

## **Supplementary Material 1 - The detailed information**

### **Enrich the meaning of ‘demand-responsive station areas’ and establish the first theme for literature searching**

Since this paper studies the very particular issues, overcrowding and emptiness, hardly studied specifically by existing spatial design research, therefore if directly using ‘railway station area’ + ‘demand-responsive’ as the keywords for searching, hardly any relevant papers regarding spatial design can be found, and no heuristics can be gained. An enriched meaning of ‘demand-responsive station areas’ is needed to serve as a basis for literature selection. This paper enriches the term’s meaning by reinterpreting the identities of ‘railway station areas’, and the nature of ‘overcrowding’ and ‘emptiness’.

According to Bertolini & Spit (1998), ‘railway stations’ are ‘nodes’ of the transport networks and ‘places’ of the cities, so stations are fundamentally ‘transport infrastructures’ for transportation activities and ‘public spaces’ for other leisure activities. ‘Station areas’ include the ‘station buildings’ and the outdoor ‘spaces’, therefore ‘open/urban/public space’ and ‘landscape’ are relevant. ‘Overcrowding’ can be seen as a type of ‘risk’ to the station system, which can be addressed by ‘resilience’ as a quality of the system. ‘Emptiness’ is a lack of use of public spaces, therefore ‘flexible’ use can be helpful. Both ‘resilience’ and ‘flexible’ mean a system that is capable of changing, and similar words can include ‘dynamic’, ‘adaptive’, ‘robust’, ‘moveable’, ‘reconfigurable’, ‘multi-functional’, ‘temporary’, and so on. The combination of these concepts facilitates this paper to find relevant literature (see section 2.3.2, the first theme of searching) and even cases.

### **The validation of research by design**

(Nijhuis & Bobbink, 2012) To some readers who deal with more scientific-oriented research, this RbD method may raise the concern of bias, but this paper argues that it is not an issue. It is not about true or false, but about useful/practical or not. Design iterations seem arbitrary, while the minimum requirement is to iterate until requirement(s) are met. RbD is useful as long as one effective solution is successfully found. Research is a systematic study of an issue, not only about repeatability, generability, xxx. Means-end knowledge (Zwart & de Vries, 2016)

### **Selection criteria**

-Regarding design: qualities - (function) - layout - space - elements - others  
-Regarding demands and users in station areas -(Mix building and outdoor spaces, otherwise too specific and not generalizable. Too complicated for design practice?)  
-expert scoring?

(as flexibility) (Exclude the planning, managerial solutions) (Ardeshiri et al., 2016) (urban spaces) prerequisites: permeability, adaptability, legibility followed by body requisites: positive outdoor spaces, spaces with multimodal behavioral patterns, multiuse buildings, active frontages, and fine amenities constructive elements: activity, place, and people Classes: versatility, convertibility, and expansibility (Geraedts, 2008) (buildings) (should only be included when meaningful transformations are found) Partitionability, adaptability, extendibility, and multifunctionality; 1 Partitionable, collective/individual, disconnectable, zonable, modular 2 Adaptable: Adaptable, dismantlable, rearrangeable, adjustable, exchangeable, alterable, mobile, shapable 3 Extendible: Extendible, capacity, dimensions, ductless 4 Multifunctional: Multifunctional, intelligent, automated, universal, integrated modularity appropriation

(as resilience) (Exclude the managerial qualities)

## 5.1 The diagrams of station areas

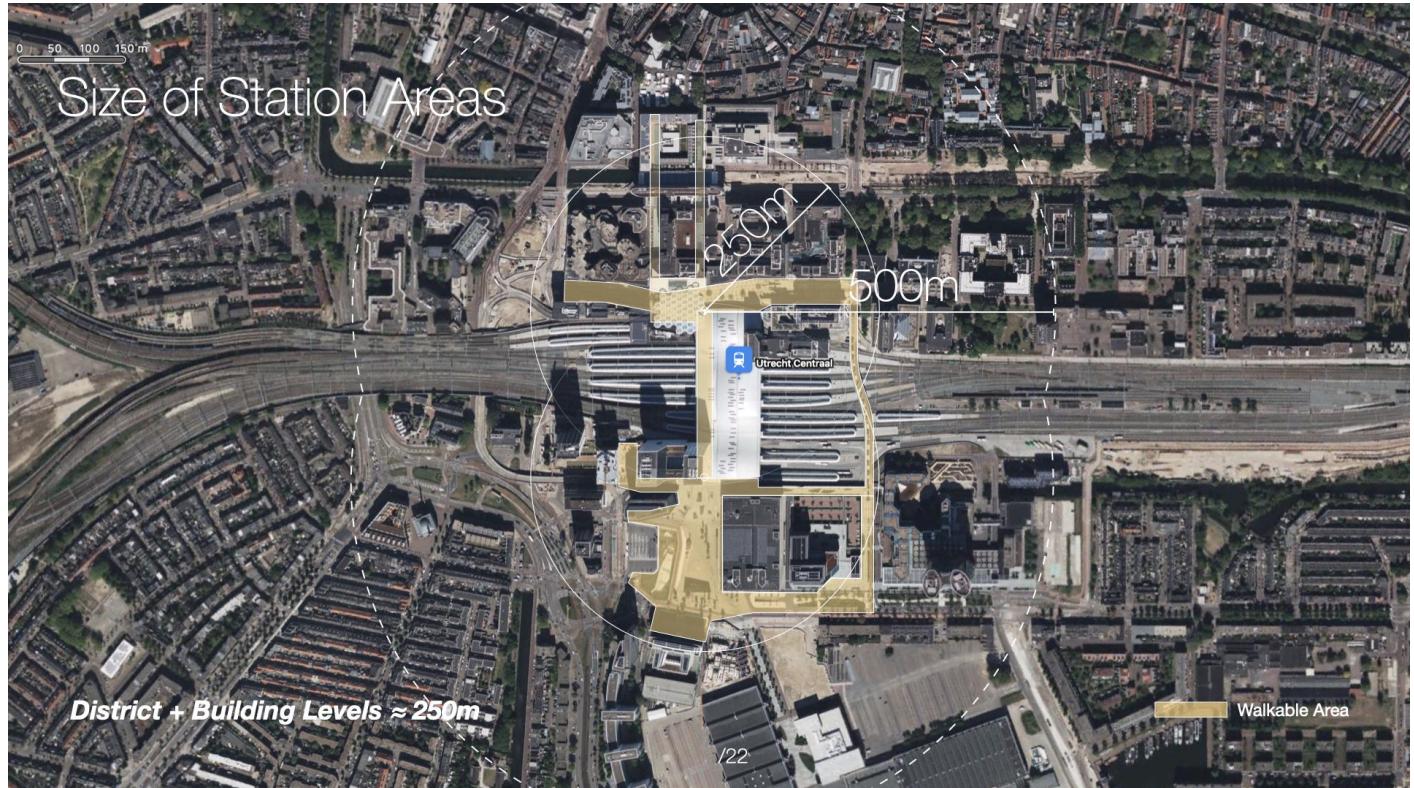


Figure 46: The Utrecht Central Station area - 250m vs 500m

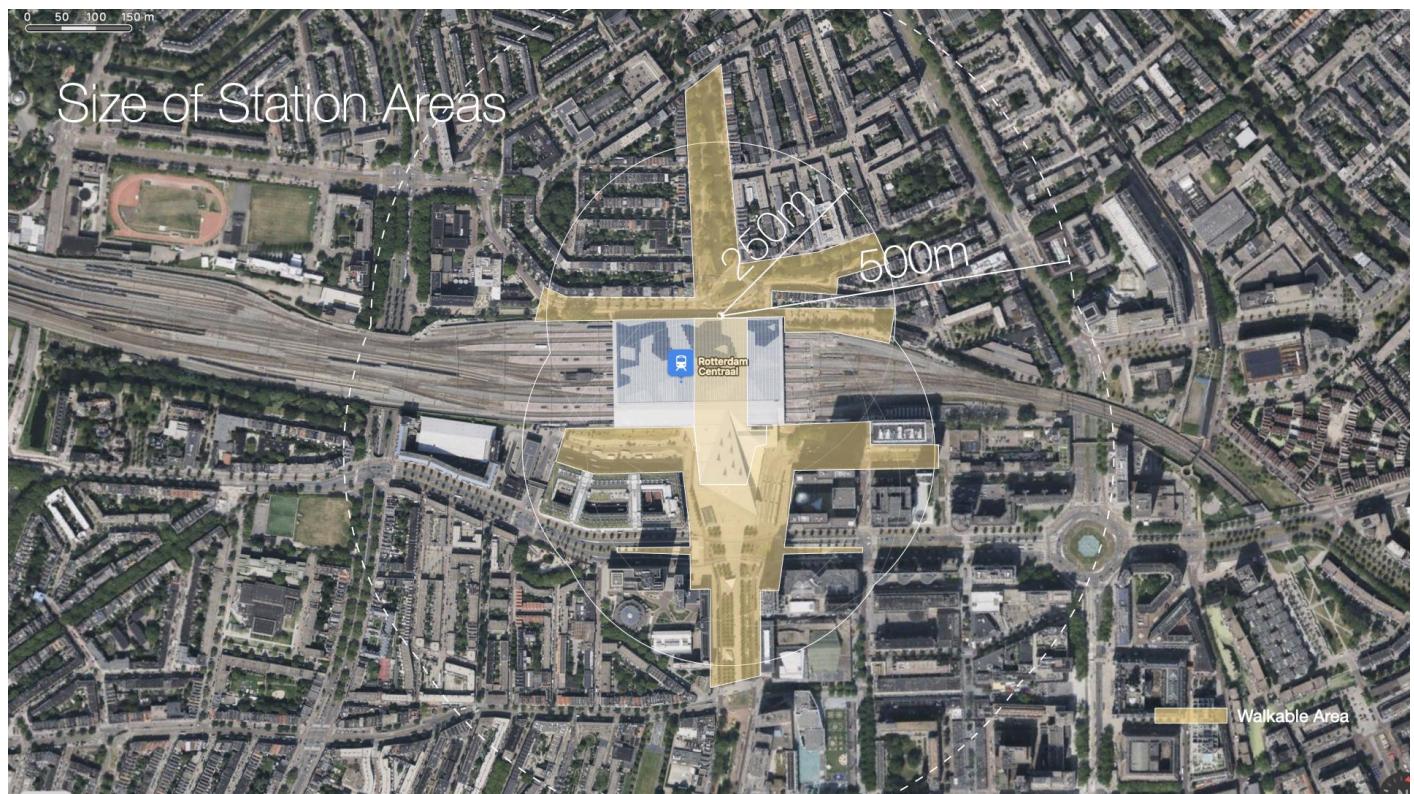


Figure 47: The Rotterdam Central Station area - 250m vs 500m



Figure 48: The Beijing West Railway Station area - 250m vs 500m

## 5.2 Initial station cases selected

Table 1: Cases selected

Stations	Size	Demand fluctuation	Performance for fluctuation	Nation
Beijing West RS	Large	Large	Poor	China
Beijing South RS	Large	Large	Poor	China
Shanghai RS	Large	Large	Good	China
Rotterdam Central Station	Large	Middle	Good	The Netherlands
Utrecht Central Station	Large	Middle	Good	The Netherlands
Bijlmer Arena RS	Middle	Large	Good	The Netherlands
Zandvoort Station	Small	Large	Good	The Netherlands

## 5.3 Initial literature selected through each search strategy and their relevance to design principles

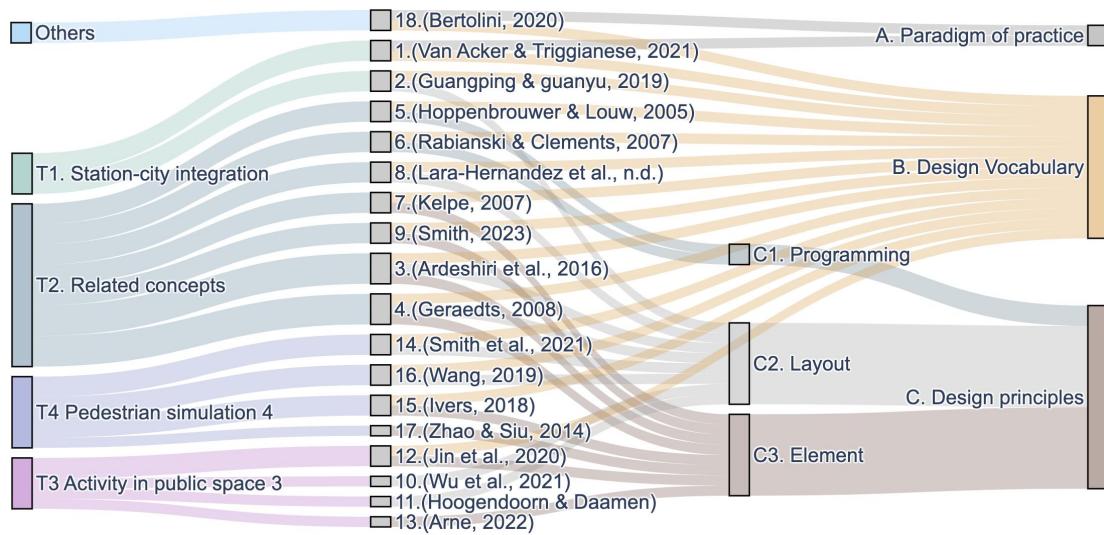


Figure 49: The literature selected and the relevance to the research findings

## 5.4 Data processing

Table 1. Data processing

		Objectives			User-based (Micro-level)			Dimensions			Management-Society?																	
		Overcrowding? (Potentially) reduce overcrowding?	Potentially) reduce emptiness? (Potentially) reduce emptiness?	And city value?	Reduce use conflicts?	Safety	Speed	Ease	Comfort	Experience	Spatial	Path?	Flow?	Programming?	Access?	Has relevant findings	J	Has relevant and positive findings	J+	Has relevant, but negative findings	J-	Not examined	—	Not relevant	—	Examinations	Primary	Relevant design principles
1	Beijing West	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J		
2	Beijing South	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J		
3	Shanghai	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J		
4	Rotterdam	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J		
5	Utrecht	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J		
6	Bilmer	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J		
7	Zandvoort	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J		
Cases	South, Shanghai, Rotterdam, Utrecht, Bilmer, Zandvoort	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J		
Other cases(s)	Guangzhou station, Shanghai South, Alipay area, Beijing West vs Beijing South, Beijing West vs Shantou, Beijing West vs Rotterdam, Beijing West vs Utrecht, Beijing West vs Bilmer, Beijing West vs Zandvoort, Beijing South vs Shanghai, Beijing South vs Rotterdam, Beijing South vs Utrecht, Beijing South vs Bilmer, Beijing South vs Zandvoort, Shanghai vs Rotterdam, Shanghai vs Utrecht, Shanghai vs Bilmer, Shanghai vs Zandvoort, Rotterdam vs Shanghai, Rotterdam vs Utrecht, Rotterdam vs Bilmer, Rotterdam vs Zandvoort, Utrecht vs Bilmer, Utrecht vs Zandvoort, Bilmen vs Zandvoort, Utrecht vs Utrecht old, Rotterdam new vs Rotterdam old, (Beijing West,Beijing South), (Shanghai), (Rotterdam, Utrecht, Bilmer, Zandvoort)	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J		
Case comparisons	(Any differences or commonalities between the different objectives/dimensions?)	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J		
1	Van Acker & Tigganese, 2021	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J		
2	Guangzhou, 2019 (Ardissi et al., 2016)	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J		
3	Genetis, 2008	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J		
4	Hoppenbrouwers & Louw, 2005 (Rabiniski & Clements, 2007)	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J		
5	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J		
6	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J		
7	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J		
Literature	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J		
10	Li et al., 2021 (Hogenboom & Daamen, 2020)	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J		
11	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J		
12	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J		
13	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J		
14	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J		
15	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J		
16	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J		
17	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J	J		
Relevant design principles																												

Legend: Primary examinations Not examined — Has relevant findings J Has relevant and positive findings J+ Has relevant, but negative findings J- Notes: Click the comment of each cell to see the detailed description.

Figure 50: Examine relevance and compare cases

Notes: Some comparisons are not examined, as shown in the following table.

## 5.5 The table for internal evaluation of design principles

Table 2. The evaluation of design principles

Index	Name	Objectives											
		Problem-oriented (Macro-level)				User (Passenger)-based (Micro-level)							
		Reduce Overcrowding?	Reduce Emptiness?	Add city value?	Reduce use conflicts?	Safety	Speed	Ease (Wayfinding)	Comfort	Experience			
1	Align open spaces with main paths	o	✓	o	o	o	o	o	o	✓			
2	Space for humans	o	✓	o	o	o	o	o	o	✓			
3	Add installations and facilities	Depend on the context ↓	✓	o	o	o	o	o	✓	✓			
4	Reconfigurable elements		✓	✓	o	o	o	o	o	o			
5	Stairs as stages or seats	o	✓	o	o	o	o	o	o	✓			
6	Shortcuts or optimizing paths	✓	✓	o	✓	o	✓	✓	o	o			
7	Reduce level change by landscape design (District-level)	✓	o	o	o	✓	o	o	o	o			
8	Changeable or moveable building	✓	✓	—	—	—	—	—	—	—			
9	Reduce bottlenecks to ease flow (District-level)	o	✓	✓	o	o	✓	o	✓	o			
10	Connect and share with neighborhoods	✓	✓	✓	o	✓	o	o	✓	o			
11	Redundant spaces	✓	↓	o	o	↓	↓	o	o	↓			
12	Redundant spaces + compact network + regulate path	✓	✓	o	✓	✓	✓	o	o	o			
13	City passage (Element)	o	✓	✓	✓	—	—	—	—	—			
14	Scattered mobility nodes to increase capacity	✓	o	o	o	✓	o	↓	o	o			
15	Set apart bottlenecks	✓	o	—	o	✓	o	o	o	o			
16	Set apart non-transport function	✓	o	o	✓	✓	o	✓	o	o			
17	Scattered mobility nodes to vibrate city environment	✓	o	✓	o	o	↓	↓	✓	✓			
18	Programming considering flexible uses in temporal dimension	✓	✓	✓	o	o	o	o	o	o			
19	Regulate path by temporary or reconfigure elements	✓	—	—	—	✓	o	o	o	✓			
20	Suitable general layout of the station and city	Depend on the context	Depend on the context	Depend on the context	Depend on the context								
21	Reduce bottlenecks to ease flow (Building-level)												
22	Reduce level change by landscape design (Building-level)												
23	Positioning City passage (Layout)												

Figure 51: The evaluation of design principles

## 5.6 Relate design principles to an event typology

(Smith et al., 2021) based on access and mobility (relevance: for spatial-managerial consideration and discussion); in station areas or not? Event relevance: -(access+mobility) Interactions/conflicts with the (passenger and non-passenger) flow or not -Size. relationship between paths and event types. No significant influence on overcrowding. Layout matters in the sense of: xxxx, xxxx. As long as it makes sense to designers who use these solutions.

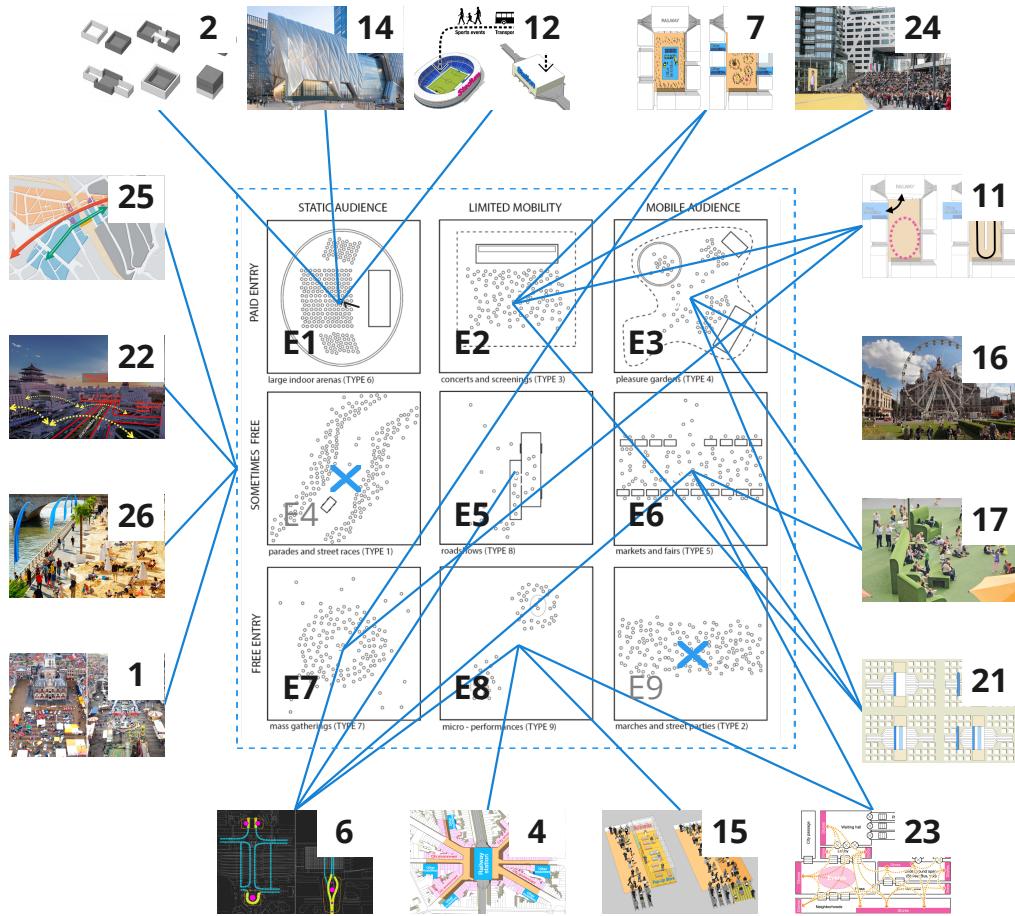


Figure 52: The design principles related to the event typology

## Supplementary Material 2 - Sources of figures

Table 2: Sources of Figures

N	Figure and Caption	Source
1	Overcrowding and emptiness in railway stations areas.	Left - <a href="https://www.163.com/dy/article/DLED9I020524TFU4.html">https://www.163.com/dy/article/DLED9I020524TFU4.html</a> ; Right - <a href="https://www.sohu.com/a/386779398_640391">https://www.sohu.com/a/386779398_640391</a>
2	A conceptual basic unit of passenger flow.	By authors
3	The mechanism of overcrowding and emptiness in Beijing West railway station area.	By authors
4	Spatial relevance shown by an example case of Beijing West Railway Station.	Original photo sources: Left - <a href="https://www.meipian.cn/">https://www.meipian.cn/</a> ; Right - <a href="https://upload.wikimedia.org/wikipedia/commons/5/5b/Beijing_West_Railway_Station_20170506_124557.jpg">https://upload.wikimedia.org/wikipedia/commons/5/5b/Beijing_West_Railway_Station_20170506_124557.jpg</a> . Drawings by authors
5	Temporal scales.	By authors, inspired by (de Jonge and van der Voordt, 2002, p. 38, fig. 13)
6	Spatial scales of station areas.	By authors
7	Architectural and urban design proposals for Amsterdam Sloterdijk station.	Upper - (Triggianese et al., 2019); Lower - (Andrianos, 2023)
8	This paper is part of a PhD project at the intersection of three topics.	By authors
9	The process of developing design principles.	By authors
10	The station at the district and building levels.	By authors
11	The configuration of the station.	By authors
12	Data sources.	By authors
13	An example of research by design.	By authors
14	Sources of heuristics.	By authors
15	The design principles (patterns) within a network.	By authors
16	The design principles viewed from different perspectives.	By authors
17	Flexible use.	<a href="https://www.stadsstrand.nl/paris-plages/">https://www.stadsstrand.nl/paris-plages/</a>
18	Different general layouts of the station and city.	(Qi and Lu, 2019)
19	Set apart non-transport function.	<a href="https://www.santenco.nl/portfolio_page/stationsplein-oost/">https://www.santenco.nl/portfolio_page/stationsplein-oost/</a>
20	Vibrate city environment by scattered mobility nodes.	By authors
21	Increase transport capacity by scattered mobility nodes.	By authors
22	Alignment between open spaces and main paths.	By authors
23	Human-oriented spaces versus vehicle-oriented spaces.	By authors
24	The old and the new Rotterdam central stations.	Upper-left - <a href="https://commons.wikimedia.org/wiki/File:Nieuw_Centraal_Station_in_Rotterdam_aangetast,_Bestanddeelnr_908-5455.jpg">https://commons.wikimedia.org/wiki/File:Nieuw_Centraal_Station_in_Rotterdam_aangetast,_Bestanddeelnr_908-5455.jpg</a> ; Upper-right - <a href="https://internaathetposthuis.nl/raldus.html">https://internaathetposthuis.nl/raldus.html</a> ; Lower-left - <a href="https://indebuurt.nl/rotterdam/nieuws/salsa-doe-gratis-mee-met-deze-gigadans-voor-rotterdam-centraal-311821/">https://indebuurt.nl/rotterdam/nieuws/salsa-doe-gratis-mee-met-deze-gigadans-voor-rotterdam-centraal-311821/</a> ; Lower-right <a href="https://mvsaarchitects.com/en/news/nos-rotterdam-central-receives-a-score-of-8-and-is-the-most-popular-large-train-station/">https://mvsaarchitects.com/en/news/nos-rotterdam-central-receives-a-score-of-8-and-is-the-most-popular-large-train-station/</a>
25	Connect with neighborhoods.	By authors
26	Smooth level changes by landscape design at the district level.	<a href="https://m.thepaper.cn/newsDetail_forward_5348462">https://m.thepaper.cn/newsDetail_forward_5348462</a>
27	Smooth level changes by landscape design at the building level.	<a href="https://www.unstudio.com/en/page/12109/arnhem-central-masterplan">https://www.unstudio.com/en/page/12109/arnhem-central-masterplan</a>
28	Adaptive redundant spaces with path regulation.	By authors
29	Path regulation using reconfigurable elements.	By authors

Table 3: Sources of Figures (continued)

N	Figure and Caption	Source
30	Programming considering the time dimension (for flexible use).	By authors
31	Shortcuts or optimizing paths.	By authors
32	A changeable building - the Shed.	<a href="https://www.architecturaldigest.com/story/the-shed-finally-opens-new-york-city-hudson-yards">https://www.architecturaldigest.com/story/the-shed-finally-opens-new-york-city-hudson-yards</a>
33	Changeable building components.	By authors
34	Add installations and facilities.	<a href="https://www.flickr.com/photos/87453322@N00/7561351848">https://www.flickr.com/photos/87453322@N00/7561351848</a>
35	Reconfigurable elements.	(Ivers, 2018)
36	Reconfigurable spaces.	Left - <a href="https://www.shutterstock.com/image-photo/vie-w-delft-market-square-nieuwe-kerk-1206141775">https://www.shutterstock.com/image-photo/vie-w-delft-market-square-nieuwe-kerk-1206141775</a> ; Right - <a href="https://nl.pinterest.com/pin/546342998538754823/">https://nl.pinterest.com/pin/546342998538754823/</a>
37	Redundant spaces or setting apart bottlenecks at the district level.	By authors
38	Redundant spaces or setting apart bottlenecks at the building level.	By authors
39	Position city passages (at the district level).	By authors
40	The city passages (at the building level).	<a href="https://www.amsterdam-viptours.com/blog/cuypers-passage/">https://www.amsterdam-viptours.com/blog/cuypers-passage/</a>
41	Barriers that hinder the flow at the district level.	By authors
42	Reduce barriers to ease flow at the building level.	By authors
43	Stairs as stages or seats.	<a href="https://architectenweb.nl/nieuws/artikel.aspx?id=43948">https://architectenweb.nl/nieuws/artikel.aspx?id=43948</a>
44	Two city axes were planned during the redevelopment of the Utrecht Central Station area.	Structuurplan, Stationsgebied Utrecht, December 2006
45	Station typology implied by the cases.	By authors
46	The Utrecht Central Station area - 250m vs 500m.	By authors
47	The Rotterdam Central Station area - 250m vs 500m	
48	The Beijing West Railway Station area - 250m vs 500m.	By authors
49	The literature selected and the relevance to the research findings.	By authors
50	Examine relevance and compare cases.	By authors
51	The evaluation of design principles.	By authors
52	The design principles related to the event typology.	By authors