Systemic perspectives on railway stations for sustainable transport and land use

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Abstract

The application of concentration strategies in the quest for sustainable development (SD) of transport and land use leads to public transport nodes, especially railway stations, becoming a centre of focus in planning. Methods to analyse a railway stations' potential contribution to SD could support such efforts, but are missing. In search of an analysis method for railway stations potential to SD, we present an extended application of the Sustainability Potential Analysis (SPA). This approach supports the combination of (1) normative value judgements necessary for SD and (2) the formally guided choice of analysis criteria upon systemic principles. We conducted expert interviews to define functions of railway stations and respective analysis criteria.

A heuristic model was developed, including multiple and potentially conflicting functions of railway stations. These show, that a railway station is not only a node and place of public transport, but that it has further influences on its catchment area. Each function is described by multiple criteria according to the framework of the SPA. On the level of criteria for SD, we show how the SPA supports formalised criteria identification. The multi-stakeholder design (i.e. multiple functional perspectives) allows for the identification of conflicts and necessary trade-offs, highlighting decisions necessary for SD.

Keywords

Railway station – systemic analysis – sustainable development – functions - perspectives

1. Introduction

Transport and land use considerably influence one another (Newman and Kenworthy 1989; Wegener and Fürst 1999; Ewing and Cervero 2001; Priemus, Nijkamp et al. 2001; Handy 2005). With respect to sustainable development (SD) it is commonly agreed, that urban built environment and rural land use resulting in less trips, shorter trips and more efficient modes of transport is to be favoured (Vester 1995; Wegener and Greene 2002). To maintain accessibility, this results in planning principles specifically supporting public transport, bicycling and walking, such as transit-oriented development (Jenks 2005), concentration strategies (Ritsema van Eck, Burghouwt et al. 2005), polycentric urban regions (Meijers 2005), or decentralised concentration (Holden 2004). These planning principles all have in common, that they encourage concentrated development along public transport infrastructures or around nodes of public transport. Although concentrated development is by no means uncontested (Gordon and Richardson 1997), nodes of public transport, especially railway stations, thereby become a centre of focus in sustainable development (cf. Hartz and Liechti 1992; Connolly and Payne 2004; Haywood 2005; Lin and Gau 2006).

To support development of railway stations in general, multiple analysis methods are available. Many of these address specific issues, such as operating profits, safety, utilisation barriers (Hayashi 2002; Becker 2005), or accessibility (Berg 1989; Ayvalik and Khisty 2002; Rastogi and Rao 2003; Armstrong and Rodriguez 2006). Some use generalised classifications and categorisations (e.g. with respect to regional importance or number of customers or services) to develop or define guidelines (cf. Juchelka 2002; De Tommasi, Oetterli et al. 2004). Wulfhorst (2003) developed a system dynamic model relating land use and transport developments at railway stations. With respect to SD, the only approach we know of which explicitly links analysis with SD is the node-place model of Bertolini (1999). The node function describes the transport activity and connectedness of the railway station to other places of interest. The place function describes the quantity and diversity of possible activities at or near the station. Bertolini’s (1999) model is dynamic and he suggests that a balance exists or will develop between node and place functions. The proposed balance between node and place provides a first criterion for assessing sustainability regarding spatial development patterns and infrastructure.

In search of a screening method to analyse Swiss railway stations with respect to their potential for SD and to guide decisions and actions in railway station development, the node-place model of Bertolini (1999) was applied (Reusser, Loukopoulos et al. online first). The results were highly instructive, but revealed considerable uncertainties concerning the interpretation, i.e. the definition and identification of "unsustainable" railway stations.

Therefore the question still remains; how can railway stations be analysed in terms of their potential for SD?

We think the difficult interpretation of the results of the node-place model is a consequence of an insufficiently guided and mostly pragmatic (i.e. data availability driven) choice of analysis criteria. In this paper we introduce an approach for such a guided choice of analysis criteria. After a short introduction to the operationalisation of SD focussing especially the need to distinguish normative and analytical aspects, we propose a way how normative value judgements may be integrated with systemic criteria definition. We emphasise especially the views of different stakeholders with potentially conflicting demands on railway stations. First results of an empirical investigation using expert interviews are presented and discussed. On the issue of railway stations, new insights concerning the functions they provide for different stakeholders are presented.

2. Operationalising sustainable development

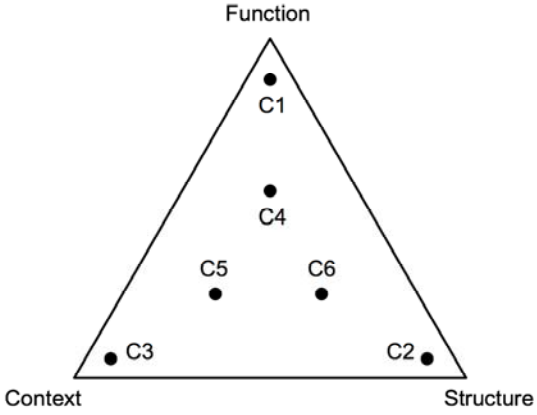
Although SD is perceived to be a fundamental guiding principle for many fields of research and practice, there is no commonly agreed definition of SD or a general consensus of how SD should be operationalised (Parris and Kates 2003). The missing operational consensus is, in general, a handicap for a systematic implementation of SD (Graedel and Klee 2002), although exactly this vagueness may have lead to broader acceptance in the first place (Bosshard 2000).

Lélé and Norgaard (1996) strongly argue, that the operationalisation of SD necessarily includes value judgements. Subsequently, for the operationalisation of SD, three questions need to be answered: "(1) What is to be sustained, at what scale, and in what form? (2) Over what time period and with what level of certainty? (3) Through what social processes and with what trade-offs against other social goals?" (Lélé and Norgaard 1996, p355). To answer these questions, a "combination of value judgments, world views and consensual knowledge" (Lélé and Norgaard 1996, p355) is necessary. Lang, Scholz et al. (2007) support this argumentation, but stress, that none the less adequate system understanding is necessary. They subsequently add a fourth question to the preceding three of Lélé and Norgaard (1996), which needs to be answered in order to operationalise SD: How can a system's potential contribution (positive or negative) to SD be quantitatively measured? With this question in mind, the Sustainability Potential Analysis (SPA) was developed.

2.1 The Sustainability Potential Analysis

The Sustainability Potential Analysis (SPA) (Lang, Scholz et al. 2007), an extension of the BEPA of Scholz and Tietje (2002), has proven useful for the description of a systems potential for SD (cf. Lang, Binder et al. 2007). The SPA analyses a system from a functional perspective. It uses the Function-Structure-Context Framework (for definitions see Table 1) to systematically derive six generic system criteria, so-called "preceptors" (Table 2). These are partly similar to the five urban sustainability principles of the European Environment Agency/Eurostat (2001), or the six Orientators of Bossel (1999; 2001). The six perceptors of the SPA evenly cover the functional, structural and contextual system dimensions as well as interdependencies of these dimensions (Figure 1). Applying the perceptors of the SPA results in the definition of so-called Functional-Key-Variables (FKVs). The SPA can thus be understood as a theoretically driven and formalised multi-criteria analysis method for SD.

Figure 1 The Function-Structure-Context triangle. The perceptors defined in Table 1 are indicated



Source: Adapted from Lang, Scholz et al. 2007, p1636

Table 1 Definition of Function, Structure and Context

Concept	Definition
Function	A goal or demand that is posed on a system, e.g. by a stakeholder.
Structure	The relevant spatial and temporal relationship, connectedness, partitioning, and modularization of the system units within defined system boudaries.
Context	External entities that represent all environmental constraints which are permanently relevant system or impact factors.

Source: Adapted from Scholz and Tietje 2002, p308ff

Table 2 The six perceptors of the SPA

Perceptor	Description with respect to SD
C_1: Performance and efficiency	A system should fulfil ist functions as effectively and efficiently as possible. If not, the utilisation of resources is suboptimal and does not comply with the concept of SD.
C_2: Buffer capacity and resilience (Assimilation)	External effects as well as internal changes can unsettle systems. Each system has an existing ability to assimilate and attain a "stable state" again (i.e. recover from stress). External stress factors may be short-term or recurring changes in inputs (e.g. resources) or outputs (e.g. sinks).
C_3: Ability to accommodate	If the capacity to assimilate is exceeded, a system has to adopt inherent structures or interdependencies with other systems in order to attain a new "stable state". Causes may be long-term changes in inputs (e.g. resources) or outputs (e.g. sinks).
C_4: Well-structuredness	Structural properties essentially determine the quality of a system and its ability to meet given functions and to satisfactorily adjust to changes. Structural aspects are internal organisation and interfaces, such as size, number, condition and connection of subunits.
C_5: Interdependencies with other systems	Each system influences and is influenced by other systems. The characteristics of these influences crutially determine the potential of a system to hinder or support SD.
C_6: Inter- and intra-generational equity	Costs and benefits of any system should be fairly allocated within the present generation and between the present and future generations. If not, the long-term stability and viability of the system is endangered.

Source: Adapted from Lang, Scholz et al. 2007, p1635

2.2 Multiple functional perspectives

A system of course fulfils multiple functions. Railway stations, for example, can be described as both a node of a transport system or as a land use site/place - as Bertolini does with the node-place model (1999). Similarly, some people may judge a railway station only by the transport function, others only by the site function, while a third group may value both functions depending on their goals and demands. In this paper we define functions of a system as goals and demands posed by different stakeholders upon the system (cf. Table 1). As a system such as a railway station has multiple stakeholders, it is to be expected, that multiple functions exist simultaneously and might conflict with each other. How these multiple functions are weighted against each other is in fact a necessary value decision when deciding on railway station development.

For the application of the SPA, multiple functions of a system means that multiple functional perspectives can be taken and are to be described. Subsequently, the application of the SPA results in an analysis matrix, stretched out through the different functional perspectives upon which the system is analysed (top row) and the six perceptors of the SPA (first column). Applying multiple functional perspectives is an advancement to the SPA, which we hope supports the linkage of analytical criteria for SD and value judgements, e.g. in showing necessary value decisions such as trade-offs between contradicting FKVs.

Thus, we propose to address the question of potential for SD of railway stations using a systematic perspective applying the SPA in multi-stakeholder design.

3. Methods

3.1 Definition and identification of stakeholders

The term stakeholder is often used to describe organised groups and their relation to organisations as an extension to shareholders (cf. the classic definition of Freeman (1984, p46): "any group or individual who can affect or is affected by the achievement of the organization's objectives"). We adopt the broadened definition of Grimble and Wellard (1997, p175) "any group of people, organised or unorganised, who share a common interest or stake in a particular issue or system".

Stakeholder identification was achieved in an iterative process: On the basis of multiple research projects (Mieg, Hübner et al. 2001; Scholz, Bösch et al. 2001; Scholz, Stauffacher et al. 2005) and initial discussions with practitioners the most important stakeholder groups concerning railway station developments were listed following the question "Who has a stake in railway stations?". Additionally, all interviewed experts were asked to name further relevant stakeholders. Table 3 resulted.

Table 3 Stakeholders of railway stations

Stakeholder group	Examples for Switzerland (noncomprehensive)
Customers	Rail transport customers, rail station customers
Rail infrastructure company	SBB Infrastrurcture
Rail passenger transport company	SBB Passenger Traffic, BLS AG
Rail cargo transport company	SBB Cargo
Real estate companies	SBB Real Estate
Transport companies (non-rail)	PostAuto, BLS, Kantonal transport services
Regulators	Federal Offices (e.g. of the Department of Environment, Transport, Energy and Communications: ARE, BAV, ASTRA, BFE, UVEK), Kantons
Proprietors and commissioners of transport services	Swiss Federal Council, Kantons, Municipalities
Retail and business	Moibility CarSharing, Rent-a-bike, Coop (-Pronto), Migros, Valora Retail, Alimentana Sista Holding, Die Post
Interest groups	Residents, proprietors of nearby real estate, environment, labour unions, transport interest groups, Swiss Heritage Society

3.2 Expert interviews for matrix development

Goals and demands of the stakeholders concerning railway stations were collected and described by the means of guided interviews[1] (cf. Hesse-Biber and Leavy 2005; Mieg and Näf 2006). For the SBB (Swiss National Rail Company) stakeholders, 13 face-to-face interviews with expert were conducted between May and July 2007, lasting around 80 minutes each (min. 50, max. 150 minutes). The interviews were structured in three parts: (1) description of the interviewees' business area; (2) general description of goals and demands concerning railway stations (i.e. definition of a functional perspective); (3) description of the functional perspective by means of the SPA perceptors (i.e. definition of FKVs). The interview was closed with the experts' practical history and explicit questioning for additional stakeholders and literature.

The primary data of the interviews was partially adapted for consistency in level of detail and wording to build one analysis matrix (cf. "sense-making" and "convergence" in Shaw, Westcombe et al. 2004).

[1] In a first step, focus groups (cf. Krueger 1998; Bloor, Frankland et al. 2001) with various customer groups were conducted to assess the perceived interactive relation of railway stations and municipalities. This lead to first insights concerning different functional perspectives and supported stakeholder definition.

4. Results

In this section we present insights from the interviews with SBB stakeholders as examples for the types of results achieved. As the study is ongoing with other stakeholder groups thematic results may still be subject to change (i.e. currently certain issues may be over- or underrepresented, or even totally missing). Nontheless, first findings can be presented and conclusions concerning the methodological approach made.

4.1 Functions of railway stations

From interviews with SBB experts, eleven functional perspectives, clustered into three groups, were derived (Table 4). The first group includes functions of a railway station as a node in a transport network ("network node"). These are "network connection" of the railway station, "pedestrian flows" within the railway station, "access to the premises" from to the surrounding catchments area and vice-versa by means of different modes of transport, and "admission sales, information and services" (includes only rail transport related services such as lost-and-found office). The second group describes functions of a railway station if considered a "real estate site". These include "meeting point", "sales and services site" (here the issue of advertisements is included), "culture, art and entertainment location", as well as "corporate image" of the real estate owner (i.e. the railway company). The difference between "sales" and "culture" is that the first primarily delivers revenues for the real estate firm, while the second may do this only indirectly. The third group consists of effects a railway station may have on the surrounding catchment area and its perception. It is called "space shaping" and includes "physical structuring" as a consequence of the barrier effects of the rail lines, "orientation support" (support for mental maps, orientation, sign network), and "local (cultural) identity".

4.2 Functional-Key-Variables (FKVs): An example

Each functional perspective was described according to the six perceptors of the SPA. This resulted in an analysis matrix with a large number of FKVs. In Table 5 we exemplarily present the FKVs of one of the functional perspectives shown in Table 4; the "access to the premises".

Table 4 Functional perspectives of railway stations

Group	Functional perspective	Description
Network node	Network connection	The connection the railway station provides to the rail network.
	Pedestrian flows	Circulation of the customers (primarily by foot) within the premises of the railway station.
	Access to the premises	Connection from the surrounding catchment area to the railway station and vice-versa by means of different modes of transport (e.g. per foot, bicycle, morotcycle, car, taxi, bus, tram).
	Admission sales, information and services	All necessary rail-transport-related services (e.g. ticket sales, information desks, static or dynamic visual or audio product information, lost-and-found office).
Real estate site	Meeting point	Use of the station premises as a meeting point.
	Sales and services site	Use of the station premises for retail, services or advertisement.
	Culture, art and entertainment site	Use of the station premises for culture, art and entertainment.
	Corporate image	Use of the station premises to convey a corporate image of the rail transport, infrastructure or real estate company
Space shaping*	Physical structuring*	Devisive structuring of the stations catchment area by means of physical barriers (e.g. rail lines, buildings).
	Orientation support*	Connective structuring of the stations catchment area by means of mental map, signs network and orientation support.
	Local (cultural) identity*	Structuring and development of the catchment areas' identity and image (e.g. as cultural document)

*these functional perspectives could not yet be satisfactorily defined and are subject to further change

Table 5 Functional-Key-Variables (FKVs) of the functional perspective "Access to the premises"

Perceptor	Functional-Key-Variables
C_1: Performance and efficiency	Number of accessing customers to/from stations Satisfaction of accessing customers per modal split Costs for access (e.g. money, time, energy)
C_2: Buffer capacity and resilience (Assimilation)	Access capacity and availability (#parking spaces for bicycles, motorcycles, cars) Access stability at demand peaks (e.g. congestion times) Access stability with weather influences (e.g. snow)
C_3: Ability to accommodate	Constructive development or downsizing possibilities Adaptability of services of public transport to station developments
C_4: Well-structuredness	Complexity and comfort of access (length, time, directness, logic, visibility, barriers, security, validity range of tickets over transport modes) Utilised capacity
C_5: Interdependencies with other systems	Local public transport services (e.g. transfer times between modes) Urban development (distances, #inhabitants, #workplaces)
C_6: Inter- and intra-generational equity	Accessibility for disabled people Cost recovery

5. Discussion

We wanted to analyse how railway stations can be analysed in terms of their potential for a SD. To this end, we used a systemic approach applying the SPA in a multi-stakeholder design. Within expert interviews different and potentially conflicting functions of railway stations were defined. These show, that a railway station is not only a node and place of public transport, but that it has further influences on its catchment area. On the level of criteria for SD potential, we show how the SPA supports criteria identification. The multi-stakeholder design (i.e. multiple functional perspectives) allows for the identification of conflicts and necessary trade-offs, highlighting decisions necessary for SD.

5.1 A heuristic model of railway stations

The analysis matrix resulting from the eleven functional perspectives described by FKVs forms a heuristic model of railway stations. While converging the interview data to the analysis matrix, two main questions arose: are there any functions missing, and how is it possible to account for future additional functions? The definition of the functions of a system is the Achilles' heel of the SPA framework, and possibly even of systems theory in general (Musters, de Graaf et al. 1998). As we define functions as "goals and demands that are posed on a system", the stakeholders included to develop the functional perspectives are key. If important stakeholders are missed or unable to convey their goals and demands, then it is probable that functions are missed. The question of future functions is similarly dependent on the stakeholders. New stakeholders may emerge, or existing stakeholders change their goals and demands. This would be a change of the context of the system and the ability of the system to adapt would consequentially be described by the perceptor C3, together with the context-related preceptors C4, C5, and C6 (cf. Figure 1 and Table 2).

The resulting heuristic model may possibly be applied to public transport nodes of very different sizes. An adaptation to very small nodes (e.g. rural bus stop) may well be possible by omitting or reducing functions. The contrary is more delicate. The larger a node (e.g. international airport hub), the more stakeholders exist and the more likely it is that additional functions are to be fulfilled. Consequentially, the incorporated experts define the limits of the model, which in this case are railway stations of all sizes in a Swiss context.

5.2 New functional perspectives and Functional-Key-Variables (FKVs)

The documented functional perspectives show that a railway station is not only a node of public transport (first group), but can also be described as a real estate (with very high customer frequencies). Additionally, a railway station has influences on its catchment area other than just improving accessibility to services. The third group with the functional perspective "local (cultural) identity" may even be a main reason for the continuous maintenance of the extensive and partly unprofitable Swiss railway network during the second half of the 20th Century (cf. Steinmann and Kirchhofer 2006). This third group is not well described in the literature. It could also not be satisfactorily defined with the SBB experts and is therefore still sketchy. Including these functional perspectives may however lead to a better representation of transport-external stakeholders' interests such as local residents or municipalities. As Steinmann and Kirchhofer (2006) have shown, this can have important consequences.

5.3 Contribution to analysis for sustainable development

A motivation for this work lay in the difficulties encountered when applying the node-place model and interpreting its results. The SPA provides support here with a robust theoretical framework, which we assume will facilitate the choice and interpretation of indicators. For example, the indicators applied in the node-place model (Reusser, Loukopoulos et al. online first), are mainly related to performance and efficiency (perceptor C1). Similarly, during the interviews certain issues were much less mentioned than others. Issues concerning the perceptors C1, C2, C5 and C6 could be discussed much more easily than those concerning the perceptors C3 or C4. Examples for "ability to accommodate" or "well-structuredness" were rarely given without explicit questioning. This can be interpreted, that the SPA improves system definition and understanding. Subsequently, indicator choice and interpretation should benefit, fostering transparency and validity in conclusions.

While developing the analysis approach, an additional benefit, relating to the issue of transparency, was discovered. The analysis matrix may be a productive didactical tool for teaching professionals dealing with railway station development, or for negotiation in development processes. By showing the different functional perspectives (i.e. different goals and demands) stakeholders can have upon railway stations, it helps developing system understanding. Comparing the eleven functional perspectives, or the FKVs, easily identifies certain contradictions and trade-offs (a prominent example are the potential conflicts between the functions "pedestrian flows" and "sales and services site"). These can so be described and better understood, at the same time highlighting that value decisions are necessary for SD.

A major drawback of SD is its common interpretation that something is to be "maintained at a certain level, held within certain limits, into the indefinite future" (Voinov and Farley 2007, p104). Subsequently any decline or destruction is denied, evolution, extinction or emergence not possible. Within the field of systems theory as applied in the SPA, SD is seen as reference to the "goal of fostering adaptive capabilities and creating opportunities" (Holling 2001, p390). This definition prevents static interpretations of SD and accentuates adaptive change. Potentially fruitful discussions about the omission or introduction of a function for the development of a railway station, or the addition or closing of stations for development on the level of transport lines are fostered and become possible upon conceptual backgrounds.

6. Conclusions

The developed heuristic model of railway stations may be of benefit to SD of railway stations, as it is explicitly linked to the decision-making process. As a decision-making process is necessary next to the analysis, it is important that such processes are supported. In the suboptimal but frequent case of a single stakeholder deciding on development actions, the matrix shows all potential functions/FKVs to be considered. This may serve as an important aide-memoire for SD. In the case of multiple stakeholders collaborating, the matrix may be used to compare legitimate goals and demands, guide discussions and weigh criteria, therefore fostering understanding and mutual learning (Scholz, Lang et al. 2006).

We conclude that systemic approaches to transport node analysis may positively influence SD operationalisation. First, within a framework such as the SPA the development and choice of criteria is put upon a thorough conceptual background. This fosters transparency in indicator choice and supports valid interpretation of results. Second, we consider the resulting analysis matrix of the SPA to be beneficial to the decision-making processes as the goals and demands of multiple stakeholders are related. Last, a systemic approach to analysis includes a definition of SD, which fosters the consideration of dynamic aspects and avoids static interpretations.

6.1 Outlook

Next steps will involve a check for consistency of the analysis matrix with external experts and validation within real world case studies. Then, for an application within an adapted node-place model, a reduction of the number of criteria as well as their weighting must be achieved.

6.2 Acknowledgements

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