Persuasive Cities for Sustainable Wellbeing: Quantified Communities

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Abstract. Can you imagine a city that feels, understands, and cares about your wellbeing? Future cities will reshape human behavior in countless ways. New strategies and models are required for future urban spaces to properly respond to human activity, environmental conditions, and market dynamics. Persuasive urban systems will play an important role in making cities more livable and resource-efficient by addressing current environmental challenges and enabling healthier routines. Persuasive cities research aims at improving wellbeing across societies through applications of socio-psychological theories and their integration with conceptually new urban designs. This research presents an ecosystem of future cities, describes three generic groups of people depending on their susceptibility to persuasive technology, explains the process of defining behavior change, and provides tools for social engineering of persuasive cities. Advancing this research is important as it scaffolds scientific knowledge on how to design persuasive cities and refines guidelines for practical applications in achieving their emergence.

Keywords: Persuasive technology · Socially influencing systems · Wellbeing · Sustainability · Urban design · Health behavior change · Quantified communities

1 Motivation

Quality of life and the health of the individual and communities are important subjects that can be studied and improved through the creation of persuasive cities, streets, buildings, homes, and vehicles [16]. Information technology and computer systems are increasingly designed to support everyday routines and advance user experience in multiple ways [6]. Novel computer systems can be also intentionally designed to influence how users think and behave. Theories of persuasion [18] and social influence [4] provide various strategies for the developers of such systems to facilitate desired effects on users.

Research on persuasive cities seeks to advance urban spaces to facilitate societal changes. According to social sciences [2], any well-designed environment can become a strong influencer of what people think and do. There is an endlessly dynamic interaction between a person, a particular behavior, and an environment in which that behavior is performed. This initiative leverages this knowledge to engineer persuasive environments and intervention for altering human behavior on individual and societal levels. This research is primarily focused on socially engaging environments for supporting

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entrepreneurship and innovation, reshaping routines and behavioral patterns in dense urban districts, intelligent outdoor sensing for shifting mobility modes, enhancing environmentally friendly behaviors through social norms, interactive public feedback channels for affecting attitudes, engaging residents through socially influencing systems, exploring methods for designing persuasive neighborhoods, testing agent-based models and simulations of persuasive interventions, and fostering adoption of novel urban systems.

2 Perspective

This research aims at tackling an area that is currently underestimated, but at the same time, bears extremely high importance for mankind to prosper. The world's population grows exponentially, especially in cities, so the architecture and design of future urban places are going to have the dominant impact on human behavior. The proposed research agenda is highly important, as it will directly influence everyone living in future cities. Environmental, personal, and behavioral factors are locked into triadic reciprocal determinism [2], meaning that all three are strongly interconnected and continuously reshaping each other. Thus, environmental design, including persuasive urban systems, is strong influencer on human behavior and attitude. In other words, quite often it is merely sufficient to improve urban spaces to help people become healthier and to create sustainable communities. This is a very powerful vision as it encompasses transformation of human behavior and urban environments at scale.

The proposed research reflects on novel ways of how socially influencing systems [20, 21] enable mechanisms to perpetually support motivation of individuals comparing to conventional methods, such as those that are based on the principle of carrots and sticks. Earlier research on motivation discusses methods that have substantial limitations. For example, monetary incentives are mostly effective only as long they are provided, so people tend returning to their earlier behavior after the motivators are taken away. Instead, persuasive urban systems harness social influence from crowd behavior to craft influential messaging aimed at shifting behavior and attitude of an individual, who naturally is an integral part of the same crowd. Such continuous interplay can ultimately result in an ongoing process that reshapes communities and societies without any other incentives.

3 Emergence of Persuasive Cities

Ongoing research streams focus on *sensitive cities* (researching sensing technologies to read human behavior in urban spaces) [12] and *smart cities* (analyzing big data to classify groups of people based on their distinct behavioral patterns) [3, 5], however there is a lack of knowledge about perspective ways to achieve persistent behavioral changes at scale. Therefore, the proposed research extends an ecosystem of future cities (Table 1) by introducing the notion of *persuasive cities* that aims to advance and refine influential strategies designed for intentionally reshaping how people think and act in urban environments.

Table 1. Ecosystem of future cities

Role	Character	Technology
Persuasive		
Change	Care	Socially influencing systems
Smart		
Classify	Understand	Big data analytics
Sensitive		
Read	Feel	Sensor networks

Each *layer* of future cities has its *role*, *character*, and supportive *technology*. Sensitive cities employ sensor networks to read crowd behaviors. In other words, these cities feel human movements. These crowd behaviors further serve as an input for big data analytics that smart cities apply to classify groups of people according to similar behavioral patterns (profiles). When that is accomplished, the groups having better routines can be exemplified to other underperforming groups through intentionally designed socially influencing systems, which are at the core of persuasive cities.

3.1 Susceptibility to Persuasive Technology

People generally can fall into one of the three generic categories depending on their susceptibility to persuasive technology (Fig. 1). *Self-contained* people (the red circle) most likely are not open for changing anything in them. They are fully satisfied with who they are and what they do on daily basis, thus many behavioral interventions might fail in attempts to influence this group of individuals. *Self-driven* people (the green circle) typically have comparatively high levels of motivation and can achieve everything that they have envisioned. Thus, these people most likely are not looking for additional sources of encouragement, and therefore persuasive technologies might become unnecessary for this group.

However, there is another group of people that oftentimes would like to change their routines, but rarely succeed in doing so. That reminds of New Year's resolutions

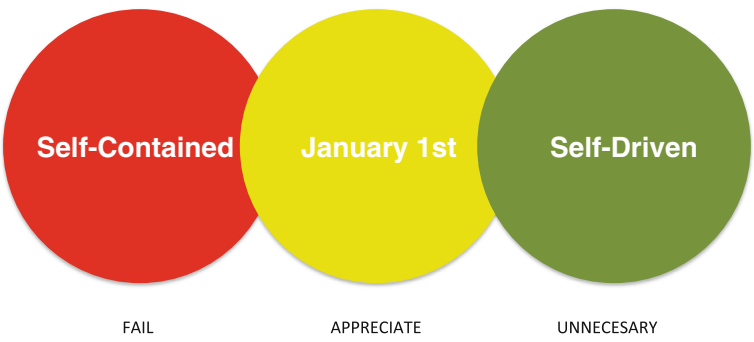

Fig. 1. Susceptibility to persuasive technology (Color figure online)

that in many cases end around February. Therefore, this group is entitled as January 1st (the yellow circle) and seem to be the most welcoming towards technology supported behavioral interventions designed to help achieving target behaviors. Although, Fig. 1 presents all three groups as equal circles, in reality the size of each group might significantly vary depending on the context and particular behavior.

3.2 Defining Behavior Change

To achieve an envisioned target behavior, the process and components of behavior change have to be well understood and clearly defined. In the process of defining behavior change, there are three main components, namely the target group, its present behavior, and its envisioned future behavior (Table 2).

Table 2. The three main components for defining behavior change

Target group	Current behavior	Future behavior
Description		
A group of people currently having an unsatisfactory behavior. It is important to narrow down the target group as precise as possible	A certain behavior of the target group that currently is not in line with an envisioned future behavior in a given context	An ultimate future behavior of the target group that is envisioned to be more beneficial for everyone
Example		
There are MIT faculty members	Who currently commute alone in their private cars	They could commute by bicycles instead whenever possible
Example		
There are other people in our residential building	Who use regular light bulbs in their apartments	They would change the regular light bulbs to energy efficient ones

3.3 Tools for Social Engineering

Earlier research on persuasive technology [8] describes several ways how social dynamics can influence human behavior, which have been further refined and structured as a framework for Socially Influencing Systems (SIS) [20, 21], see Fig. 2. The SIS framework is a useful tool for scholars and practitioners aiming at improving future cities by introducing persuasive urban interventions targeted to support wellbeing.

The framework describes seven socially influencing principles that can support persuasive urban interventions. The principles are interlinked and have potential to exert stronger effects depending on the context of a particular behavioral challenge. Normative influence and social comparison seem to be more effective to achieve involvement of the target group as the two principles focus on attitudinal changes. Cooperation and social facilitation seem to be more effective to make individuals

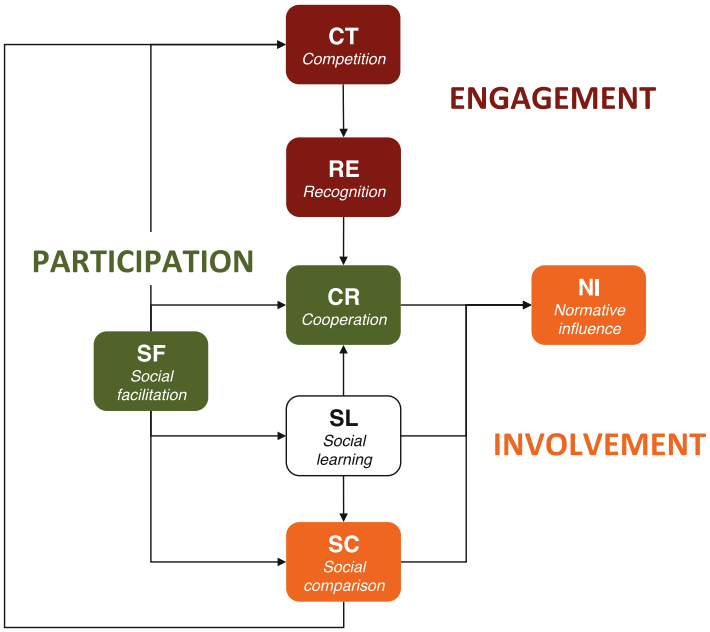

Fig. 2. Socially Influencing Systems (SIS) framework

participate and do the envisioned future behavior even without a formed attitude towards it. Competition and recognition seem to be more effective in engaging the target group to do the future behavior as the principles focus on both attitude and behavior simultaneously. For example, the effects several socially influencing principles have already been studied in the context of urban mobility, e.g. bicycling [24].

4 Contexts of Future Persuasive Cities

To achieve substantial behavior changes at scale, the persuasive cities research agenda is focused on reshaping and redesigning three main urban areas: outdoor environments, indoor environments, and mobility in cities.

4.1 Outdoor Environments

Public spaces can be advanced in many ways, e.g. supermarkets can project a portion of how many healthy products have been purchased that day, week, or month. Responsive environments can use ambient lights to provide feedback about behavioral patterns of crowds. For example, streetlights can change color depending of how many joggers have been on that street on that morning. The window frames of residential buildings can be illuminated for those apartments, which have changed regular light bulbs to energy-efficient ones.

4.2 Indoor Environments

Computer-supported strategies can be implemented to motivate using stairs instead of an elevator. For example, a situated display that represents various comparisons of what can happens when stairs or an elevator is chosen. Strategies can be introduced to increase water intake in offices. For example, a situated display can present an increase of water consumption, which can be used to compete with other offices. New ways can be designed for office workers to increase socializing among individuals from various groups and departments. For example, specific game-like activities can be set up for employees to promote socializing.

4.3 Mobility

Mobility within dense urban districts can be reshaped in multiple ways, for example, by introducing influential strategies to facilitate bicycle commuting. Street signage can be used to display how many bicyclists have ridden over a bridge today, for instance. Mobile apps can be developed to engage bicycle riders in reporting experiences with bike lanes and their quality in a selected urban area. Electric bicycles can be complemented with influential strategies to attract more riders and persuade them to pedal. To care for satisfaction of public transit commuters, a city bus with happier passengers on board can obtain more colorful outlook.

5 Application to Bicycling in Cities

Besides investing in road infrastructure, cities can work on shifting mobility patterns towards bicycling as one the most sustainable and healthiest forms of individual transportation. It also has several major advantages as compared to conventional motorized transport, e.g. bicycling is carbon neutral, provides major health and financial benefits, and requires less space than private motorized transport. Therefore, it is necessary to design interventions for promoting bicycling, experience the enjoyment from this activity, and develop new mobility patterns [9].

Previous research points out that interventions to promote modal shift can be effective, however most of these follow traditional policy approaches like publicity campaigns, engineering measures or financial incentives [17] leaving a blind spot for behavior oriented soft-policy measures [19]. Persuasive cities have potential to significantly contribute to this effort, for example, through publicly displayed street signage with interactive social comparison [22] on how quickly bicycles move as compared to the speed of cars on the same street.

5.1 Biking Tourney

In a recent Biking Tourney study [23], a socially influencing system [21] was engineered and implemented to provoke competition between and cooperation [7] within organizations. In that study, the participating organizations were ranked under four

different categories related to their performance related to bicycling. The categories were designed to reflect the goals of the Biking Tourney, that is, to encourage employees to ride bicycles instead of choosing high-energy means of transportation for their daily commutes.

The hypothesis of the study was that the competition between organizations would provoke cooperation among employees in each of the organizations. Furthermore, the use of publicly displayed rankings in common areas of the companies should raise awareness of the tourney and facilitate [10] commuting by bicycles. Out of the total number of 239 registered participants, 127 people filled out the ex post survey that contained intentionally designed set of questions for assessing their engagement in the Biking Tourney.

5.2 Assessing Engagement

We used partial least squares structural equation modeling (PLS-SEM) to analyze factors influencing participants' engagement in the Biking Tourney. Based on the relevance to this study, five factors were included as constructs in the research model (Fig. 3). Three of them were derived from the framework of socially influencing systems [21], namely social facilitation [10], competition, and cooperation [7]. Rankings and public display were added, as they were fundamental components of the study design. The indicators for main constructs (Appendix A) were adopted from Stibe [20] for this particular study.

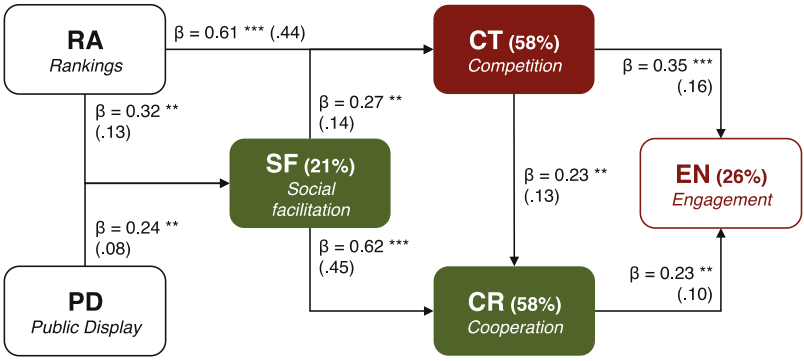

Fig. 3. The structural model with the results of PLS-SEM analysis

All constructs of the research model demonstrate good internal consistency, as evidenced by their composite reliability scores, which range from .85 to .98 (Table 3), and the fact that they share more variance with own indicators (AVE) than with other constructs.

The research model (Fig. 3) was built upon the framework for socially influencing systems [21] and shaped by the strongest correlations between the constructs (Table 3). Further, it was analyzed using PLS regression algorithm [13] and the results provide

Table 3. Latent variable coefficients and correlations

	COR	CRA	AVE	VIF	PD	RA	SF	CT	CR	EN
PD	.98	.97	.95	1.2	**.97**					
RA	.90	.83	.75	2.1	.20	**.86**				
SF	.87	.78	.70	2.3	.33	.36	**.84**			
CT	.85	.74	.66	2.6	.34	.71	.51	**.81**		
CR	.90	.83	.75	2.5	.38	.32	.73	.53	**.86**	
EN	.92	.87	.80	1.3	.18	.34	.39	.38	.42	**.89**

COR = Composite Reliability; CRA = Cronbach's Alpha; VIF = variance inflation factor (full collinearity); Bolded diagonal = square root of Average Variance Extracted (AVE)

substantial support for the research model. The β-values demonstrate the strength of relationships between the constructs and the asterisks mark their statistical significance, while the R-squared contributions are presented in brackets.

The five influencing factors are intricately interconnected and altogether they explain 26 % of the variance in engagement in the Biking Tourney. The main direct contributors to explain the variance in engagement were competition (16 %) and cooperation (10 %). Social facilitation (45 %) and competition (13 %) together explain 58 % of the variance in cooperation. Rankings (44 %) and social facilitation (14 %) together explain 58 % of the variance in competition. Rankings (13 %) and public display (8 %) together explain 21 % of the variance in social facilitation.

For a more elaborate view of the model, total effects and effect sizes for total effects are presented in Table 4. Effect sizes (f^2) determine whether the effects indicated by the path coefficients are small ($f^2 \geq .02$), moderate ($f^2 \geq .15$), or large ($f^2 \geq .35$). The results of PLS-SEM analysis also provide fit and quality indices that well support the model [13], such as average path coefficient (APC = .357, $p < .001$) and average adjusted R-squared (AARS = .399, $p < .001$). Overall, the model demonstrates quite large explanatory power (GoF = .560). Moreover, both Sympson's paradox ratio (SPR = 1.000) and the nonlinear bivariate causality direction ratio (NLBCDR = 1.000) provide evidence that the model is free from Sympson's paradox instances, and the direction of causality is supported.

Table 4. Total effects and effect sizes.

	PD	RA	SF	CT	CR
SF	.24** (.08)	.32*** (.13)			
CT	.06 (.02)	.69*** (.50)	.27** (.14)		
CR	.16** (.06)	.36*** (.11)	.68*** (.50)	.23** (.13)	
EN	.06 (.01)	.32*** (.11)	.25** (.10)	.40*** (.19)	.23** (.10)

***p < .001; **p < .01; *p < .05;
(f^2) = Cohen's f-squared

The results of PLS-SEM analysis illustrate how competition and cooperation [7] made employees feel engaged in the Biking Tourney. Although social facilitation [10] and rankings are not directly pointed to engagement, both contributed with strong and significant indirect effects on it. Interestingly, public display exerted also a significant indirect effect on cooperation, which emphasizes the importance of ubiquitous feedback channels in facilitating social dynamics.

6 Future Research Opportunities

This section describes several potential applications of how the previously introduced concepts of persuasive cities can be designed and introduced in various urban contexts to support wellbeing.

6.1 Sedentary Behavior

Recent reports show that a growing number of students are becoming obese not just because of their lack of exercise, poor diet, and excessive screen time but simply because they do not stand up during the active hours of their day. Even when they get enough daily exercise, students who spend the rest of the day seated suffer from a greater risk of obesity as well as of diabetes, cardiovascular disease, and even some cancers than students who stand. Thereby, the more stand-biased furniture there is, for example, installed in classrooms, the more likely students are to stand more than sit and gradually come to like or at least expect that behavior as the norm.

When implemented, socially influencing systems supported by a technologically enabled built environment may have a more sustainable impact on behavior change than stand-biased furniture alone. Therefore, a behavioral intervention can be designed for the built environment of the classroom with a technologically enabled seating system that serves as a persuasive change agent [8] even when students are not directly using it.

6.2 Water Conservation

A large component of urban water is attributed to residential use, which includes water for drinking, bathing, clothes and dish washing, toilet flushing, and landscaping. Use of persuasive technology [11] paves the way to new channels of influencing behavior towards sustainability, e.g. better access to quick and frequent feedback, personalization and two-way interaction, optimized information source for feedback, and ability to scale amongst others. The power of persuasive technology lies in its customizability and opportunity for scale.

Persuasive cities research takes advantage of digital platforms to influence impact to the individual. By taking this one step further and sharing the tool among users, the concept of “environmental feedback” can harness the benefits of normative influence among crowds. This can prove to be very powerful when considering tenants of an apartment building, or local residents of a neighborhood, or even a city. Thus, by first using a platform customized to the user, the data among a larger network can be aggregated and then re-shared to a group of users on situated displays.

6.3 Walking

There are modifications that city planners can potentially make, and have made, to the urban environment to promote walking. For instance, walkability can be improved through the provision of clean, well-lit and safe sidewalks, shelter from rain and sun, an attractive urban environment and so on. However, while these are all important elements, they alone do not seem to be sufficient to bring about the behavior changes that could be so beneficial to health. In addition to meeting the basic requirements of safe and navigable walking conditions, there are proven methods of causing attitudinal change through social influence [4] that can promote sustained behavior change. Through persuasive changes to the environment, barriers to walking such as normative influence [14], social learning, and social facilitation [10] can change the way people think about walking and lead to increased physical activity. Recognition [15], competition [7], and cooperation [1] can be leveraged to build on the initial activity of walking and promote sustained adoption.

Persuasive cities can make walking experience more engaging by combining a mobile phone app that interacts with retrofitted traffic light junctions. To participate, users will have to download a mobile app and provide information on where they live, in order to be placed into a team that corresponds to their address. When waiting at traffic light junctions, users obtain riddles either through a small screen attached to the junctions or directly messaged to their phones. They would input their answers into the mobile app, and correct answers win points for the team. When playing outside own neighborhood, or when teaming up with other users, the user gets additional points, for example. An interactive color strip could be placed on each traffic light, which would display the top three teams with the highest points scored that day at each light.

7 Conclusions

Fundamentally new strategies must be found for creating the places where people live and work, and the mobility systems that connect these places, in order to meet the profound challenges of the future [16]. Novel models for urban architecture and personal vehicles should be more responsive to the unique needs and values of individuals though the application of disentangled systems and smart customization technology. Future research should be directed towards exploring how urban design might be combined with persuasive technology and socially influencing systems to encourage healthy behaviors at scale.

Future computer-supported innovations should be designed with intent to understand and respond to human activity, environmental conditions, and market dynamics. The design of future cities requires optimal combinations of automated systems, just-in-time information for personal control, and interfaces to persuade people to adopt sustainable behaviors. Drawing on socio-psychological theories and integrating them with new concepts for urban design and technology, the proposed persuasive cities research will advance the livability in future cities.

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Appendix A: Measurement Items and Combined Loadings

Constructs	Indicators	Load
Social facilitation	I noticed that my colleagues were participating in the Biking Tourney	.880
	I noticed how other coworkers rode bikes as part of the Biking Tourney	.826
	I recognized that there were other people from my organization biking to work during the Biking Tourney	.799
Cooperation	I noticed that my colleagues cooperated during the Biking Tourney	.897
	I noticed how my co-workers encouraged each other to ride during the Biking Tourney	.843
	I observed that my colleagues are collaborating during the Biking Tourney	.853
Competition	I was able to follow my organization in standings of the Biking Tourney	.826
	I followed how organizations were competing during the Biking Tourney	.852
	I noticed how competitive my organization was in the Biking Tourney	.755
Public display	My organization had a public screen which displayed the Biking Tourney standings	.983
	I noticed the rankings of Biking Tourney on a public screen in my organization	.962
	There was a public screen in my organization for everyone to see the Biking Tourney activity	.977
Rankings	I noticed the ranking of organizations based on total miles ridden	.823
	I noticed the ranking of organizations depending on average miles ridden	.910
	I noticed the ranking of organizations based on number of employees biking to work	.856
Engagement	The Biking Tourney encouraged me to commute by bike to work	.937
	The Biking Tourney motivated me to continue riding my bike to work	.917
	I felt engaged in riding to work during the Biking Tourney	.818

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