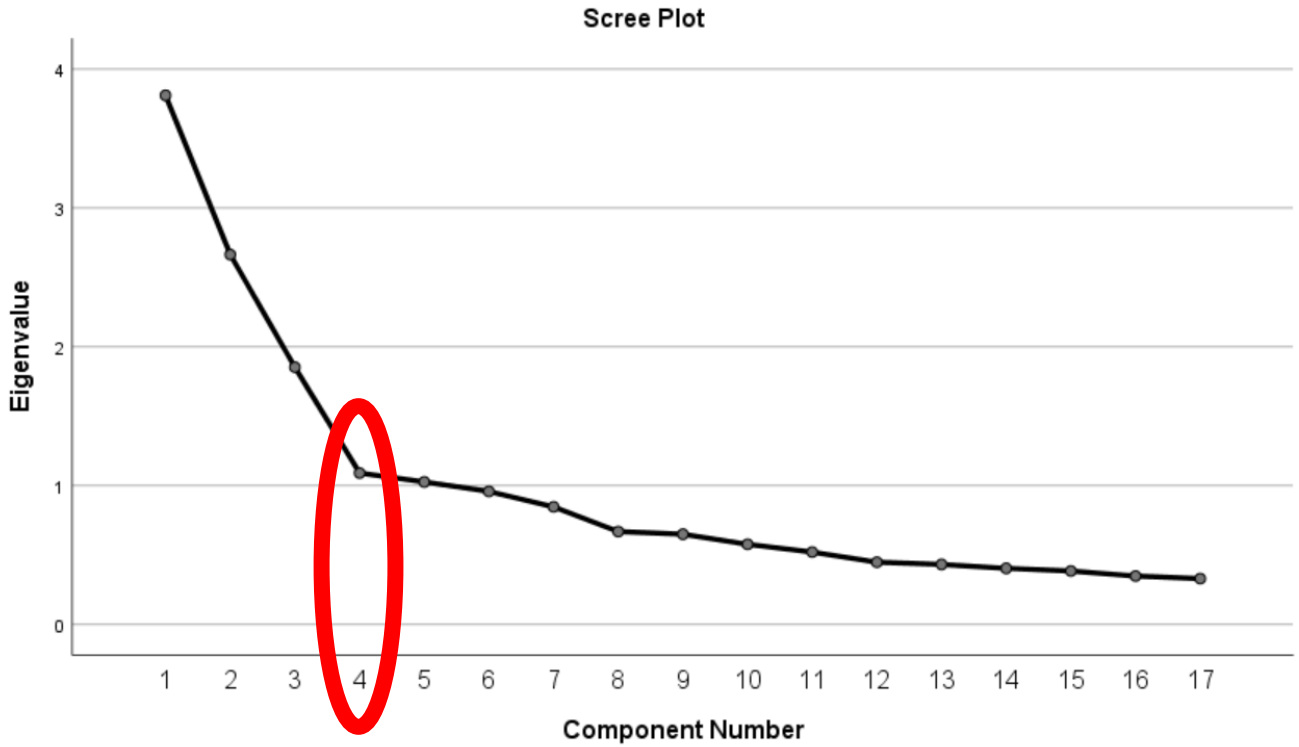
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3,811	22,415	22,415	3,811	22,415	22,415
2	2,663	15,667	38,082	2,663	15,667	38,082
3	1,852	10,894	48,976	1,852	10,894	48,976
4	1,089	6,410	55,385	1,089	6,410	55,385
5	1,025	6,032	61,418	1,025	6,032	61,418
6	,957	5,631	67,049			
7	,846	4,977	72,026			
8	,668	3,930	75,955			
9	,649	3,816	79,772			
10	,576	3,389	83,161			
11	,520	3,059	86,220			
12	,447	2,629	88,849			
13	,431	2,538	91,387			
14	,403	2,372	93,759			
15	,384	2,260	96,019			
16	,348	2,045	98,064			
17	,329	1,936	100,000			

Extraction Method: Principal Component Analysis.

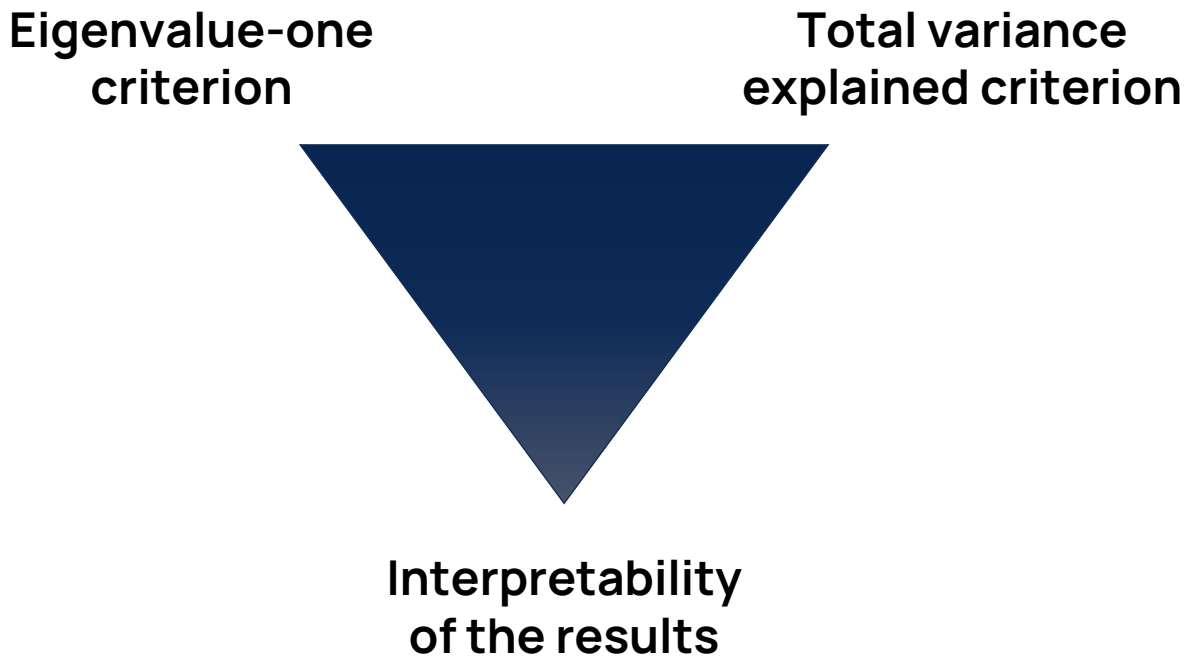
(Kaiser, 1960



PCA: Scree plot



PCA: Number of principal component definition



PCA: Number of principal component definition

4-Factor solution

Rotated Component Matrix[a]

	Component			
	1	2	3	4
Classicalmusic	,788			
Opera	,769			
Folk	,678			
SwingJazz	,562			
Country	,502			
Rock		,779		
Punk		,769		
Rocknroll		,668		
MetalorHardrock		,660		
Alternative		,553		
ReggaeSka		,478	,431	
Techno			,779	
HiphopRap			,666	
Dance			,665	
Pop				,738
Latino				,626
Musical	,512			,533

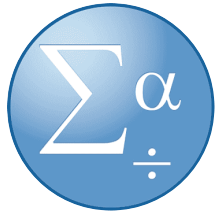
Extraction Method: Principal Component Analysis.

5-Factor solution

Rotated Component Matrix[a]

	Component				
	1	2	3	4	5
Classicalmusic	,790				
Opera	,788				
Folk	,671				
Musical	,518		,517		
Country	,514				
Rock		,837			
Punk		,775			
MetalorHardrock		,763			
Rocknroll		,554			
Alternative		,411			,408
Pop			,793		
Latino			,585		
Techno				,880	
Dance			,455	,681	
HiphopRap				,513	
ReggaeSka					,794
SwingJazz	,466				,637

Extraction Method: Principal Component Analysis.



PCA: Results interpretation

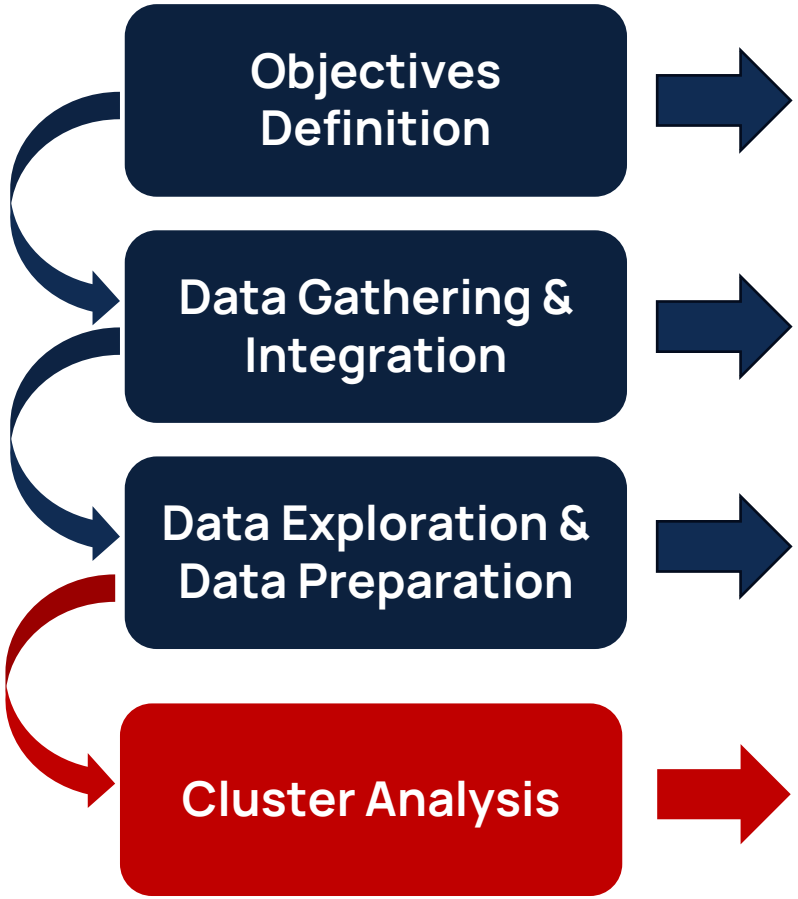
5-Factor solution

Rotated Component Matrix[a]

		Component				
		1	2	3	4	5
Classy	Classicalmusic	,790				
	Opera	,788				
	Folk	,671				
	Musical	,518		,517		
	Country	,514				
Rocky	Rock		,837			
	Punk		,775			
	MetalorHardrock		,763			
	Rocknroll		,554			
	Alternative		,411			,408
Dancy	Pop			,793		
	Latino			,585		
Disco	Techno				,880	
	Dance			,455	,681	
	HiphopRap				,513	
Jazzy	ReggaeSka					,794
	SwingJazz	,466				,637

Extraction Method: Principal Component Analysis.

Exercise: Young People Survey



Objective: to investigate music preferences of young people

Data collection: a large-scale survey among young people was conducted

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Data preparation: anomalies and inconsistencies have been identified and removed. PCA was used to reduce the dimensionality of the dataset.

K-means clustering

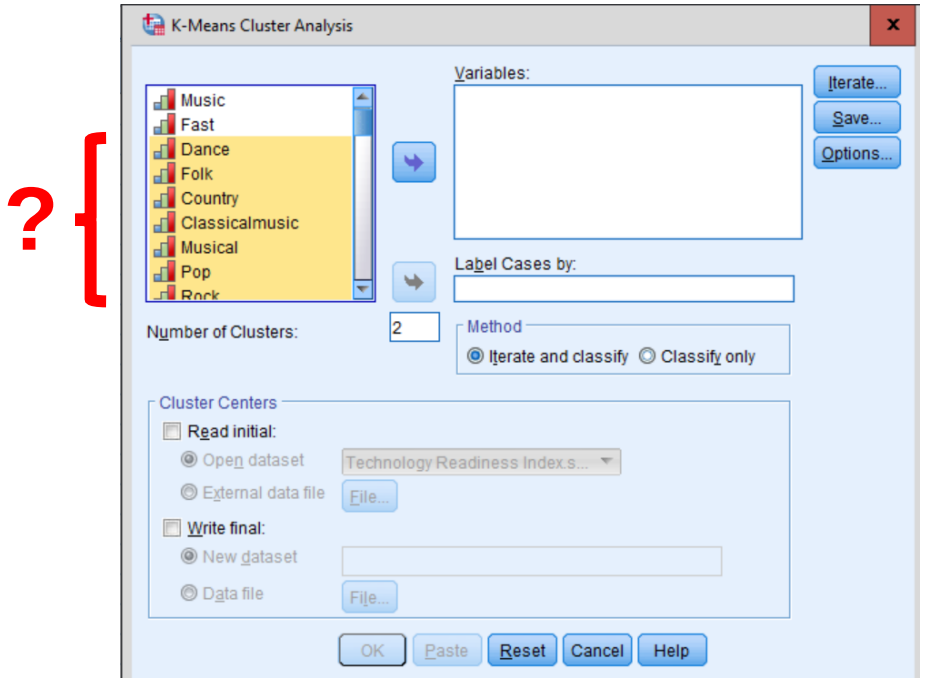
K-Means clustering: Steps

- Variables selection
- Number of clusters identification
- Convergence assessment
- Robustness assessment
- Results interpretation

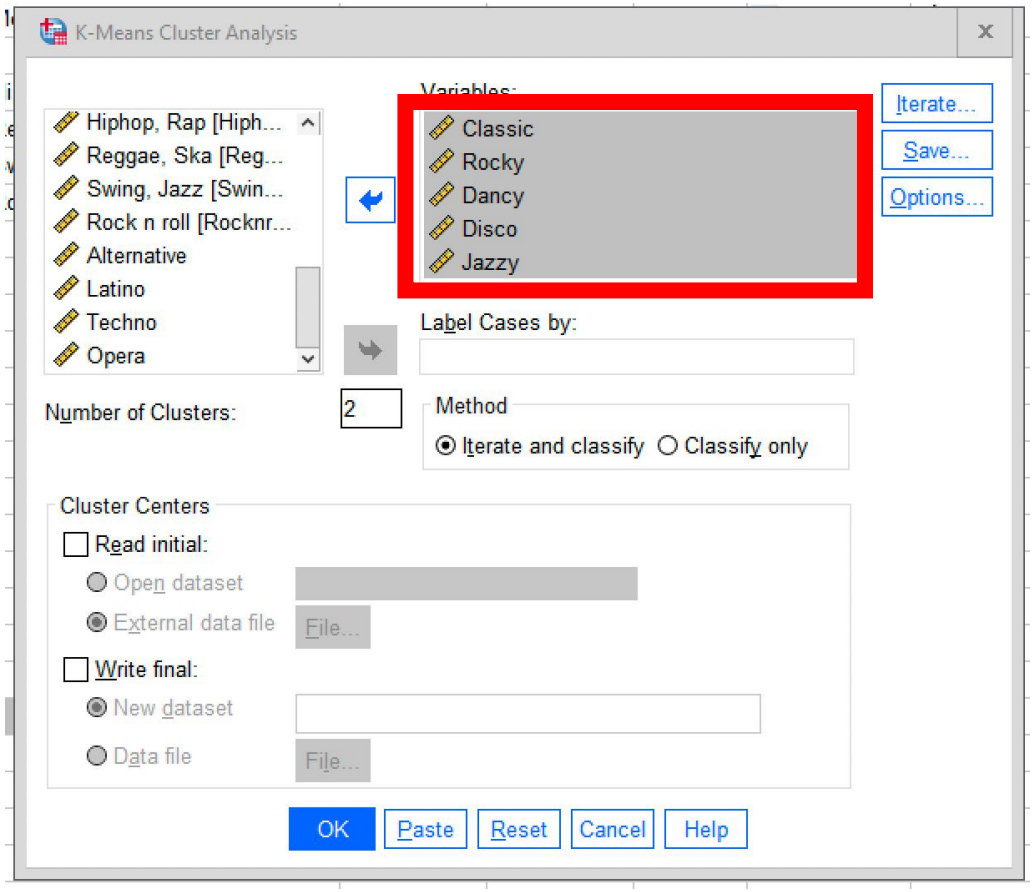
K-Means on SPSS

K-Means clustering: Variables selection

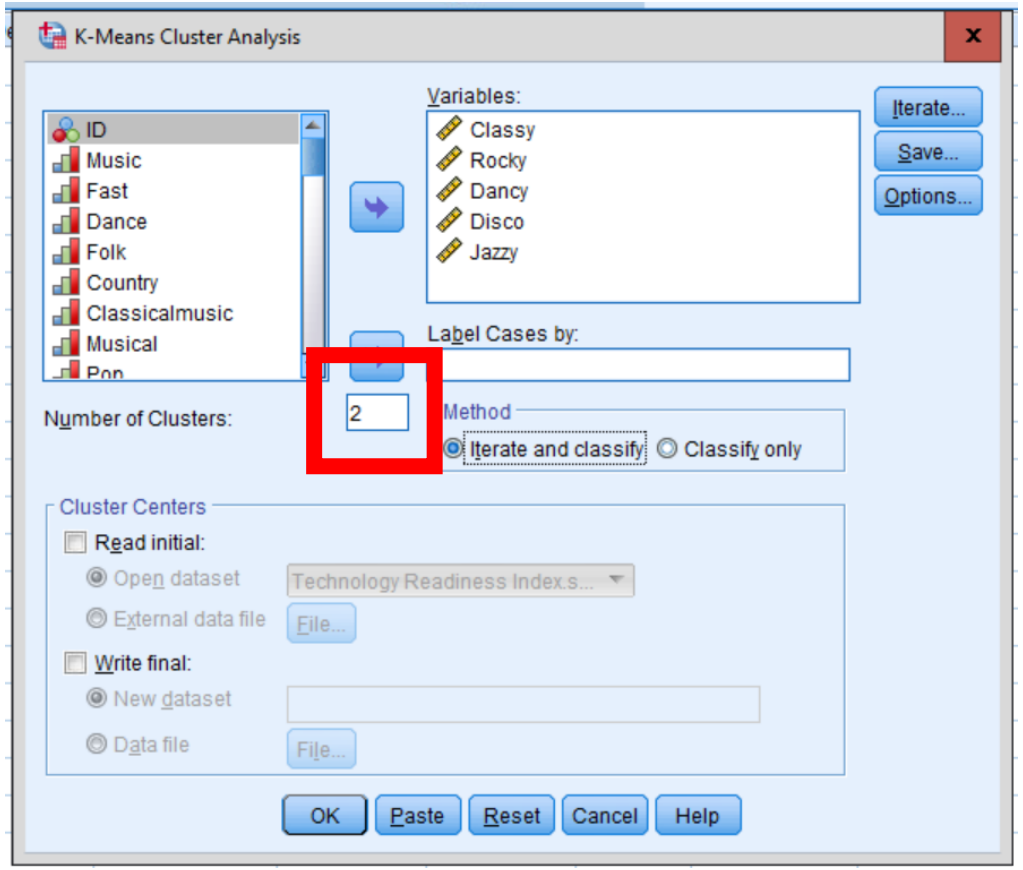
Not all the variables in a dataset should be put together in a cluster analysis.
You should consider the relationships between the input variables



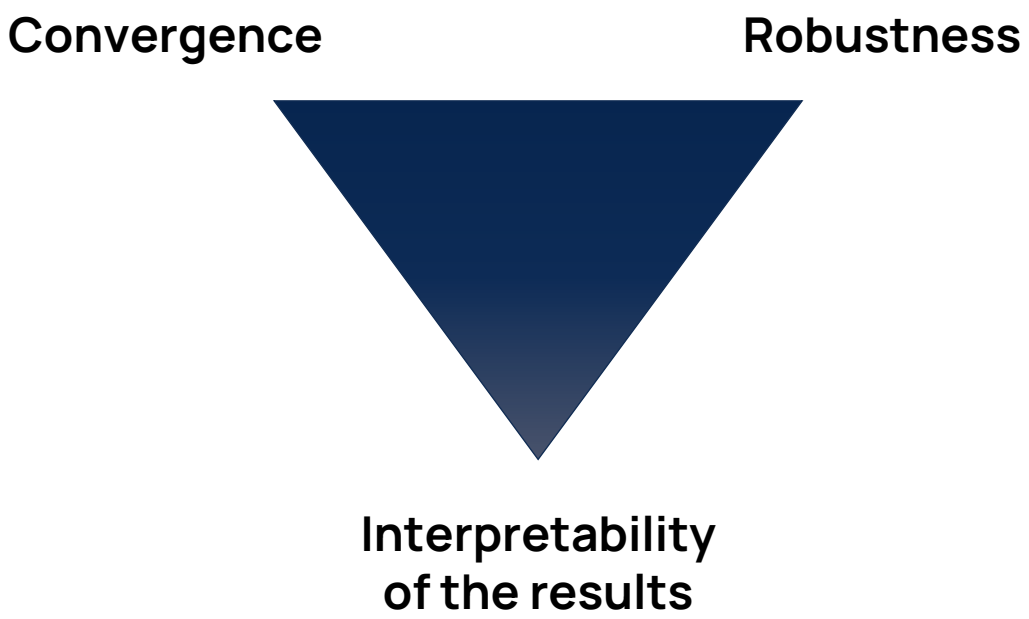
K-Means clustering: Variables selection



K-Means clustering: Number of clusters identification



K-Means: Defining k



K-Means clustering: Convergence assessment

Iteration History[a]

Iteration	Change in Cluster Centers 1	2
1	2,994	3,275
2	,087	,126
3	,074	,095
4	,059	,068
5	,035	,039
6	,035	,039
7	,040	,045
8	,037	,042
9	,047	,053
10	,062	,071
11	,077	,093
12	,073	,087
13	,063	,077
14	,040	,048
15	,039	,045
16	,043	,049
17	,026	,030
18	,031	,035
20	,034	,039

a. Iterations stopped because

Iteration History[a]

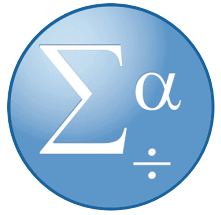
Iteration	Change in Cluster Centers 1	2	3	4	5
1	1,932	2,589	1,944	2,057	2,361
2	,192	,404	,157	,177	,461
3	,153	,225	,113	,200	,289
4	,119	,165	,096	,127	,152
5	,096	,115	,116	,178	,121
6	,053	,092	,117	,139	,055
7	,067	,097	,082	,080	,037
8	,064	,079	,071	,097	,065
9	,054	,082	,115	,151	,075
10	,026	,051	,099	,130	,149
11	,051	,046	,064	,050	,068
12	,021	,027	,023	,040	,055
14	,000	,000	,000	,000	,000

K-Means clustering: Robustness assessment

ANOVA

	Cluster		Error			
	Mean Square	df	Mean Square	df	F	Sig.
Classy	87,237	4	,593	848	147,056	,000
Rocky	59,897	4	,722	848	82,940	,000
Dancy	71,404	4	,668	848	106,907	,000
Disco	120,142	4	,438	848	274,292	,000
Jazzy	72,332	4	,664	848	109,011	,000

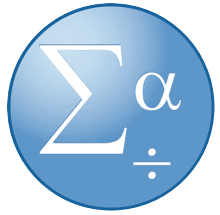
The F tests should be used only for descriptive purposes because the clusters have been chosen to maximize the differences among cases in different clusters. The observed significance levels are not corrected for this and thus cannot be interpreted as tests of the hypothesis that the cluster means are equal.



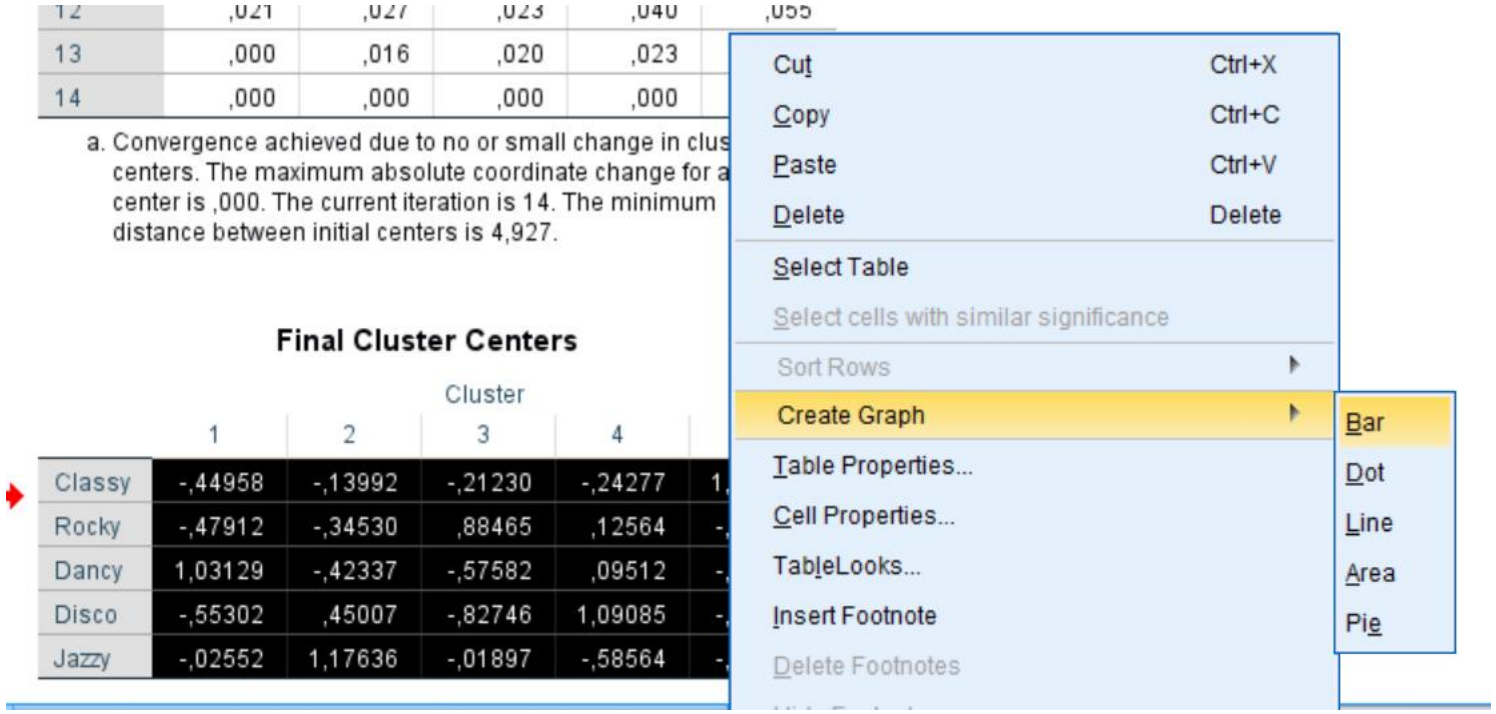
K-Means clustering: Robustness & Interpretability of the Results

Number of Cases in each Cluster

Cluster	1	176,000
	2	147,000
	3	191,000
	4	212,000
	5	127,000
Valid		853,000



K-Means clustering: Interpretability of the Results



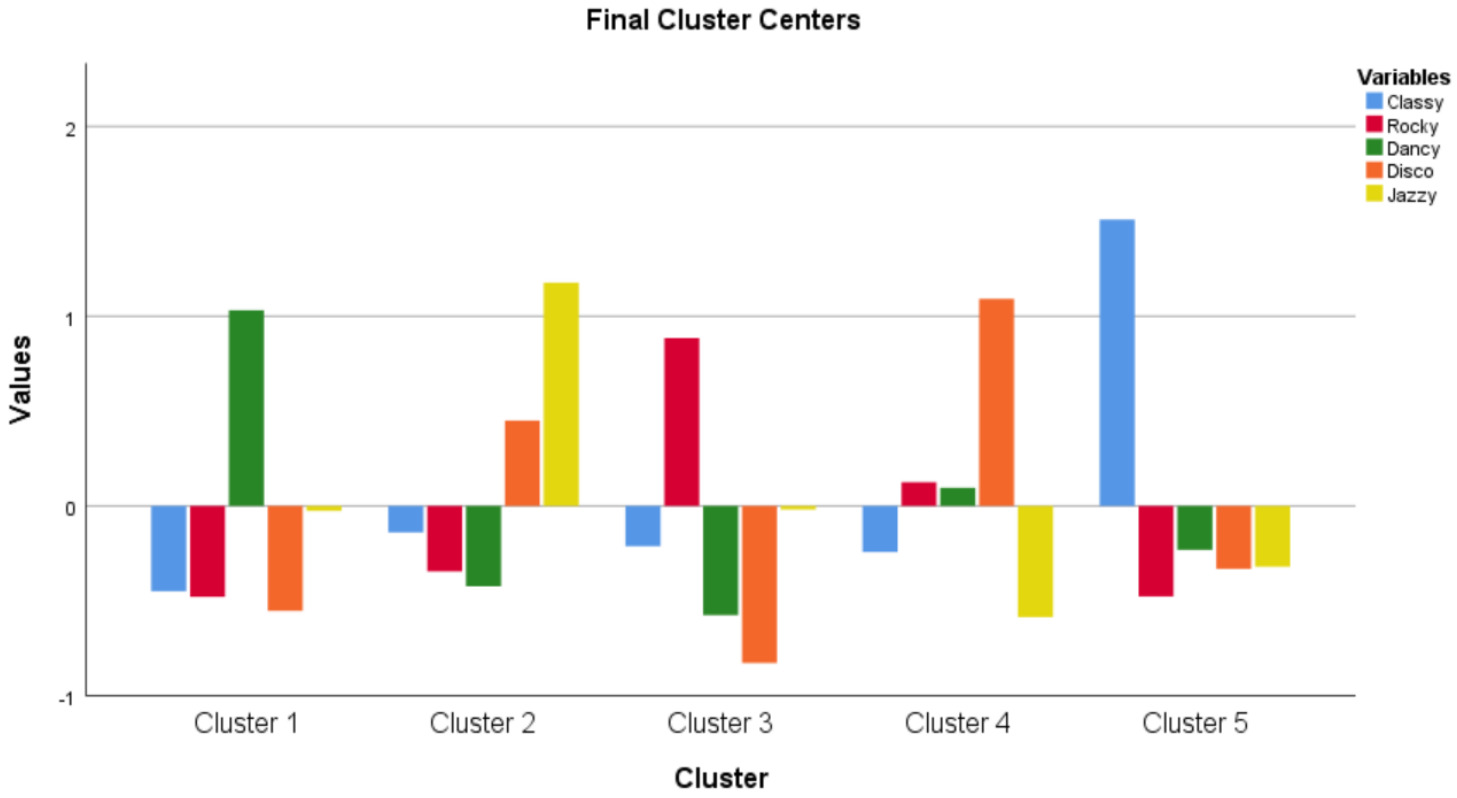
12	,021	,027	,023	,040	,055
13	,000	,016	,020	,023	
14	,000	,000	,000	,000	

a. Convergence achieved due to no or small change in clus
centers. The maximum absolute coordinate change for a
center is ,000. The current iteration is 14. The minimum
distance between initial centers is 4,927.

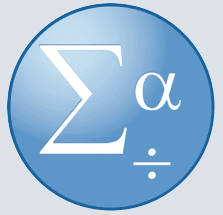
Final Cluster Centers

	Cluster				
	1	2	3	4	
Classy	-,44958	-,13992	-,21230	-,24277	1,
Rocky	-,47912	-,34530	,88465	,12564	-,
Dancy	1,03129	-,42337	-,57582	,09512	-,
Disco	-,55302	,45007	-,82746	1,09085	-,
Jazzy	-,02552	1,17636	-,01897	-,58564	-,

K-Means clustering: Interpretability of the Results



Exercise 2: Technology readiness index



Exercise: Technology readiness index

In order to **assess people's propensity to embrace and use new technology** for accomplishing goals in home life and at work, a survey was designed. The survey included a series of questions:

1. Technology makes me more productive in my personal life
2. Technical support lines are not helpful because they don't explain things in terms I understand
3. I keep up with the latest technological developments in my areas of interest
4. People are too dependent on technology to do things for them
5. New technologies contribute to a better quality of life
6. There is no such thing as a manual for a high-tech product that is written in plain text
7. I can usually figure out high-tech products without help from others
8. Too much technology distracts people to a point that is harmful
9. Technology gives me more freedom of mobility
10. Sometimes, i think technology systems are not designed for use by ordinary people
11. Other people come to me for advice on new technologies
12. Technology lowers the quality of relationships by reducing personal interaction
13. Technology give more control over my daily lives
14. When I get technical support for a high-tech product, I feel as if I'm been taken advantage of by someone who knows more than I do
15. In general Iam among the first in my circle of friends to acquire new technology when it appears
16. I do not feel confident doing business with a place that can only be reached online

Exercise: Technology readiness index

281 observations

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1	ID	Productive	Confusing	Updated	Freedom	Dependen	Complicat	Savvy	Quality	Relationba	Notforeve	Adviser	Distractio	Control	Asymetric	Earlyadop	Uncomfort	Gender	Age
2	1	3	5	2	5	2	5	1	4	2	5	1	2	4	2	1	1	2	4
3	2	4	2	4	5	3	1	4	4	2	4	5	3	4	4	2	1	2	4
4	3	5	1	4	4	2	2	4	4	1	3	3	2	4	2	4	1	1	2
5	4	5	3	4	5	1	3	5	5	1	4	4	1	5	1	2	1	2	3
6	5	3	3	1	4	4	5	3	3	1	3	1	5	4	2	1	5	1	5
7	6	4	1	3	4	4	2	5	4	2	1	2	3	4	1	2	1	2	4
8	7	5	1	5	5	2	4	5	5	3	2	4	3	4	1	5	1	1	2
9	8	4	2	4	4	4	1	5	4	2	2	2	4	3	3	1	4	2	2
10	9	4	1	4	4	4	1	5	5	2	1	4	4	4	1	2	1	1	3
11	10	4	2	4	4	5	3	4	4	4	3	4	4	3	1	4	3	2	2
12	11	3	2	3	2	1	1	3	3	2	2	2	1	2	2	1	2	2	2
13	12	4	2	4	5	3	2	5	5	3	2	5	4	4	1	3	2	2	3
14	13	4	2	3	4	5	2	5	4	3	4	5	4	4	2	2	2	2	3
15	14	3	3	2	2	3	2	3	3	3	4	3	3	3	3	2	3	1	5
16	15	4	2	4	4	3	2	4	4	5	3	2	2	4	1	2	2	1	4
17	16	5	3	4	5	1	2	5	5	2	3	4	2	5	2	3	2	2	3
18	17	5	4	5	5	4	4	4	5	2	2	5	2	4	4	3	4	2	2
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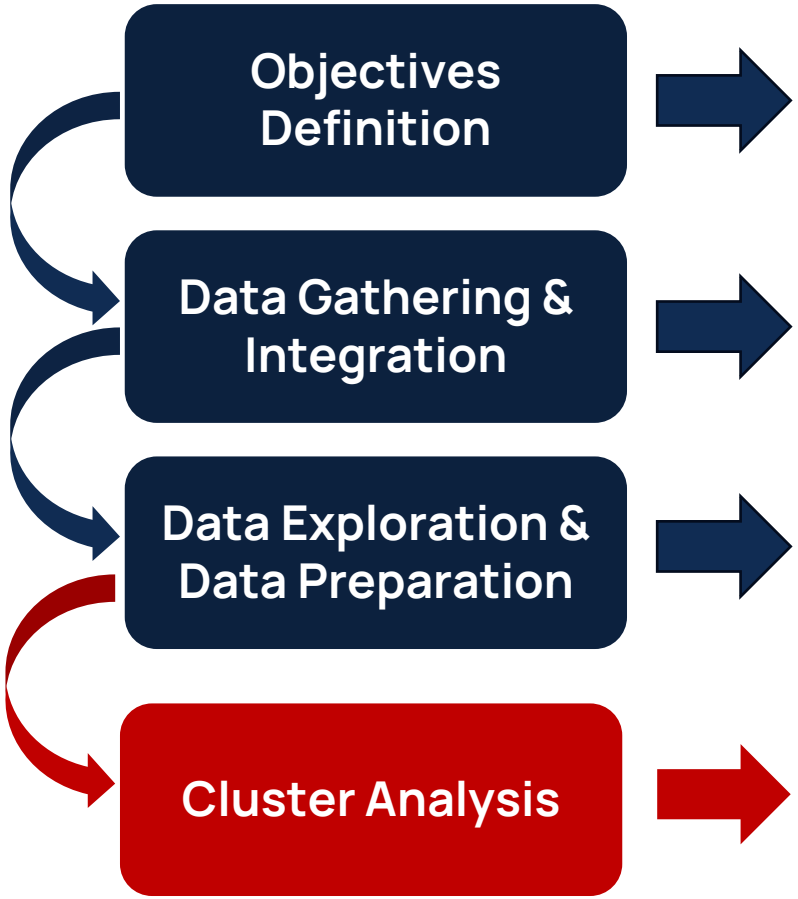
Exercise: Technology readiness index



Objective: to assess people's propensity to embrace and use new technology

Data collection: a survey was conducted

Data exploration: descriptive analysis was performed

Data preparation: anomalies and inconsistencies have been identified and removed. **PCA allows to reduce the dimensionality of the dataset.**

K-means clustering

PCA & K-Means on SPSS

Exercise 1: Young People Survey

PLS-SEM - Exercises

05

Exercise 3: Corporate Reputation

Exercise: Corporate Reputation

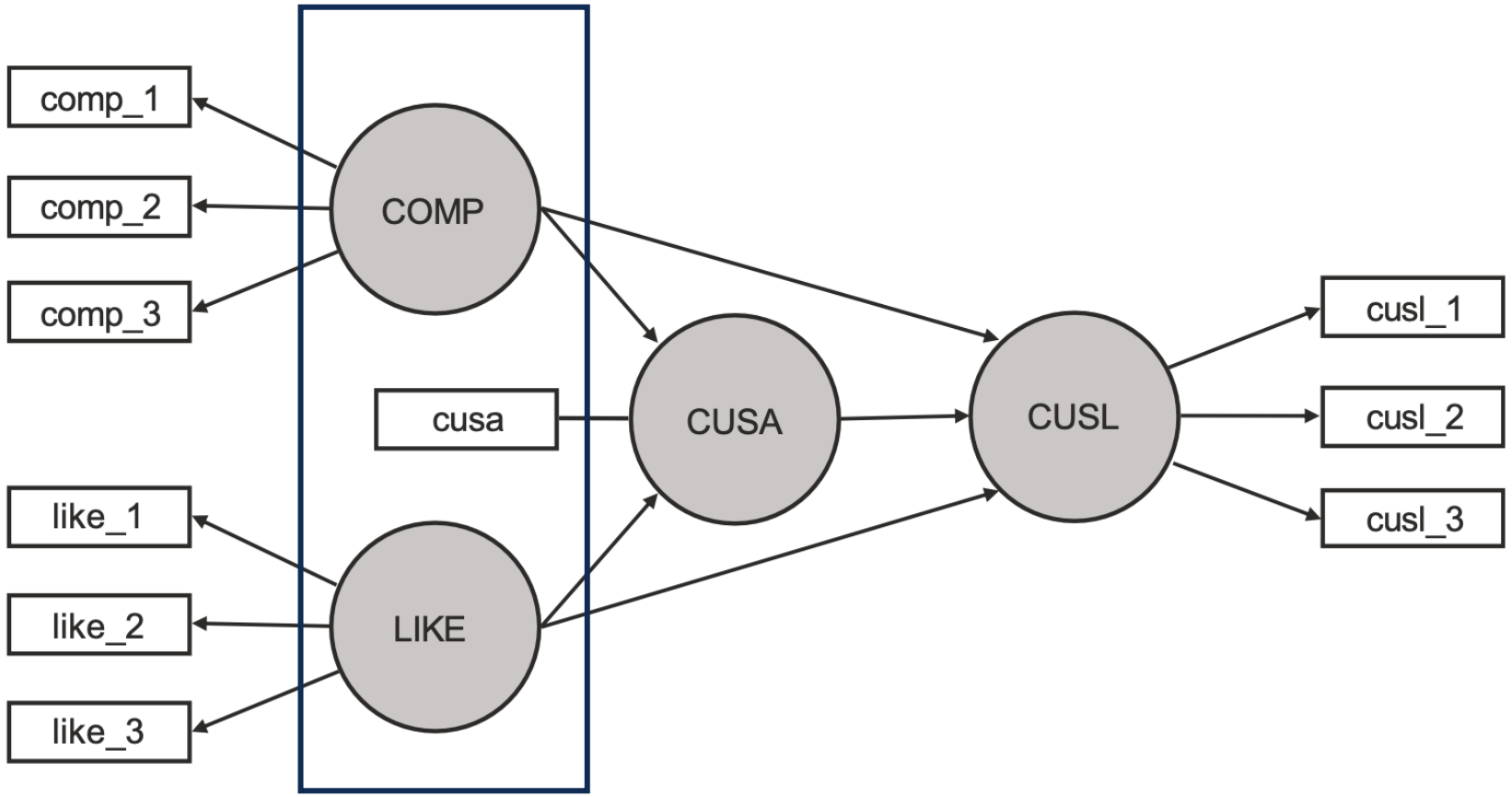
Objective: explain the effects of **corporate reputation** on **customer satisfaction** (CUSA) and, ultimately, **customer loyalty** (CUSL).

Corporate reputation represents a company's overall evaluation by its stakeholders. This construct is typically measured using two dimensions:

- The first dimension represents cognitive evaluations of the company, which is **the company's competence (COMP)**.
-
- the second dimension captures affective judgments, which determine **the company's likeability (LIKE)**.

Exercise: Corporate Reputation

Objectives Definition



Exercise: Corporate Reputation

Objective: explain the effects of **corporate reputation** on **customer satisfaction** (CUSA) and, ultimately, **customer loyalty** (CUSL).

Data collection: a survey was conducted

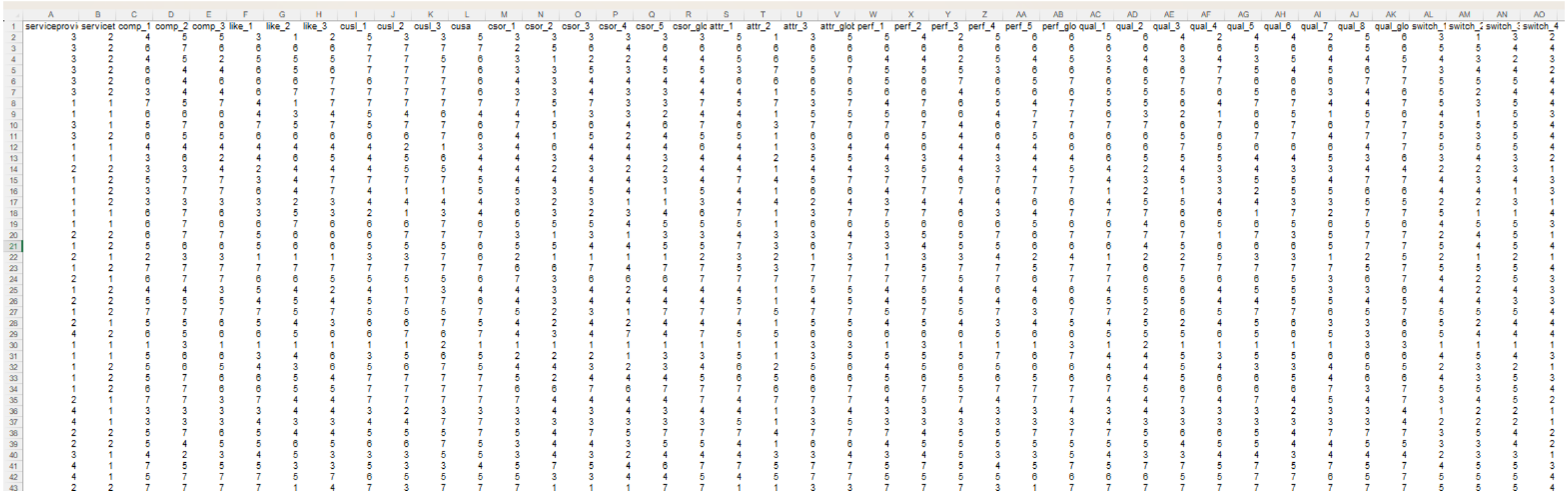
Exercise: Corporate Reputation

Competence (*COMP*)	
comp_1	[The company] is a top competitor in its market
comp_2	As far as I know, [the company] is recognized worldwide
comp_3	I believe [the company] performs at a premium level
Likeability (*LIKE*)	
like_1	[The company] is a company I can better identify with than other companies
like_2	[The company] is a company I would regret more not having if it no longer existed than I would other companies
like_3	I regard [the company] as a likeable company
Customer satisfaction (*CUSA*)	
cusa	I am satisfied with [the company]
Customer loyalty (*CUSL*)	
cusl_1	I would recommend [company] to friends and relatives
cusl_2	If I had to choose again, I would choose [company] as my mobile phone service provider
cusl_3	I will remain a customer of [company] in the future

Source: Hair et al. (2022), Chap. 2; used with permission by Sage

Exercise: Corporate Reputation

344 observations



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1	serviceprovi	servicet	comp_1	comp_2	comp_3	like_1	like_2	like_3	cusl_1	cusl_2	cusl_3	cusa	csor_1	csor_2	csor_3	csor_4	csor_5	csor_glo	attr_1	attr_2	attr_3	attr_glot	perf_1	perf_2	perf_3	perf_4	perf_5	perf_glo	qual_1	qual_2	qual_3	qual_4	qual_5	qual_6	qual_7	qual_8	qual_glo	switch_1	switch_2	switch_3	switch_4
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Exercise: Corporate Reputation

Objective: explain the effects of **corporate reputation** on **customer satisfaction** (CUSA) and, ultimately, **customer loyalty** (CUSL).

Data collection: a survey was conducted

Data exploration: descriptive analysis was performed

Data preparation: anomalies and inconsistencies have been identified and removed.

PLS-SEM

Interpretation

PLS-SEM on SmartPLS 4

- Link: https://www.smartpls.com/downloads/
- Free version available **with limitations** (e.g., databases with less than 100 observations)
- Premium version free trial for **one month** registering here.

From the previous lecture: Exogenous vs. Endogenous constructs

Exogenous Constructs

- Exogenous constructs are the latent, multi-item **equivalent of independent variables**. They use a linear combination of measures to represent the construct, which acts as an independent variable in the model.
- The term exogenous is used to describe latent constructs that **do not have any structural path relationships pointing at them**.

Endogenous constructs

- Endogenous constructs are the latent, multi-item **equivalent to dependent variables.** These constructs are theoretically determined by factors within the model.
- The term endogenous describes latent target constructs in the structural model **that are explained by other constructs** via structural model relationships.

From the previous lecture: Inner model vs. Outer model

A structural equation model consists of different sub-models.

Structural Model or Inner Model

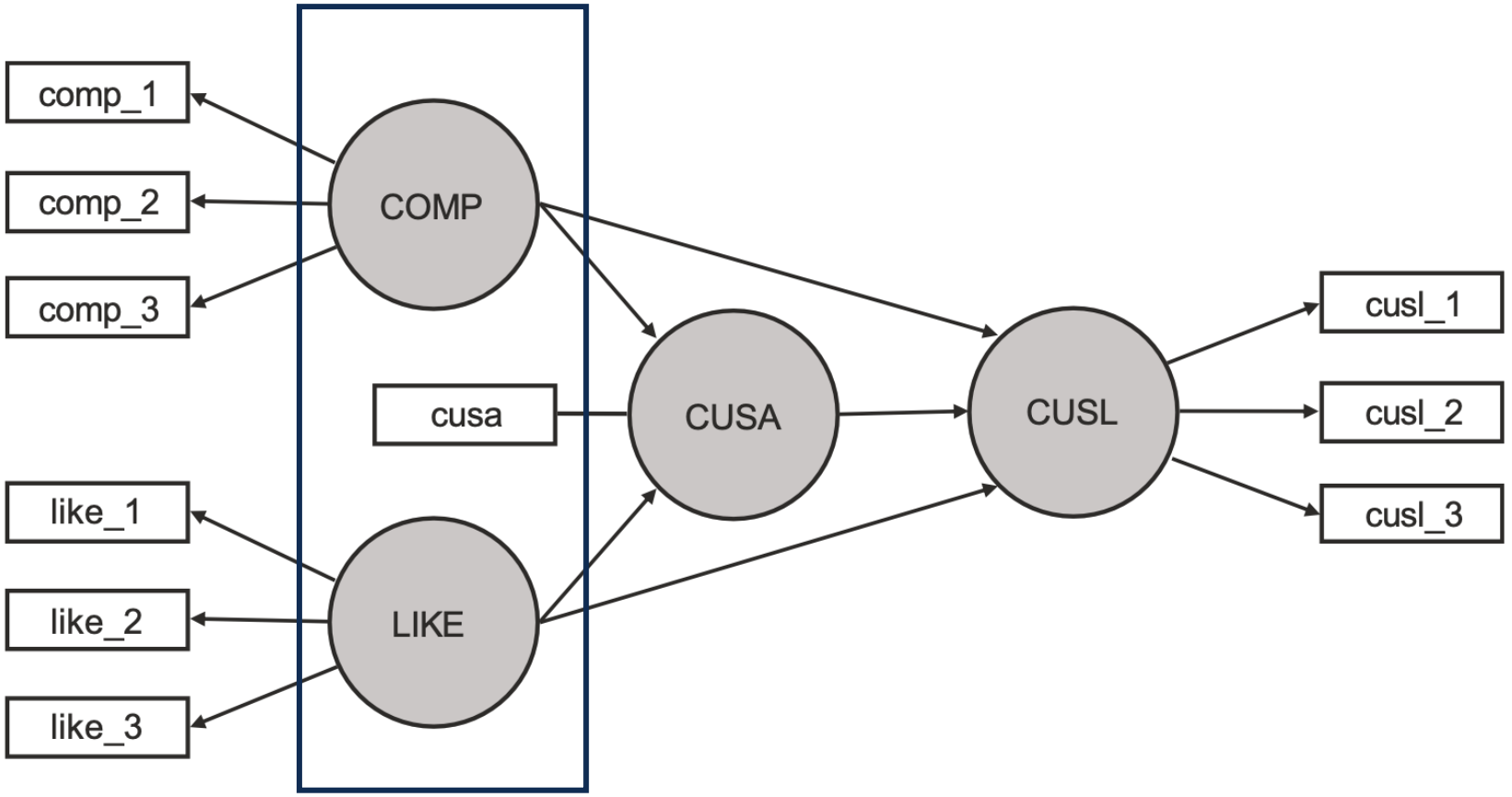
- The structural model (or inner model) comprises the **relationships between the latent variables**, which has to be derived from theoretical considerations.

Measurement Model/Outer Model

- For **each** of the **latent variable** within the structural equation model, a **measurement model** has to be defined.
- These models embody the relationship between the empirically observable **indicator variables and the latent variables**.

→ The combination of structural model and measurement models leads to a complete structural equation model.

Exercise: Corporate Reputation



PLS-SEM: measurement model and structural model

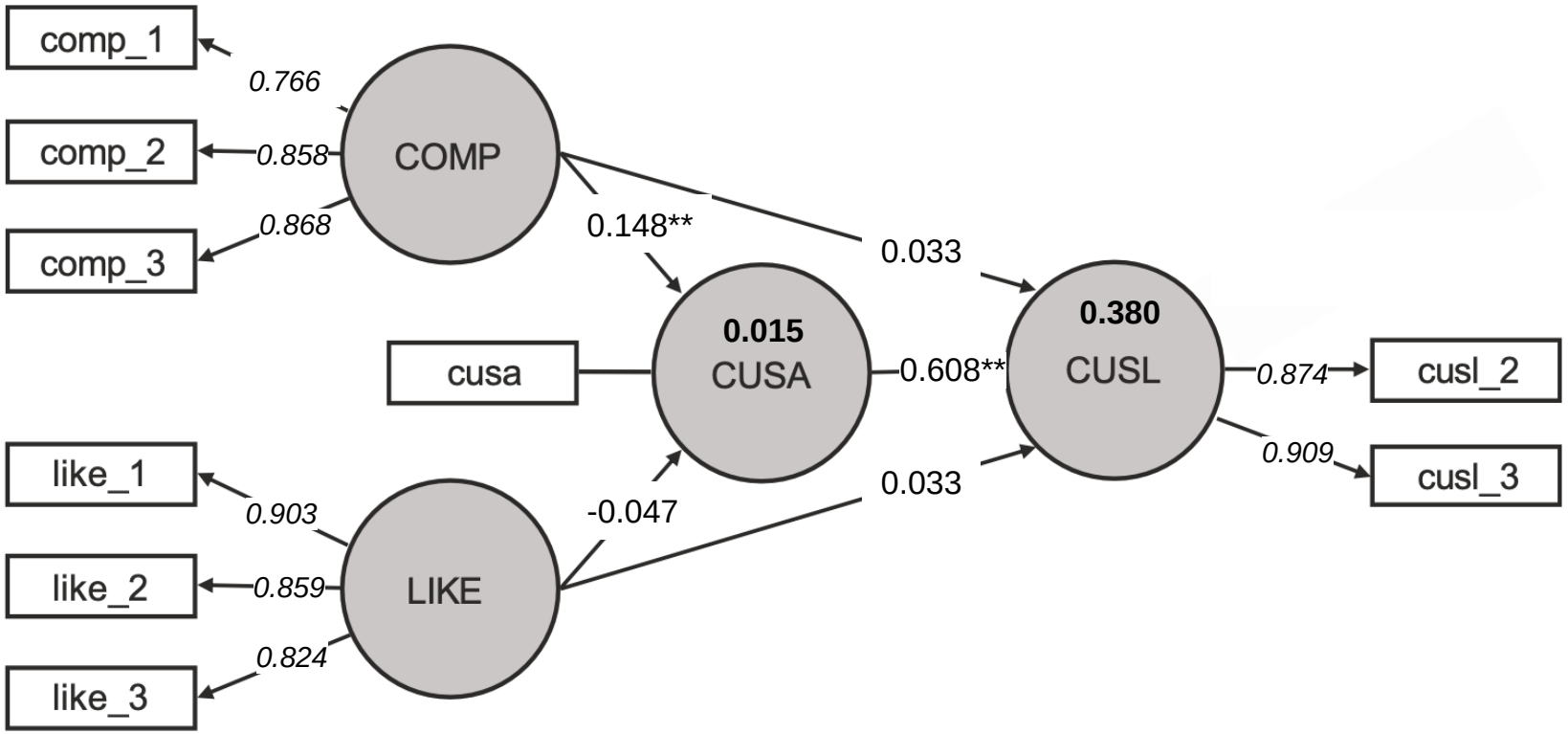
Measurement Model Assessment

1. Assess the **indicator reliability** (loadings)
2. Assess the **internal consistency reliability** (Composite reliability rhoc and Cronbach's alpha)
3. Assess the **convergent validity** (AVE)
4. Assess the **discriminant validity** (HTMT)

Structural Model Assessment

1. Assess **collinearity issues** the structural model
2. Assess the **significance and relevance** of the structural model relationships
3. Assess the model's **explanatory power**

Exercise 3: Corporate Reputation



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POLITECNICO MILANO 1863

Gloria Peggiani

AY 2024/2025